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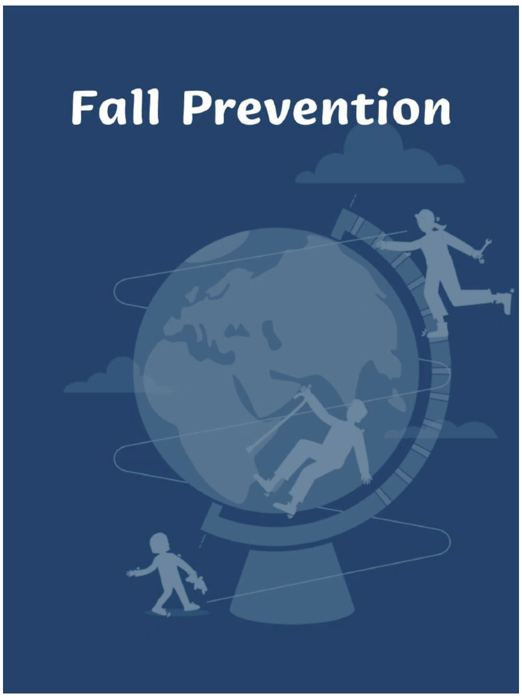




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Preplanned Studies

# Evaluation of the Effectiveness of "5E" Comprehensive Injury Prevention Strategy for Fall Prevention Among the Rural Elderly — Six Pilot Villages, Yunnan Province and Chongqing Municipality, China, 2018–2023

Fujin Sun[1]; Rong Luo[1]; Hui Han[1,#]

**Summary**

### What is already known about this topic?

The mortality rate and disease burden associated with falls among the elderly in China are on the rise. Interventions can play a crucial role in preventing and managing falls.

### What is added by this report?

The application of the "5E" injury prevention strategy led to a decrease in both the occurrence of falls and the likelihood of subsequent falls. Regular physical activity and maintaining a positive outlook were identified as protective measures against falls, while sleep issues and hearing impairment were found to increase the risk of falling.

### What are the implications for public health practice?

The group-based comprehensive intervention strategy is crucial as it offers an innovative intervention model and empirical evidence for decreasing fall rates among elderly individuals living in rural areas.

As of 2021, China has entered a phase of moderate aging, with a significant projected increase in the elderly population over the next decade due to a second baby boom starting in 1962. This demographic shift poses significant challenges for national finances, social healthcare services, and home assistance. Falls are the primary cause of fatal injuries and illnesses among Chinese individuals over 65 years old (*1*). Research indicates that about 1/3 of 65-year-olds and half of 80-year-olds have experienced a fall, with a high likelihood of recurrence for those with a history of falls. Prompt prevention and diagnosis of falls using clear criteria can yield visible results quickly (*2*). Preventing and managing falls among the elderly is a key priority for facilitating healthy and active aging in China. Domestic researchers have successfully implemented the "5E" strategy — Education, Environmental modifications, Engineering improvements, Enforcement measures, and Evaluation — to mitigate fall risks among elderly inpatients (*3–4*). Nonetheless, there is a scarcity of studies evaluating the efficacy of group-based fall prevention interventions for rural older adults.

This study aims the effectiveness of a group-based comprehensive intervention strategy to prevent falls in older adults through a prospective cohort study conducted from October 2022 to September 2023. Using random cluster sampling, six project townships were chosen from Yunnan Province and Chongqing Municipality, with one project village selected from each township. The survey involved 1,536 rural elderly individuals aged 60 and above across 6 project villages. Baseline data from 1,276 rural elderly individuals aged 60 and over from the same villages collected from November to December 2018 was used for self-control. The research was part of the "Community Participation to Promote Rural Elderly Health – Phase II" project by the National Health Commission (NHC). Inclusion criteria included individuals aged 60 and above residing in the project area for at least six months, while exclusion criteria involved severe mental illness, paralysis, and epilepsy.

The research team implemented a detailed, household-level investigation by deploying a specifically designed questionnaire. This questionnaire encompassed a wide array of topics, capturing essential resident demographics, lifestyle choices, daily activity capabilities, overall physical health, and impressions of the intervention project. The multifaceted "5E" strategy for injury prevention was employed, focusing on the following dimensions: 1) Provision of targeted health education, which addressed themes such as fall prevention and awareness, handling falls, the significance of physical activity, and safety measures associated with exercise. 2) Modification of the living environment in an age-sensitive manner, entailing upgrades such as smoothing out uneven surfaces, enhancing lighting in communal areas, bathroom repairs, handrail installations, and setting up fitness equipment. 3) Dispensation of age-friendly assistive devices that included items like reading glasses for presbyopia, portable commodes, walking sticks, and crutches aimed at reducing the fall risk for the elderly. 4) Oversight of the entire intervention process, from the development and procurement of necessary resources to the actual execution and subsequent assessment of the interventions. 5) Conducting risk evaluations for potential recurrent falls. Evaluation metrics involved measuring the frequency of falls, defined as the percentage of participants who reported experiencing a fall in the preceding year, as well as quantifying re-fall risk. For assessing re-fall risk, we employed the endorsed scoring systems of the Fall Risk For Older People-Community Setting (FROP-Com) (*5*) and the Falls Risk Assessment Tool (FRAT) (*6*), resulting in a comprehensive 37-point score with 13 primary factors, comprising: fall history, medications influencing fall risk, medical conditions affecting balance and flexibility, paresthesia occurrences, sleep quality, health literacy, urinary incontinence, nutritional health, environmental safety assessment, level of physical activity, proficiency in everyday activities, engagement in physical exercise, and emotional well-being.

Data analysis was performed using SPSS statistical software (version 27.0, SPSS Inc., Chicago, IL, USA). This study was approved by the Ethics Review Committee of the National Center for Women and Children's Health, China CDC, under the protocol (Ethics Review Number: FY2018-07). Before the intervention, participants were well-informed about the study procedures and provided their informed consent.

The initial data indicated that 159 individuals suffered falls; however, in the subsequent survey, only 33 reported falls. The prevalence of falls decreased from 12.46% to 2.15% following the intervention (Table 1). The mean scores for the reassessment of fall risk decreased from 9.64±2.99 to 7.79±2.44. Analysis using a regression model revealed that regular physical activity [odds ratio (*OR*): 0.34, 95% confidence interval (*CI*): 0.16, 0.72] and a positive attitude (*OR*: 0.22, 95% *CI*: 0.07, 0.64) were protective factors, while sleep disturbances (*OR*: 2.86, 95% *CI*: 1.21, 6.77) and hearing impairment (Wald $\chi^2$=8.46, *P*=0.037) were identified as risk factors for falls. Visual impairments such as blurred vision can be corrected with the use of presbyopia glasses (Table 2). The ratio of falls attributed to intrinsic factors versus environmental factors was approximately 1∶1. Slippery surfaces or obstacles in the surroundings (33.33%) were identified as the primary causes of falls (Table 3).

## DISCUSSION

The introduction of an intervention led to a decrease in fall incidence from 12.46% to 2.15%. Additionally, re-fall risk assessment scores dropped from an average of 9.64±2.99 to 7.79±2.44. Both the reduced fall incidence and lower re-fall risk assessment scores were statistically significant, demonstrating that the intervention effectively minimized falls among elderly individuals in the research locations and mitigated the risk of recurring falls. Consequently, the study affirms that a group-based holistic intervention approach notably diminishes fall rates among older adults residing in rural areas.

The initial fall incidence rate of 12.46% aligns with prior research in Chongqing Municipality (10.45%) (*7*) and Yunnan Province (9.60%) (*8*), affirming the baseline data's reliability. This study consistently involved participants aged 65 years and older across all sites, excluding those unavailable for follow-up. New local residents joining during the intervention phase maintained the data's comparability. Results demonstrated that physical exercise is an effective fall prevention strategy. According to Li Jinmei (*9*), balance is a modifiable fall risk factor. Practices such as Tai Chi and Baduanjin — a series of Qigong exercises — can enhance postural stability when walking or standing, and fortify the lower body's strength and endurance in the elderly. A positive mindset also corresponds to a reduced fall occurrence. In our study, 19 individuals (57.58%) experienced a fear of falling (FOF), paralleling Xu Peimei's (*10*) meta-analysis findings on FOF prevalence. FOF may curtail activity levels and diminish physical activity, leading to a decline in muscle strength and balance, hence raising the fall risk and perpetuating a detrimental cycle. Consequently, organizing recreational events, fostering social interaction, and providing emotional sustenance via caregivers is crucial (*9–10*). Moreover, the hazard of falls is heightened by the distractions and sluggish reactions stemming from sleep disturbances and sensory degradation. Auditory issues delay the elderly's response to auditory fall-risk warnings, while visual impairments directly disrupt their vision and wayfinding abilities. Improvement in

TABLE 1. Univariate analysis of the impact factors of falls among rural elderly pre- and post-intervention in six pilot villages, Yunnan and Chongqing, China, 2018–2023.

| Item | Post-intervention | | $X^2$ | P | Pre-intervention | | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|
| | Number | Number of falls (%) | | | Number | Number of falls (%) | | |
| Sex | | | 2.899 | 0.089 | | | 0.489 | 0.484 |
| Male | 737 | 11 (1.49) | | | 635 | 75 (11.81) | | |
| Female | 799 | 22 (2.75) | | | 641 | 84 (13.10) | | |
| Ethnicity | | | 5.729 | 0.126 | | | 4.903 | 0.179 |
| Han | 426 | 15 (3.52) | | | 316 | 46 (14.56) | | |
| Tujia | 423 | 7 (1.65) | | | 453 | 61 (13.47) | | |
| Lahu | 469 | 6 (1.28) | | | 317 | 29 (9.15) | | |
| Other | 218 | 5 (2.29) | | | 190 | 23 (12.11) | | |
| Age (years) | | | 2.981 | 0.225 | | | 6.353 | 0.042 |
| 60– | 773 | 12 (1.55) | | | 698 | 73 (10.46) | | |
| 70– | 551 | 14 (2.54) | | | 417 | 65 (15.59) | | |
| ≥80 | 212 | 7 (3.30) | | | 161 | 21 (13.04) | | |
| Educational level | | | 10.750 | 0.005 | | | 4.871 | 0.088 |
| Illiterate | 969 | 28 (2.89) | | | 827 | 112 (13.54) | | |
| Primary school | 506 | 3 (0.59) | | | 327 | 39 (11.93) | | |
| Junior high school and above | 61 | 2 (3.28) | | | 122 | 8 (6.56) | | |
| Occupation | | | 7.821 | 0.020 | | | 0.485 | 0.785 |
| Housework | 416 | 14 (3.37) | | | 513 | 67 (13.06) | | |
| Farming | 1,075 | 16 (1.49) | | | 721 | 86 (11.93) | | |
| Other | 45 | 3 (6.67) | | | 42 | 6 (14.29) | | |
| Alcohol consumption | | | 0.329 | 0.566 | | | 1.456 | 0.228 |
| Yes | 441 | 8 (1.81) | | | 456 | 50 (10.96) | | |
| No | 1095 | 25 (2.28) | | | 820 | 109 (13.29) | | |
| Having sleeping problems | | | 7.498 | 0.006 | | | 3.757 | 0.053 |
| Yes | 169 | 9 (5.33) | | | 389 | 59(15.17) | | |
| No | 1,367 | 24 (1.76) | | | 887 | 100(11.27) | | |
| Physical exercise | | | 10.054 | 0.002 | | | 4.661 | 0.031 |
| Yes | 964 | 12 (1.24) | | | 541 | 80 (14.79) | | |
| No | 572 | 21 (3.67) | | | 735 | 79 (10.75) | | |
| Having chronic disease | | | 0.001 | 0.971 | | | 1.322 | 0.250 |
| Yes | 554 | 12 (2.17) | | | 368 | 52 (14.13) | | |
| No | 982 | 21 (2.14) | | | 908 | 107 (11.78) | | |
| Vision | | | 7.845 | 0.049 | | | 14.512 | 0.002 |
| Normal | 504 | 8 (1.59) | | | 338 | 29 (8.58) | | |
| Slightly blurred | 835 | 17 (2.04) | | | 609 | 79 (12.97) | | |
| Often unable to see clearly | 176 | 5 (2.84) | | | 192 | 22 (11.46) | | |
| Blurred | 21 | 3 (14.29) | | | 137 | 29 (21.17) | | |
| Hearing | | | 7.894 | 0.048 | | | 11.647 | 0.009 |
| Normal | 672 | 8 (1.19) | | | 694 | 68 (9.80) | | |
| Sometimes cannot hear | 689 | 20 (2.90) | | | 367 | 62 (16.89) | | |
| Often cannot hear | 139 | 5 (3.60) | | | 131 | 19 (14.50) | | |
| Severe hearing loss | 36 | 0 | | | 84 | 10 (11.90) | | |
| Mentality | | | 6.793 | 0.009 | | | 8.881 | 0.003 |
| Positive | 1,025 | 4 (0.39) | | | 971 | 106 (10.92) | | |
| Loneliness, anxiety or depression | 511 | 29 (5.68) | | | 305 | 53 (17.38) | | |

TABLE 2. Multivariate logistic regression analysis of the impact factors of falls among rural elderly pre- and post-intervention in six pilot villages in Yunnan and Chongqing, China, 2018–2023.

| Impact factors (Reference groups) | *β* | *S.E.* | *Wald* $\chi^2$ | *P* | *OR* | 95% *CI* |
|---|---|---|---|---|---|---|
| Pre-intervention | | | | | | |
| With exercise (No) | −0.392 | 0.174 | 5.100 | 0.024 | 0.68 | 0.48, 0.95 |
| Vision (Blurred vision) | | | 8.417 | 0.038 | | |
| Normal vision | −0.259 | 0.241 | 1.159 | 0.282 | 0.77 | 0.48, 1.24 |
| Slightly blurred | −0.829 | 0.313 | 7.028 | 0.008 | 0.44 | 0.24, 0.81 |
| Often unable to see clearly | −0.110 | 0.324 | 0.116 | 0.733 | 0.90 | 0.48, 1.69 |
| Mentality (Loneliness, anxiety or depression) | −0.466 | 0.188 | 6.173 | 0.013 | 0.63 | 0.43, 0.91 |
| Post-intervention | | | | | | |
| Having sleeping problems (No) | 1.050 | 0.440 | 5.686 | 0.017 | 2.86 | 1.21, 6.77 |
| With exercise (No) | −1.089 | 0.387 | 7.897 | 0.005 | 0.34 | 0.16, 0.72 |
| Hearing (Normal) | | | 8.464 | 0.037 | | |
| Sometimes cannot hear | 1.161 | 0.750 | 2.393 | 0.122 | 0.31 | 0.07, 1.36 |
| Often cannot hear | 0.527 | 0.622 | 0.718 | 0.397 | 1.69 | 0.50, 5.73 |
| Severe hearing loss | 18.903 | 6041.682 | − | 0.998 | − | − |
| Mentality (Loneliness, anxiety or depression) | −1.534 | 0.557 | 7.571 | 0.006 | 0.22 | 0.07, 0.64 |

Note: "−": The number of falls due to severe hearing loss is zero.
Abbreviation: *S.E.*=standard error; *OR*=odds ratio; *CI*=confidence interval.

TABLE 3. The comparison of the leading cause of falls among rural elderly, pre- and post-intervention in six pilot villages, Yunnan and Chongqing, China, 2018–2023.

| Cause of fall | Post-intervention | | Pre-intervention | |
|---|---|---|---|---|
| | *N* | % | *N* | % |
| Elderly themselves | | | | |
| Leg weakness | 14 | 16.67 | 30 | 8.33 |
| Poor body balance ability | 11 | 13.10 | 64 | 17.78 |
| Distraction | 11 | 13.10 | 30 | 8.33 |
| Vision problems | 6 | 7.14 | 25 | 6.94 |
| Unwell episodes | 3 | 3.57 | 45 | 12.50 |
| Surroundings | | | | |
| Slippery grounds and obstacles | 28 | 33.33 | 118 | 32.78 |
| Insufficient or blinding light | 8 | 9.52 | 26 | 7.22 |
| Steps with large height difference | 2 | 2.38 | 13 | 3.61 |
| Furniture too high or too low | 1 | 1.19 | 7 | 1.94 |
| No handrails in bathroom | 0 | 0 | 2 | 0.56 |

visual acuity after prescribing appropriate glasses significantly mitigates the fall risk, underscoring the value of investing in suitable assistive devices for the elderly in fall prevention efforts.

The research sites in Yunnan and Chongqing, situated in mountainous regions with high seasonal rainfall, present challenging environmental conditions that elevate the risk of falls among the elderly, particularly within the Tujia and Lahu ethnic communities residing in traditional stilt houses. Approximately one-third of older adults experience falls due to slippery surfaces or obstacles, influenced by the unique geography, climate, and living conditions. Prior studies indicate that enhancing the living environment through personalized age-appropriate modifications indoors and outdoors can significantly reduce fall occurrences. Hence, feasible intervention strategies include decluttering and incorporating age-appropriate adjustments like slope modifications at home.

The comprehensive injury prevention strategies known as the “5E” approach, which involves age-appropriate modifications and aids, demonstrated substantial and swift efficacy in decreasing fall rates. It is essential to tackle root causes like slippery surfaces and obstacles to prevent falls effectively. These findings offer empirical support for health departments in devising future fall prevention initiatives and equipping healthcare workers with efficient strategies for preventing falls in elderly populations.

This study is subject to some limitations, including the absence of a control group due to its prospective cohort design and the omission of socialeconomic factors that may influence falls. Moreover, the study did not assess the long-term effects of the interventions. In summary, a group-based comprehensive intervention strategy demonstrated efficacy in decreasing fall rates and re-fall risks among older individuals.

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Preplanned Studies

# The Burden of Hypertension-Related Chronic Kidney Disease — China, 2010–2019

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**Summary**

### What is already known about this topic?

The global burden of chronic kidney disease (CKD) is on the rise.

### What is added by this report?

In 2019, 5.58 million individuals in China were affected by CKD related to hypertension, leading to 70,260 fatalities and 1.69 million disability-adjusted life years (DALYs). The most affected groups were men, older individuals, and residents of western China. Over the period from 2010–2019, the age-standardized prevalence rate (ASPR) remained constant, and the age-standardized mortality rate (ASMR) and age-standardized DALY rate (ASDR) showed a decreasing trend. However, there was an increase in the number of cases, deaths, and DALYs associated with this condition.

### What are the implications for public health practice?

Hypertension significantly contributes to the burden of CKD; therefore, raising awareness and implementing early screening measures are essential.

Chronic kidney disease (CKD) has emerged as a pervasive global public health concern. Globally, it accounted for 1.2 million deaths in 2017, standing out as one of the leading causes of mortality (*1*). Hypertension stands as a significant risk factor in the onset and progression of CKD. Notably, in the United States, about 27.5% of patients are compelled to commence dialysis annually due to hypertensive nephropathy (*2*). In China, the staggering figure of 245 million individuals grapples with hypertension, warranting timely interventions to avert CKD progression (*3*). Ascertaining the landscape of hypertension-linked CKD burdens, particularly across various provincial-level administrative divisions (PLADs) in China, is critical for shaping informed health policies and interventions. Surprisingly, no pertinent studies addressing this topic have been disseminated. Consequently, our analysis of the Global Burden of Disease 2019 (GBD 2019) dataset sought to delineate the scope of hypertension-related CKD in China. In 2019, 5.58 million individuals in China were afflicted with hypertension-induced CKD, culminating in 70,260 fatalities and 1.69 million disability-adjusted life years (DALYs). Alarmingly, the number of cases, deaths, and DALYs witnessed an uptrend from 2010 to 2019. These findings underscore the pivotal role of hypertension in exacerbating the CKD burden, necessitating immediate and concerted interventions.

Disease burden indicators data were sourced from the GBD 2019 database and are available at https://vizhub.healthdata.org/gbd-results/. The GBD 2019 database covers 369 diseases and injuries, and catalogs 87 risk factors across 204 countries and territories. This database provides estimates for various metrics such as morbidity, prevalence, mortality, years of potential life lost (YLLs), years lived with disability, and DALYs. The data within this database were obtained from population censuses, death registries, disease surveillance, health service utilization, and published literature (*4*).

Within the GBD 2019 database, CKD is categorized into five subtypes: CKD attributable to type 1 diabetes mellitus, type 2 diabetes mellitus, hypertension, glomerulonephritis, and other and unspecified causes. For the purpose of this report, we focused exclusively on evaluating the burden of CKD resulting from hypertension. Coding for CKD due to hypertension was conducted using the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10), with the pertinent codes falling under I12-I13.9.

Microsoft Excel software (version 16.7; Microsoft Corporation, Redmond, USA) was utilized to analyze the burden of CKD based on gender, age, and presence of PLAD. Joinpoint software (version 5.0.2; Applications Branch, National Cancer Institute, Bethesda, USA) was employed to determine the average annual percentage change (AAPC) to assess the disease burden trend.

In 2019, the prevalence of CKD attributed to hypertension was 5.58 million, resulting in 70,260 fatalities and 1.69 million DALYs. A higher burden was observed in males; although fewer males (2.70 million) were affected compared to females (2.88 million), the fatalities were higher in males (men: 36,733, women: 33,526), with males also accounting for a greater number of DALYs (men: 0.91 million, women: 0.78 million). The impact of the disease was more pronounced among older individuals; prevalence, mortality, and DALY rates increased with age, peaking in individuals aged ≥70 years (prevalence rate: 2,435.51/$10^5$, mortality rate: 43.21/$10^5$, DALY rate: 660.38/$10^5$). Over the period from 2010 to 2019, the disease burden consistently rose, with a 30.96% increase in the number of cases, a 28.92% rise in deaths, and a 17.25% surge in DALYs (Table 1).

The three PLADs with the highest age-standardized prevalence rates (ASPRs) of hypertension-associated CKD were Hunan (363.54/$10^5$), Hebei (348.94/$10^5$), and Jilin (325.56/$10^5$), respectively. Conversely, Beijing (220.02/$10^5$), Shanghai (242.35/$10^5$), and Henan (251.12/$10^5$) exhibited the lowest ASPRs. The age-standardized mortality rates (ASMRs) were highest in Hunan (8.42/$10^5$), Xizang (Tibet) (7.95/$10^5$), and Yunnan (6.85/$10^5$), and lowest in Shandong (2.28/$10^5$), Beijing (2.39/$10^5$), and Jiangsu (2.41/$10^5$). The three PLADs with the highest age-standardized DALY rates (ASDRs) were Xizang (171.42/$10^5$), Hunan (163.42/$10^5$), and Qinghai (141.17/$10^5$). In contrast, Beijing (55.27/$10^5$), Jiangsu (56.45/$10^5$), and Shandong (57.46/$10^5$) had the lowest ASDRs, as shown in Table 2.

The ASPR of hypertension–induced CKD showed no significant change over the period from 2010 (299.83/$10^5$) to 2019 (300.76/$10^5$), with an AAPC of 0.04% [95% confidence interval (*CI*): −0.09%, 0.16%, *P*=0.57]. The ASPR increased from 2010 to 2017 (311.89/$10^5$) with an annual percentage change (APC) of 0.59% (95% *CI*: 0.50%, 0.68%; *P*<0.001), followed by a decrease from 2017 to 2019 with an APC=−1.88% (95% *CI*: −2.53%, −1.23%; *P*<0.001). The ASMR and age–standardized DALY rate also showed declining trends, with AAPCs of −1.06% (95% *CI*: −1.29%, −0.83%; *P*<0.001) and −1.12% (95% *CI*: −1.63%, −0.62%; *P*<0.001), respectively. The ASMR decreased from 4.45/$10^5$ in 2010 to 4.09/$10^5$ in 2019, and the ASDR decreased from 98.74/$10^5$ in 2010 to 88.48/$10^5$ in 2019 (Figure 1).

## DISCUSSION

This study conducted an analysis of the burden of hypertension-related CKD in China using the GBD 2019 database. Our findings revealed a greater burden among males, the elderly population, and in the western region of China. Notably, from 2010 to 2019, there was no significant change in ASPR and both ASMR and ASDR showed a declining trend. Despite this, there was an increase in the number of cases, deaths, and DALYs, indicating a high burden of CKD attributed to hypertension in China.

Gender disparities in the disease burden may be attributed to gender-based differences in the prevalence of advanced CKD, with men showing a higher prevalence of stage 4 (1.1‰ *vs*. 0.9‰) and stage 5 (0.5 ‰ *vs*. 0.4 ‰) CKD (*5*). Given that older individuals typically experience a greater disease burden, it is plausible that advanced age correlates significantly with a higher prevalence of hypertension and the development and progression of CKD. Zhang et al. (*6*) observed an age-related increase in hypertension prevalence (<60% among younger age groups, 65.2% among individuals aged 70–80 years, and 66.7% among those aged ≥80 years). Moreover, Wang et al. (*5*) reported a progressive rise in the risk of CKD and renal impairment across age groups of 30–39, 40–49, 50–59, 60–69, and ≥70 years compared to the 18–29 years age group, with individuals aged ≥70 years being 4.75 and 329 times more likely to develop the conditions than those aged 18–29 years, respectively.

This study unveiled that in Hunan, CKD attributed to hypertension had the highest burden, with the highest ASPR and ASMR, and the second-highest ASDR. A previous national burden-of-disease study reported that in terms of CKD-related YLLs, Hunan ranked second overall, underscoring the substantial burden of CKD in this province (*7*). Limited research exists on the disease burden of hypertension-related CKD in Hunan, warranting further exploration into the specific factors contributing to this elevated burden. Across other provinces, the ASPR did not exhibit notable clustering, while the ASMR and ASDR were elevated in the West and lower in the East, potentially linked to the unequal distribution of healthcare resources between these regions in China (*8*).

From 2010 to 2019, there was an increase in the number of cases of CKD related to hypertension, as well as an uptick in related deaths and DALYs. These

TABLE 1. The prevalence, deaths, and DALYs due to hypertension-related CKD in China, 2010–2019.

| Gender | Age group (years) | Year | Prevalence (95% UI) | | Deaths (95% UI) | | DALYs (95% UI) | |
|---|---|---|---|---|---|---|---|---|
| | | | *N* (1,000) | Rate (1/100,000) | *N* (1,000) | Rate (1/100,000) | *N* (1,000) | Rate (1/100,000) |
| Male | | | | | | | | |
| | 15–49 | 2010 | 498.84 (434.26, 571.44) | 122.36 (106.52, 140.16) | 2.59 (1.79, 3.58) | 0.64 (0.44, 0.88) | 186.39 (140.79, 241.91) | 45.72 (34.53, 59.34) |
| | | 2019 | 454.05 (392.20, 522.45) | 122.84 (106.11, 141.35) | 2.18 (1.46, 3.10) | 0.59 (0.40, 0.84) | 154.58 (114.16, 204.87) | 41.82 (30.88, 55.43) |
| | | Increased (%) | −8.98 (−11.26, −6.72) | 0.40 (−2.12, 2.89) | −15.96 (−38.84, 13.19) | −7.31 (−32.54, 24.84) | −17.06 (−32.34, 1.17) | −8.52 (−25.37, 11.59) |
| | | AAPC (%) (95% *CI*) | −1.03* (−1.16, −0.90) | −0.03 (−0.15, 0.10) | −1.89* (−2.13, −1.65) | −0.84* (−1.07, −0.60) | −1.87* (−2.29, −1.45) | −0.68 (−1.45, 0.09) |
| | 50–69 | 2010 | 736.62 (650.54, 828.42) | 544.97 (481.29, 612.89) | 8.70 (6.63, 11.09) | 6.43 (4.90, 8.20) | 311.15 (246.62, 385.56) | 230.20 (182.46, 285.25) |
| | | 2019 | 1,030.10 (913.51, 1,154.38) | 558.33 (495.14, 625.69) | 11.21 (7.95, 15.40) | 6.08 (4.31, 8.35) | 395.57 (293.03, 523.84) | 214.41 (158.83, 283.93) |
| | | Increased (%) | 39.84 (36.69, 43.36) | 2.45 (0.15, 5.03) | 28.95 (−5.66,73.95) | −5.53 (−30.88, 27.44) | 27.13 (−1.33, 63.03) | −6.86 (−27.71, 19.44) |
| | | AAPC (%) (95% *CI*) | 3.97* (3.63, 4.31) | 0.30* (0.04, 0.55) | 2.73* (2.20, 3.26) | −0.64* (−1.06, −0.22) | 2.70* (2.07, 3.33) | −0.93 (−2.03, 0.18) |
| | 70+ | 2010 | 848.10 (748.93, 956.79) | 2,371.76 (2,094.43, 2,675.71) | 17.12 (13.78, 20.70) | 47.89 (38.55, 57.88) | 277.59 (227.43, 334.90) | 776.28 (636.01, 936.55) |
| | | 2019 | 1,214.35 (1,078.15, 1,362.97) | 2,466.18 (2,189.58, 2,768.01) | 23.34 (17.95, 29.55) | 47.41 (36.45, 60.02) | 363.68 (285.11, 452.21) | 738.58 (579.03, 918.38) |
| | | Increased (%) | 43.18 (39.47, 46.66) | 3.98 (1.28, 6.50) | 36.32 (10.30, 68.95) | −1.00 (−19.90, 22.69) | 31.01 (7.66, 60.05) | −4.86 (−21.81, 16.23) |
| | | AAPC (%) (95% *CI*) | 4.13* (3.83, 4.42) | 0.45* (0.38, 0.53) | 3.36* (3.04, 3.68) | −0.10 (−0.34, 0.14) | 2.92* (2.33, 3.51) | −0.56* (−1.07, −0.05) |
| | All | 2010 | 2,083.56 (1,913.49, 2,264.09) | 298.37 (274.01, 324.22) | 28.41 (23.20, 33.92) | 4.07 (3.32, 4.86) | 775.12 (651.21, 918.75) | 111.00 (93.25, 131.56) |
| | | 2019 | 2,698.50 (2,481.89, 2,929.26) | 372.30 (342.41, 404.14) | 36.73 (28.43, 46.30) | 5.07 (3.92, 6.39) | 913.83 (727.74, 1,145.85) | 126.08 (100.40, 158.09) |
| | | Increased (%) | 29.51 (27.03, 31.95) | 24.78 (22.39, 27.12) | 29.30 (2.14, 64.06) | 24.57 (−1.60, 58.07) | 17.89 (−4.65, 45.33) | 13.59 (−8.14, 40.02) |
| | | AAPC (%) (95% *CI*) | 2.94* (2.86, 3.02) | 2.50* (2.39, 2.61) | 2.82* (2.53, 3.11) | 2.38* (2.08, 2.68) | 1.86* (1.45, 2.27) | 1.42* (1.01, 1.83) |
| Female | | | | | | | | |
| | 15–49 | 2010 | 519.79 (447.04, 596.70) | 132.38 (113.85, 151.97) | 1.64 (1.14, 2.25) | 0.42 (0.29, 0.57) | 144.15 (111.93, 184.46) | 36.71 (28.51, 46.98) |
| | | 2019 | 454.17 (389.44, 527.81) | 129.36 (110.92, 150.33) | 1.14 (0.74, 1.68) | 0.33 (0.21, 0.48) | 106.01 (78.97, 140.56) | 30.19 (22.49, 40.03) |
| | | Increased (%) | −12.63 (−14.93, −10.14) | −2.29 (−4.86, 0.49) | −30.31 (−48.98, −8.58) | −22.06 (−42.94, 2.24) | −26.46 (−37.53, −14.21) | −17.76 (−30.14, −4.05) |
| | | AAPC (%) (95% *CI*) | −1.49* (−1.86, −1.12) | −0.18 (−0.46, 0.11) | −4.08* (−4.67, −3.49) | −2.96* (−3.38, −2.54) | −3.05* (−3.97, −2.11) | −1.43* (−2.23, −0.61) |
| | 50–69 | 2010 | 698.41 (619.37, 781.06) | 534.70 (474.19, 597.98) | 7.17 (5.33, 9.29) | 5.49 (4.08, 7.12) | 256.28 (200.07, 321.62) | 196.20 (153.18, 246.23) |
| | | 2019 | 1,009.52 (899.36, 1,126.30) | 547.50 (487.76, 610.84) | 9.08 (6.52, 12.17) | 4.92 (3.54, 6.60) | 322.98 (245.02, 419.48) | 175.17 (132.88, 227.50) |
| | | Increased (%) | 44.55 (40.86, 47.99) | 2.39 (−0.21, 4.83) | 26.52 (−2.69, 60.01) | −10.38 (−31.06, 13.35) | 26.03 (1.58, 52.57) | −10.72 (−28.04, 8.08) |
| | | AAPC (%) (95% *CI*) | 4.33* (4.04, 4.62) | 0.27 (−0.01, 0.55) | 2.62* (2.44, 2.81) | −1.33* (−1.59, −1.08) | 3.31* (2.55, 4.08) | −0.78* (−1.42, −0.13) |
| | 70+ | 2010 | 956.96 (856.31, 1,068.56) | 2,291.95 (2,050.89, 2,559.24) | 17.28 (13.92, 20.73) | 41.38 (33.33, 49.66) | 267.59 (220.01, 315.15) | 640.89 (526.93, 754.80) |
| | | 2019 | 1,415.15 (1,278.82, 1,574.44) | 2,409.79 (2,177.65, 2,681.04) | 23.31 (17.69, 29.40) | 39.69 (30.12, 50.06) | 349.31 (274.15, 430.44) | 594.82 (466.84, 732.97) |
| | | Increased (%) | 47.88 (43.63, 51.68) | 5.14 (2.12, 7.84) | 34.91 (10.89, 60.64) | −4.08 (−21.16, 14.21) | 30.54 (9.96, 52.57) | −7.19 (−21.82, 8.48) |
| | | AAPC (%) (95% *CI*) | 4.51* (4.32, 4.71) | 0.52* (0.28, 0.77) | 3.09* (2.81, 3.38) | −0.58* (−1.02, −0.14) | 3.16* (2.80, 3.53) | −0.84* (−1.57, −0.09) |
| | All | 2010 | 2,175.16 (2,010.93, 2,353.79) | 326.50 (301.85, 353.31) | 26.09 (21.37, 31.17) | 3.92 (3.21, 4.68) | 668.02 (567.07, 786.09) | 100.27 (85.12, 117.99) |
| | | 2019 | 2,878.84 (2,666.82, 3,112.65) | 412.72 (382.32, 446.24) | 33.53 (25.76, 42.24) | 4.81 (3.69, 6.06) | 778.30 (620.28, 952.58) | 111.58 (88.92, 136.56) |
| | | Increased (%) | 32.35 (29.76, 34.92) | 26.41 (23.94, 28.87) | 28.50 (3.30, 56.07) | 22.73 (−1.34, 49.06) | 16.51 (−3.15, 38.30) | 11.28 (−7.50, 32.09) |
| | | AAPC (%) (95% *CI*) | 3.19* (3.08, 3.29) | 2.64* (2.51, 2.78) | 2.70* (2.23, 3.17) | 2.16* (1.68, 2.65) | 2.17* (1.60, 2.75) | 1.63* (1.08, 2.19) |

Continued

| Gender | Age group (years) | Year | Prevalence (95% UI) | | Deaths (95% UI) | | DALYs (95% UI) | |
|---|---|---|---|---|---|---|---|---|
| | | | *N* (1,000) | Rate (1/100,000) | *N* (1,000) | Rate (1/100,000) | *N* (1,000) | Rate (1/100,000) |
| Both | | | | | | | | |
| | 15–49 | 2010 | 1,018.63 (885.83, 1,170.12) | 127.28 (110.68, 146.20) | 4.23 (3.02, 5.69) | 0.53 (0.38, 0.71) | 330.54 (256.36, 419.93) | 41.30 (32.03, 52.47) |
| | | 2019 | 908.22 (786.28, 1,048.19) | 126.01 (109.10, 145.44) | 3.32 (2.29, 4.55) | 0.46 (0.32, 0.63) | 260.59 (199.16, 338.19) | 36.16 (27.63, 46.92) |
| | | Increased (%) | −10.84 (−12.85, −8.66) | −0.99 (−3.22, 1.44) | −21.53 (−37.98, −2.82) | −12.86 (−31.12, 7.91) | −21.16 (−31.31, −10.03) | −12.45 (−23.72, −0.09) |
| | | AAPC (%) (95% *CI*) | −1.34* (−1.63, −1.05) | −0.11 (−0.28, 0.06) | −2.72* (−2.87, −2.56) | −1.50* (−1.72, −1.28) | −2.37* (−2.96, −1.79) | −1.12* (−1.98, −0.25) |
| | 50–69 | 2010 | 1,435.03 (1,272.88, 1,605.78) | 539.92 (478.92, 604.17) | 15.87 (12.32, 19.85) | 5.97 (4.64, 7.47) | 567.42 (453.40, 694.22) | 213.49 (170.59, 261.20) |
| | | 2019 | 2,039.62 (1,815.02, 2,273.49) | 552.92 (492.03, 616.32) | 20.29 (15.25, 26.15) | 5.50 (4.13, 7.09) | 718.55 (554.74, 898.06) | 194.79 (150.39, 243.45) |
| | | Increased (%) | 42.13 (39.21, 44.82) | 2.41 (0.30, 4.35) | 27.85 (4.90, 57.42) | −7.88 (−24.42, 13.42) | 26.63 (7.51, 49.69) | −8.76 (−22.54, 7.85) |
| | | AAPC (%) (95% *CI*) | 4.14* (3.83, 4.46) | 0.28* (0.02, 0.54) | 2.66* (2.33, 2.98) | −0.93* (−1.15, −0.71) | 2.86* (2.17, 3.57) | −0.95* (−1.72, −0.17) |
| | 70+ | 2010 | 1,805.07 (1,607.57, 2,021.62) | 2,328.77 (2,073.97, 2,608.16) | 34.40 (28.11, 40.87) | 44.38 (36.26, 52.73) | 545.18 (447.97, 640.85) | 703.35 (577.94, 826.78) |
| | | 2019 | 2,629.49 (2,364.44, 2,924.39) | 2,435.51 (2,190.01, 2,708.65) | 46.65 (37.34, 56.27) | 43.21 (34.58, 52.12) | 712.98 (584.18, 852.91) | 660.38 (541.08, 789.99) |
| | | Increased (%) | 45.67 (42.56, 48.81) | 4.58 (2.35, 6.84) | 35.61 (16.59, 56.07) | −2.64 (−16.30, 12.05) | 30.78 (14.32, 48.39) | −6.11 (−17.92, 6.54) |
| | | AAPC (%) (95% *CI*) | 4.37* (4.23, 4.50) | 0.49* (0.33, 0.65) | 3.29* (2.96, 3.63) | −0.39* (−0.62, −0.16) | 3.00* (2.45, 3.55) | −0.80* (−1.43, −0.17) |
| | All | 2010 | 4,258.73 (3,937.49, 4,617.97) | 312.10 (288.56, 338.43) | 54.50 (45.88, 64.50) | 3.99 (3.36, 4.73) | 1,443.14 (1,232.51, 1,685.79) | 105.76 (90.32, 123.54) |
| | | 2019 | 5,577.33 (5,161.60, 6,034.39) | 392.12 (362.89, 424.25) | 70.26 (56.87, 84.48) | 4.94 (4.00, 5.94) | 1,692.13 (1,393.41, 2,014.21) | 118.97 (97.97, 141.61) |
| | | Increased (%) | 30.96 (28.88, 33.03) | 25.64 (23.65, 27.62) | 28.92 (9.43, 51.03) | 23.68 (4.98, 44.89) | 17.25 (1.91, 35.02) | 12.49 (−2.23, 29.53) |
| | | AAPC (%) (95% *CI*) | 3.07* (2.98, 3.16) | 2.58* (2.46, 2.69) | 2.78* (2.56, 2.99) | 2.29* (2.06, 2.53) | 1.92* (1.34, 2.51) | 1.44* (0.89, 1.99) |

Note: The percentage change (%) was calculated as the difference in value between 2019 and 2010, divided by the value in 2010. Data for Taiwan, China were not included. N: number of cases.
Abbreviation: CKD=chronic kidney disease; DALYs=disability-adjusted life years; AAPC=average annual percentage change; *CI*=confidence interval; UI=uncertainty interval.
* $P<0.05$.

trends are likely influenced by population growth and aging. Although the ASPR remained relatively stable, there was a noticeable rise from 2010 to 2017. This increase may be attributed to the evolving epidemiological landscape of hypertension itself, seeing as the prevalence of hypertension escalated from 23.2% in 2012–2015 to 27.5% in 2018 (*6*). The subsequent decline from 2017 to 2019 may be linked to various factors, including the implementation of the Healthy China 2030 initiative and the enactment of China's Medium-to-Long-Term Plan for the Prevention and Treatment of Chronic Diseases (2017–2025). These strategic plans focus on improving air quality, promoting physical activity, reducing salt consumption, and curbing smoking rates, all of which can positively impact CKD prevention. Furthermore, the ASMR and ASDR exhibited a downward trajectory. This decline may be associated with advancements in socioeconomic conditions, the incorporation of CKD surveillance into chronic disease and risk factor monitoring, and enhanced hypertension management within the CKD population. Notably, the Chinese Cohort Study of CKD documented an increase in hypertension control rates among CKD patients, rising from 41.1% in 2013 to 61.7% in 2016 (*9*).

No studies have been published on the disease burden of hypertension-related CKD in China. In 2019, the global ASPR was $397.32/10^5$, the ASMR was $5.88/10^5$, and the ASDR was $123.41/10^5$, all of which were lower in China. Despite lower rates, the significant population size led to 70,260 deaths attributed to hypertension-related CKD in China in 2019, ranking it the highest globally. Globally, reported ASPR, ASMR, and ASDR have increased from 1990 to 2019 (*10*). Interestingly, China has

TABLE 2. Distribution of disease burden of hypertension-related CKD by PLAD, 2019.

| PLADs | Prevalence (95% UI) | | Deaths (95% UI) | | DALYs (95% UI) | |
|---|---|---|---|---|---|---|
| | *N* (1,000) | R' (1/100,000) | *N* (1,000) | R' (1/100,000) | *N* (1,000) | R' (1/100,000) |
| Anhui | 250.77 (224.62, 281.31) | 291.24 (260.11, 329.24) | 2.42 (1.85, 3.11) | 2.94 (2.27, 3.74) | 61.39 (48.80, 75.54) | 69.47 (55.78, 85.33) |
| Beijing | 70.40 (64.46, 77.09) | 220.02 (201.89, 240.42) | 0.72 (0.56, 0.89) | 2.39 (1.88, 2.96) | 18.27 (14.63, 22.49) | 55.27 (44.63, 67.37) |
| Chongqing | 126.29 (112.66, 140.94) | 318.79 (283.15, 358.98) | 1.82 (1.38, 2.33) | 4.68 (3.57, 5.91) | 39.65 (31.02, 49.48) | 97.33 (77.20, 121.29) |
| Fujian | 148.85 (133.41, 167.84) | 307.62 (275.37, 346.82) | 1.57 (1.24, 1.96) | 3.56 (2.84, 4.42) | 38.25 (30.97, 46.14) | 77.40 (63.14, 92.91) |
| Gansu | 92.92 (82.61, 105.43) | 294.52 (262.64, 333.08) | 1.40 (1.10, 1.75) | 5.29 (4.21, 6.51) | 32.22 (25.53, 39.47) | 101.10 (81.73, 122.03) |
| Guangdong | 375.88 (336.53, 421.30) | 290.79 (262.13, 322.75) | 3.93 (3.10, 4.88) | 3.37 (2.67, 4.18) | 99.97 (80.95, 122.84) | 75.83 (62.02, 92.67) |
| Guangxi | 184.60 (166.07, 205.76) | 317.65 (285.62, 356.74) | 3.37 (2.57, 4.36) | 6.07 (4.70, 7.77) | 77.57 (59.76, 99.21) | 128.89 (100.40, 163.71) |
| Guizhou | 124.02 (110.96, 138.34) | 303.79 (271.52, 339.71) | 2.39 (1.83, 3.02) | 6.48 (4.99, 8.05) | 53.91 (41.95, 67.54) | 128.90 (100.33, 159.07) |
| Hainan | 31.83 (28.42, 36.05) | 299.02 (267.68, 336.60) | 0.44 (0.34, 0.56) | 4.66 (3.59, 5.79) | 10.63 (8.35, 13.26) | 97.47 (77.67, 120.25) |
| Hebei | 329.49 (288.33, 379.53) | 348.94 (305.18, 404.12) | 3.95 (3.06, 4.97) | 4.93 (3.85, 6.11) | 96.65 (76.91, 120.03) | 101.11 (81.83, 123.31) |
| Heilongjiang | 161.96 (144.29, 181.89) | 295.51 (264.41, 333.86) | 1.44 (1.11, 1.83) | 2.95 (2.32, 3.67) | 42.00 (33.41, 52.73) | 72.08 (58.81, 88.88) |
| Henan | 293.45 (257.88, 333.06) | 251.12 (221.34, 286.57) | 3.50 (2.71, 4.47) | 3.24 (2.52, 4.11) | 88.02 (69.84, 109.04) | 72.85 (58.26, 89.00) |
| Hong Kong SAR | 47.22 (43.02, 51.71) | 325.31 (293.83, 361.18) | 0.78 (0.56, 1.05) | 4.71 (3.33, 6.32) | 13.27 (10.02, 17.13) | 91.13 (69.08, 117.21) |
| Hubei | 255.28 (228.11, 287.46) | 321.39 (288.39, 362.21) | 3.75 (2.92, 4.80) | 5.19 (4.06, 6.53) | 85.76 (67.87, 106.74) | 104.52 (83.93, 128.31) |
| Hunan | 334.70 (298.57, 373.80) | 363.54 (323.45, 409.03) | 7.20 (5.52, 8.99) | 8.42 (6.52, 10.37) | 154.41 (120.05, 191.20) | 163.42 (128.13, 201.46) |
| Inner Mongolia | 98.78 (88.05, 111.65) | 305.21 (271.72, 345.93) | 1.03 (0.81, 1.29) | 3.79 (2.99, 4.66) | 27.49 (22.27, 34.04) | 81.78 (67.00, 99.41) |
| Jiangsu | 351.76 (312.67, 394.35) | 271.57 (240.86, 307.33) | 3.06 (2.34, 3.99) | 2.41 (1.84, 3.12) | 73.61 (58.69, 91.47) | 56.45 (45.27, 69.71) |
| Jiangxi | 171.05 (151.24, 191.10) | 316.45 (281.12, 353.50) | 2.86 (2.22, 3.56) | 6.01 (4.72, 7.40) | 62.47 (50.11, 75.47) | 113.88 (92.63, 137.32) |
| Jilin | 128.26 (114.20, 143.41) | 325.56 (288.88, 364.07) | 1.42 (1.17, 1.75) | 3.97 (3.31, 4.75) | 38.18 (30.99, 47.10) | 91.71 (75.62, 110.21) |
| Liaoning | 225.02 (201.51, 253.29) | 317.56 (283.41, 359.92) | 2.16 (1.67, 2.80) | 3.19 (2.48, 4.06) | 57.52 (45.30, 71.78) | 77.63 (62.22, 95.40) |
| Macao SAR | 2.77 (2.46, 3.14) | 305.78 (271.86, 346.79) | 0.02 (0.02, 0.03) | 2.74 (2.00, 3.66) | 0.61 (0.47, 0.78) | 65.73 (50.57, 83.18) |
| Ningxia | 20.71 (18.33, 23.35) | 296.09 (264.50, 328.79) | 0.23 (0.17, 0.30) | 3.96 (3.05, 5.02) | 6.27 (4.84, 7.91) | 85.62 (68.20, 106.90) |
| Qinghai | 18.38 (16.28, 20.89) | 302.02 (270.14, 340.67) | 0.34 (0.26, 0.42) | 6.80 (5.37, 8.30) | 8.98 (7.07, 11.27) | 141.17 (113.29, 172.84) |
| Shaanxi | 153.68 (137.59, 171.98) | 308.47 (276.27, 346.28) | 2.04 (1.52, 2.60) | 4.64 (3.55, 5.84) | 50.55 (39.20, 63.59) | 98.02 (77.23, 121.55) |
| Shandong | 417.17 (375.61, 462.47) | 289.92 (261.04, 325.41) | 3.13 (2.43, 4.00) | 2.28 (1.79, 2.88) | 84.71 (67.77, 104.96) | 57.46 (46.39, 70.22) |
| Shanghai | 100.23 (91.13, 110.46) | 242.35 (219.59, 267.90) | 1.11 (0.85, 1.38) | 2.74 (2.09, 3.39) | 24.74 (19.75, 29.98) | 58.86 (47.20, 71.45) |
| Shanxi | 136.79 (122.42, 154.86) | 305.28 (273.04, 343.62) | 1.52 (1.14, 1.92) | 3.97 (3.03, 4.90) | 38.88 (30.07, 48.72) | 84.07 (65.66, 103.98) |
| Sichuan | 344.44 (305.25, 387.89) | 284.79 (251.15, 323.06) | 5.17 (3.91, 6.56) | 4.49 (3.50, 5.58) | 121.77 (95.94, 149.89) | 96.43 (77.13, 117.41) |
| Tianjin | 60.97 (54.39, 69.38) | 299.01 (266.54, 340.00) | 0.48 (0.36, 0.62) | 2.54 (1.95, 3.28) | 13.87 (11.01, 17.27) | 64.81 (52.27, 80.08) |
| Xizang | 7.07 (6.12, 8.28) | 259.04 (229.46, 292.24) | 0.17 (0.13, 0.22) | 7.95 (6.32, 9.95) | 4.82 (3.81, 6.12) | 171.42 (137.34, 213.09) |
| Xinjiang | 72.39 (64.48, 82.81) | 307.37 (277.16, 347.93) | 1.22 (0.95, 1.55) | 6.41 (4.99, 8.09) | 32.53 (25.63, 40.48) | 133.03 (106.18, 164.92) |
| Yunnan | 161.26 (143.21, 182.01) | 307.25 (273.68, 346.74) | 3.14 (2.48, 3.88) | 6.85 (5.50, 8.38) | 74.96 (60.30, 92.15) | 138.39 (112.61, 168.16) |
| Zhejiang | 278.98 (248.46, 311.14) | 324.35 (287.47, 364.77) | 2.45 (1.91, 3.05) | 3.02 (2.34, 3.72) | 58.23 (46.88, 70.09) | 67.24 (54.73, 80.53) |
| Total | 5,577.33 (5,161.60, 6,034.39) | 300.76 (278.72, 325.76) | 70.26 (56.87, 84.48) | 4.09 (3.32, 4.88) | 1,692.13 (1,393.41, 2,014.21) | 88.48 (73.38, 104.46) |

Note: N: number of cases; R': age-standardized rate calculated using the 2010 National Census as the standard population. Data for Taiwan, China were not included.

Abbreviation: DALYs=disability-adjusted life years; UI=uncertainty interval; PLAD=provincial-level administrative division; SAR=Special Administrative Region.

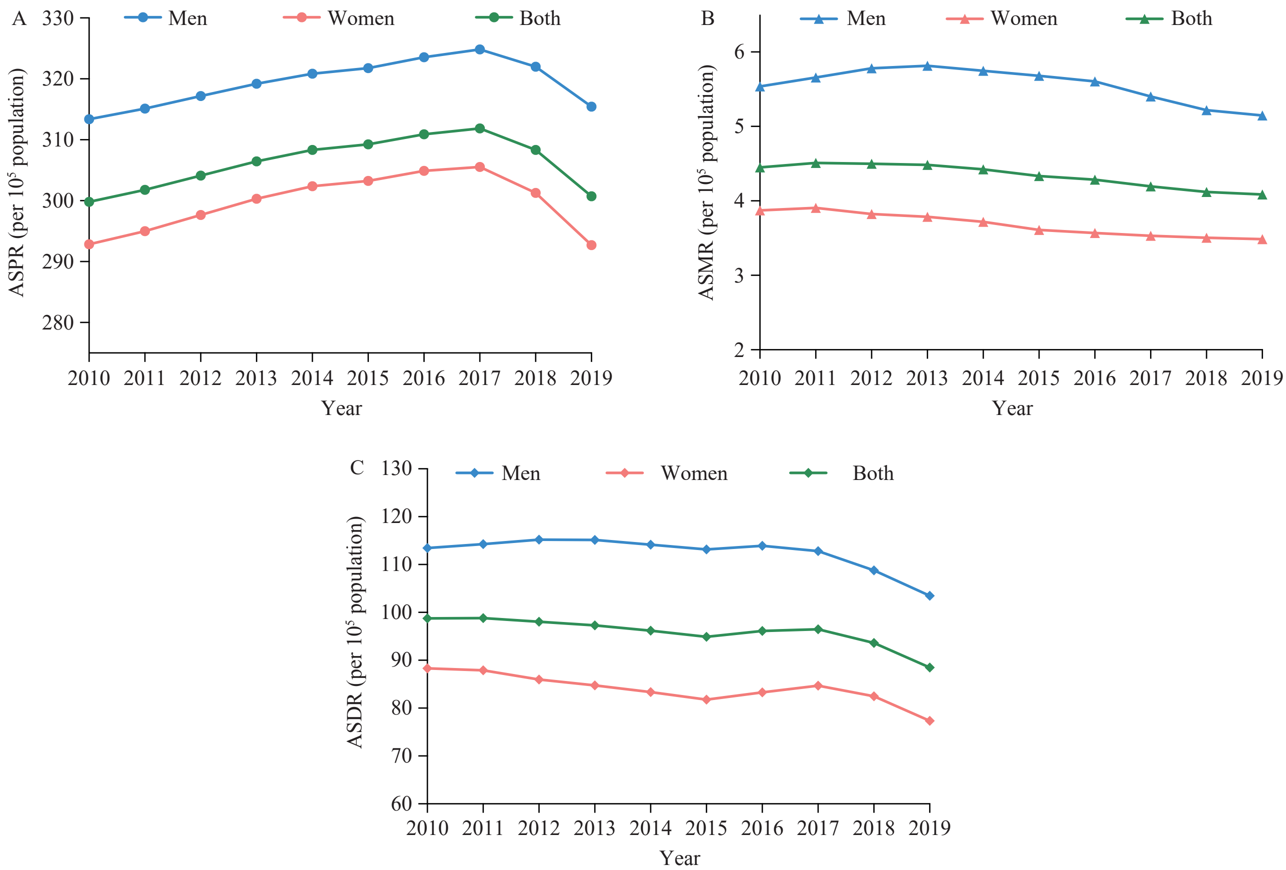


FIGURE 1. Trends of disease burden of hypertension-related chronic kidney disease by gender, 2010–2019. (A) ASPR; (B) ASMR; (C) ASDR.

Note: Data for Taiwan, China were not included.

Abbreviation: ASPR=age-standardized prevalence rate; ASMR=age-standardized mortality rate; ASDR=age-standardized DALY rate.

shown better management of the disease burden in recent years.

This study is subject to some limitations. First, the GBD 2019 database offered estimates of disease burden rather than actual observations, resulting in discrepancies with real-world scenarios. Second, the etiology of CKD is intricate, and the underlying causes remain uncertain.

In conclusion, hypertension stands as a prominent contributor to the burden of CKD in China, with a persistently high prevalence. Implementing strategies to enhance CKD awareness, conducting early screenings among hypertensive individuals and the elderly, and equitably distributing healthcare resources across Eastern and Western regions of China are vital steps toward mitigating the CKD burden attributed to hypertension.

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Preplanned Studies

# The Impact of New Regulations on Prevention and Control of E-Cigarettes on Adolescents in Middle Schools — A City in China, 2022–2023

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**Summary**

**What is already known about this topic?**

To protect the health of young people from the harmful impacts of electronic cigarettes (e-cigarettes), China has enacted various policies and regulations since 2018. As of October 1, 2022, the *Electronic Cigarette Management Measures* were put into action. They prohibited the sale of flavored e-cigarettes, permitting only those of plain tobacco flavor to be sold.

**What is added by this report?**

The illegal market for flavored e-cigarettes, often disguised as milk tea cups, cola cans, and violent bear images, continues to flourish. There is an increased need to bolster support for the prohibition of flavored e-cigarettes and enhance public awareness of associated regulations.

**What are the implications for public health practice?**

To advance the health of China's youth, it is crucial to improve the implementation and understanding of e-cigarette policies and guidelines.

Electronic cigarette (e-cigarette) emissions is typically comprised of nicotine, known to adversely affect brain development in children and adolescents, potentially leading to learning and anxiety disorders (*1*). Non-smoking teenagers who engage in e-cigarette use are twice as likely to initiate traditional smoking later in life (*1*). In response, China has enforced regulations to safeguard young individuals from the detrimental consequences of e-cigarette use. A directive in June 2021 prohibited the sale of e-cigarettes to minors (*2*). Subsequently, in November 2021, new tobacco products, including e-cigarettes, were required to align with mandates applicable to conventional cigarettes (*3*). Further, the *Electronic Cigarette Management Measures*, put into action on October 1, 2022 (*4*), explicitly banned the sale of e-cigarettes featuring flavors other than tobacco and outlawed the use of e-cigarettes capable of generating aerosols independently.

In October 2023, a survey was conducted among middle school students in Shenzhen City, Guangdong Province using a custom-made questionnaire. The purpose of the study was to evaluate the effects of certain *Measures* on adolescents' knowledge, attitude/belief, practice (KAP) regarding e-cigarettes. The intention was for the results of the study to contribute scientific evidence and data to help enhance e-cigarette regulation. The analysis disclosed a lack of awareness among the students about policies and regulations pertaining to e-cigarettes. Furthermore, bans related to e-cigarettes had not been effectively put into practice. As such, a more robust effort to promote and enforce e-cigarette regulations is proposed.

This study utilized convenience sampling to select one junior high school, one senior high school, and one vocational high school in Shenzhen. We employed a cluster sampling technique to select three classes from each grade at these schools, excluding the fourth grade in the senior high school. A selection criterion stated that class sizes should consist of at least 40 students. If fewer than 40, classes were combined. Without the interference of teachers, students autonomously completed the questionnaire survey. The final tally showed that 1,089 students completed the questionnaire, yielding an overall response rate of 95.61%. Additionally, using convenience sampling, we selected 20 e-cigarette stores in Shenzhen, comprised of 12 specialty and eight combined stores, for evaluating the availability of fruit-flavored e-cigarette cartridges. The data obtained were analyzed using SAS software (Version 9.3, SAS Institute Inc., Cary, USA). We used statistical tests, including the chi-square and Fisher's exact probability tests, to examine group differences, maintaining a significance level at $\alpha=0.05$. The study secured approval from the Chinese Center for Disease Control and Prevention Institutional Review Board (No. 202321).

We gathered a total of 1,089 valid questionnaires, of which 61.07% were from male respondents and 38.93% were from female respondents. When considering education level, 37.74% of respondents were junior high school students, 31.31% were senior high school students, and 30.95% were students from vocational high schools.

Approximately 82.37% of survey participants indicated concerns over potential health risks linked to e-cigarette use. Among varying education levels, a reduced perception of the hazards of e-cigarettes was observed in senior high school (80.06%) and vocational high school respondents (78.34%) in comparison to those from junior high school (87.59%). In addition, a lower awareness of the hazards associated with e-cigarettes was demonstrated by males (80.15%), as compared to females (85.85%). These observed differences were statistically significant ($P$<0.05).

The survey encompassed six queries related to knowledge of e-cigarette policies and regulations. Overall, male respondents demonstrated a higher awareness level than females, and students from senior high schools exhibited greater understanding compared with those in vocational high schools (Table 1). Middle school students obtained information on e-cigarette regulations and policies primarily from the Internet (77.50%), followed by public place slogans (55.60%), television broadcasts (50.95%), alternative sources (50.95%), billboards or posters (43.45%), and finally from newspapers or magazines (28.69%).

The study found that 5.51% of the participants had used e-cigarettes. In 2022, 43 people reported using e-cigarettes, of whom 27 continued their usage into 2023. In 2023, a total of 29 individuals reported e-cigarette usage. When asked about their perception of e-cigarette usage among their peers, 16.80% of the participants perceived an increase in 2023 compared to 2022. On the other hand, 25.53% perceived a decrease and 57.67% believed there had been no change in usage from 2022 to 2023.

In 2023, e-cigarettes were purchased by 23 participants in our study. Of these, 78.26% opted for models shaped like milk tea cups, cola cans, or "violent bears". Moreover, among these buyers, 18 chose flavors other than the traditional tobacco variant (Table 2). In a survey of 20 e-cigarette retail outlets, it was discovered that 17 stocked fruit-flavored cartridges. Of the 21 participants who made e-cigarette purchases in both 2022 and 2023, 14.29% reported that obtaining these products was more difficult in 2023 compared to 2022; however, 85.71% reported no change in accessibility. Surprisingly, almost half (47.83%) of the 2023 purchasers reported no age-related restrictions at the point of sale. In addition, among those who shopped in physical outlets in 2023, 27.27% did not take notice or show any concern to health warnings exhibited in the stores.

In 2023, of a total of 1,029 students who reported they had never used e-cigarettes, 284 (27.60%) had peers who did. Out of these, 150 students knew the flavor that their peers were using, and 148 of those students disclosed that their peers used non-tobacco flavored e-cigarettes. Information about how these e-cigarettes were obtained was familiar to 92 students, with the majority reporting that they were procured from physical e-cigarette stores (Table 3). In the preceding year, 59 students expressed interest in trying

TABLE 1. Awareness of e-cigarette-related policies and regulations among middle school students in Shenzhen, categorized by gender and school type, 2022–2023.

| Project | Total (%) | Male (%) | Female (%) | $X^2$ | *P* value | Junior high school (%) | Senior high school (%) | Vocational high school (%) | $X^2$ | *P* value |
|---|---|---|---|---|---|---|---|---|---|---|
| *Electronic Cigarette Management Measures* | 58.77 | 61.35 | 54.72 | 4.706 | <0.05 | 60.10 | 58.65 | 57.27 | 0.614 | 0.736 |
| Ban on the sale of fruit-flavored e-cigarettes | 66.67 | 68.87 | 63.21 | — | 0.056* | 65.21 | 71.85 | 63.20 | 6.330 | <0.05 |
| Ban on the sale of e-cigarettes through Taobao, Pinduoduo and WeChat | 65.56 | 68.42 | 61.08 | 6.172 | <0.05 | 64.72 | 70.09 | 62.02 | 5.098 | 0.078 |
| Prohibit the sale of e-cigarettes to minors | 89.07 | 88.12 | 90.57 | 1.591 | 0.207 | 90.02 | 92.08 | 84.87 | 9.681 | <0.05 |
| Prohibit the sale of 'milk tea cup' and 'violent bear' shaped electronic cigarettes | 68.04 | 70.38 | 64.39 | 4.271 | <0.05 | 66.67 | 73.31 | 64.39 | 6.781 | <0.05 |
| E-cigarettes are managed according to the relevant provisions of cigarettes. | 55.10 | 58.35 | 50.00 | 7.290 | <0.05 | 56.20 | 58.94 | 49.85 | — | 0.051* |

Note: "—" means not applicable.

* This value is the Fisher's exact probability value.

TABLE 2. Types, flavors, and purchasing methods of e-cigarettes procured by middle school students in Shenzhen, 2022–2023.

| Project | Response | | Percentage of cases (%) |
|---|---|---|---|
| | *n* | Percentage (%) | |
| Types of e-cigarettes purchased | | | |
| Disposable e-cigarettes (excluding modelling e-cigarettes) | 20 | 30.77 | 86.96 |
| Milk tea cups, coke cans, violent bears and other modelling e-cigarettes | 18 | 27.69 | 78.26 |
| Replaceable cartridge e-cigarettes | 18 | 27.69 | 78.26 |
| Refillable e-cigarettes | 9 | 13.85 | 39.13 |
| Flavors of e-cigarettes purchased | | | |
| Tobacco flavor | 10 | 30.30 | 43.48 |
| Fruits, beverages, herbs or tea flavors | 18 | 54.55 | 78.26 |
| Other flavors | 5 | 15.15 | 21.74 |
| Ways to buy e-cigarettes | | | |
| E-cigarette stores | 18 | 28.57 | 78.26 |
| Online social platforms | 16 | 25.40 | 69.57 |
| E-commerce platforms | 9 | 14.29 | 39.13 |
| Supermarkets, convenience stores, and grocery stores | 7 | 11.11 | 30.43 |
| Relatives, friends, classmates, and agents | 13 | 20.63 | 56.52 |
| Ways to buy non-tobacco flavored e-cigarettes | | | |
| E-cigarette stores | 14 | 26.92 | 77.78 |
| Online social platforms | 14 | 26.92 | 77.78 |
| E-commerce platforms | 7 | 13.46 | 38.89 |
| Supermarkets, convenience stores, and grocery stores | 6 | 11.54 | 33.33 |
| Relatives, friends, classmates, and agents | 11 | 21.16 | 61.11 |

e-cigarettes. A year later, 74.58% maintained their earlier stance, 5.08% indicated an increased interest, but 20.34% saw a decrease in their willingness to try e-cigarettes.

Over half of the participants (52.16%) asserted their support for the prohibition of flavored e-cigarettes. The level of support varied significantly across different school levels; it was lower amongst vocational high school students (41.25%) compared to their counterparts in junior high school (57.18%) and senior high school (56.89%) ($P$<0.05). Support for the ban was more pronounced amongst those who were aware of the *Measures* (57.19%) in comparison to their unaware peers (44.99%). A higher proportion of flavored e-cigarette ban support of individuals (60.17%) were knowledgeable about the management of e-cigarettes according to the relevant regulations on cigarettes compared to those who were not aware (42.33%) and was markedly greater among respondents conscious of the detrimental effect of e-cigarettes on health (55.41%) compared to those unaware of the risks (36.98%). All these disparities were statistically significant ($P$<0.05). On another note, the ban encountered more favor among non-users of e-cigarettes in the period running from 2022 to 2023 (53.16%), compared to the users (28.89%), a difference that was statistically significant ($P$<0.05).

## DISCUSSION

Among middle school students, 82.37% acknowledged the risks associated with e-cigarettes. However, familiarity with e-cigarette-related regulations generally fell below 70%. Surprisingly, 23.10% of these students, specifically those from Chengdu City, Sichuan Province, were not aware that e-cigarettes produce second-hand smoke, and 38.60% reported receiving no information about the associated harm or regulatory measures over the last 30 days (*5*). Additionally, in 2023, 27.60% of the surveyed students disclosed that their peers were using e-cigarettes. Past research has suggested that peer influence contributes significantly to middle school students' temptation to experiment with e-cigarettes

TABLE 3. Flavors of e-cigarettes and purchasing methods used by peer middle school students in Shenzhen, 2022–2023.

| Project | Response | | Percentage of cases (%) |
|---|---|---|---|
| | *n* | Percentage (%) | |
| Flavors of e-cigarettes purchased | | | |
| Tobacco flavor | 41 | 19.07 | 27.33 |
| Fruits, beverages, herbs or tea flavors | 145 | 67.44 | 96.67 |
| Other flavors | 29 | 13.49 | 19.33 |
| Methods of buying e-cigarettes | | | |
| E-cigarette stores | 61 | 30.05 | 66.30 |
| Online social platforms | 52 | 25.62 | 56.52 |
| E-commerce platforms | 43 | 21.18 | 46.74 |
| Relatives, friends, classmates, and agents | 47 | 23.15 | 51.09 |

(*6–7*). Those who were cognizant of the dangers of e-cigarettes and their respective governance were more inclined to support the prohibition of flavored e-cigarettes. Notably, vocational high school students had less awareness of the pertinent policies and indicated less support for a ban on flavored e-cigarettes. These students are often identified as having a higher susceptibility to e-cigarette use (*8*). Therefore, it is imperative to amplify public information campaigns concerning the hazards of e-cigarettes and associated regulatory measures.

A total of 78.26% of survey participants reported purchasing e-cigarettes with unique designs, such as those resembling milk tea cups, soda cans, and cartoon bears. Among these, 18 respondents indicated that they obtained flavored e-cigarettes that did not have a tobacco flavor. It was also observed that fruit-flavored cartridges were still available for purchase at brick-and-mortar e-cigarette retailers in Shenzhen. One reporter's field visit confirmed the continued sale of both designed e-cigarettes styled as milk tea cups and fruit flavored cartridges (*9*). Furthermore, in 2023, 47.83% of respondents reported that they were not denied a sale of e-cigarettes due to their age. Similarly, among middle school students who had used e-cigarettes in 2021, 70.8% indicated that they were not refused their latest e-cigarette purchase (*10*). In 2023, of the e-cigarette buyers, 27.27% reported not encountering or noticing any health warning notices at stores. It appears that e-cigarette-related policies and regulations, including the *Measures*, have not been effectively enforced.

This study was subject to some limitations. Due to a cross-sectional survey, recall bias cannot be neglected. In addition, owing to the sample selection that is not random, it cannot reflect the overall study population.

In conclusion, there is a clear requirement for improved awareness surrounding policies and regulations of e-cigarettes, in addition to endorsing the prohibition of flavored e-cigarettes. The enforcement of the ban on both flavored e-cigarettes and the sale of e-cigarettes to minors has not been effectively implemented. Thus, it is advisable to augment the advocacy of these *Measures* and to expand the understanding of middle school students about the hazards of e-cigarettes and related regulations. Appropriate guidance should be furnished to students in vocational training. Regulatory policies, such as the ban on selling e-cigarettes to minors and flavored e-cigarettes, must be stringently executed to shield adolescents from the potential risks posed by e-cigarettes.

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Vital Surveillances

# Injury Mortality of Children and Adolescents Aged 0–19 Years — China, 2010–2021

Jingtao Zhou[1]; Min Zhao[1]; Hao Huang[1]; David C. Schwebel[2]; Peishan Ning[1]; Zhenzhen Rao[1]; Peixia Cheng[3]; Li Li[1,#]; Guoqing Hu[1,4,#]

## ABSTRACT

**Introduction**: To examine the recent trends in child injury mortality in China.

**Methods**: Injury mortality data of 2010–2021 for children and adolescents aged 0–19 years were from the China Health Statistics Yearbook. Injury mortality disparities across urban vs. rural locations, gender, and age groups were scrutinized. Annual percent change (APC), average annual percent change (AAPC), and their 95% confidence intervals (95% *CI*) were estiamted usimg Joinpoint regression models.

**Results**: The age-standardized injury mortality significantly dropped from 21.87 to 9.41 per 100,000 population among children and youth aged 0–19 years during 2010–2021, with an AAPC of −6.7% (95% *CI*: −8.2%, −5.2%). The urban-rural disparity and gender gap in injury mortality reduced gradually. In 2021, drowning and road traffic crashes were the top two causes of child injury deaths, explaing 31.1% and 27.9% of total injury deaths, respectively. Suffocation accounted for 62.3% of injury deaths among infants younger than a year. Alarmingly, the suicide mortality rate rose from 2.16 to 3.42 per 100,000 population between 2010 and 2021 among teenagers aged 15–19 years. Subgroup analyses yielded similar results.

**Conclusions**: During 2010–2021, the injury mortality decreased significantly among Chinese children and adolescents, and the responding urban-rural disparities narrowed.

Injuries pose a significant global challenge to the health and safety of children and adolescents (*1*). According to estimates by the Global Burden of Disease (GBD) study group, injuries caused 595,621 deaths and 233,114,563 incident cases worldwide among individuals aged 0–19 years in 2019. Of these, 6.5% of the deaths and 9.3% of the incident cases occurred in China (*2*).

The United Nations (UN) has outlined several Sustainable Development Goals (SDGs) pertinent to preventing injuries amongst children and adolescents (*3*). In the same vein, the Chinese central government promulgated a series of developmental outlines for children, and the current outline (2021–2030) sets an ambitious goal of a 20% reduction in child injury mortality by 2030 compared to 2020 (*4*).

To effectively mornitor the progress towards the specified targets in China, it is critical to regularly analyze nationwide data to discern patterns in child and adolescent mortality due to injuries. Several studies have documented trends in this field until 2020. Research by Luo et al. (*5*) analyzed the temporal progression of mortality due to injuries in children and adolescents aged 1–24 years, utilizing the Chinese Cause of Death Surveillance dataset spanning from 2010 to 2020. Zheng et al. (*6*) reported a notable reduction in mortality from drowning and road traffic crashes in children and adolescents aged 5–19 years between 2008 and 2019. Elevated injury mortality were reported occurring among boys, children, and early adolescents aged 5–14, and individuals residing in the western and rural areas. Yao et al. explored disparities in injury-induced mortality among children by gender and area (urban vs. rural) in Sichuan Province (*7*), but their findings were not nationally representative.

This study scrutinized nationally representative data to assess trends in overall injury mortality rates among Chinese children and adolescents (aged 0–19 years) from 2010 to 2021. In addition, we evaluated subgroup mortality rates according to demographic factors including area (rural *vs*. urban), sex, and age group.

## METHODS

This study sourced annual data on child and adolescent injury mortality from the Chinese Health

Statistical Yearbook (2010–2021), which provides age-specific mortality data for 11 categories of unintentional and intentional injuries (*8*): motor vehicle crashes, non-motor vehicle crashes, poisoning, falls, fire/burn injuries, drowning, mechanical suffocation, falling object injuries, electric shocks, homicide, and suicide. To estimate the year-end population for each year from 2010 to 2021, we employed linear interpolation (*9*) using China's census data of 2010 and 2020. The population data from 2020 was then utilized as the standard population for calculating age-standardized injury mortality.

Linear graphs were utilized to display variations in both overall and subgroup injury mortality, separated by area, gender, and age group for Chinese children and adolescents aged 0 to 19 years. Furthermore, stacked area charts were constructed to show the cause spectrum of child and adolescent injury mortality from 2010 to 2021, segmented by area and age group.

Significant injury mortality changes throughout the study time period were quantified using average annual percent change (AAPC) and annual percent change (APC), alongside their corresponding 95% confidence intervals (95% *CI*s), which were estimated via Joinpoint regression models. We used the Joinpoint Regression Program (Version 4.9.1.0, National Cancer Institute, Calverton, USA) to perform statistical analysis.

## RESULTS

### Overall Injury Mortality and Subgroup Mortality by Area and Age Group

Between 2010 and 2021, the overall age-standardized injury mortality for children and adolescents in China decreased from 21.87 to 9.41 per 100,000 population (AAPC=−6.7%, 95% *CI*: −8.2%, −5.2%). The age-standardized injury mortality for urban children was continuously lower than and declined more slowly than that for rural children (urban–rural mortality ratio: 0.53 to 0.70; AAPC: −4.6% *vs*. −6.9%) (Figure 1A and Table 1). Injury mortality declined significantly during 2010–2021 in four age groups (under 1 year: AAPC=−7.9%, 1–4 years: AAPC=−11.6%, 5–9 years: AAPC=−7.5%,

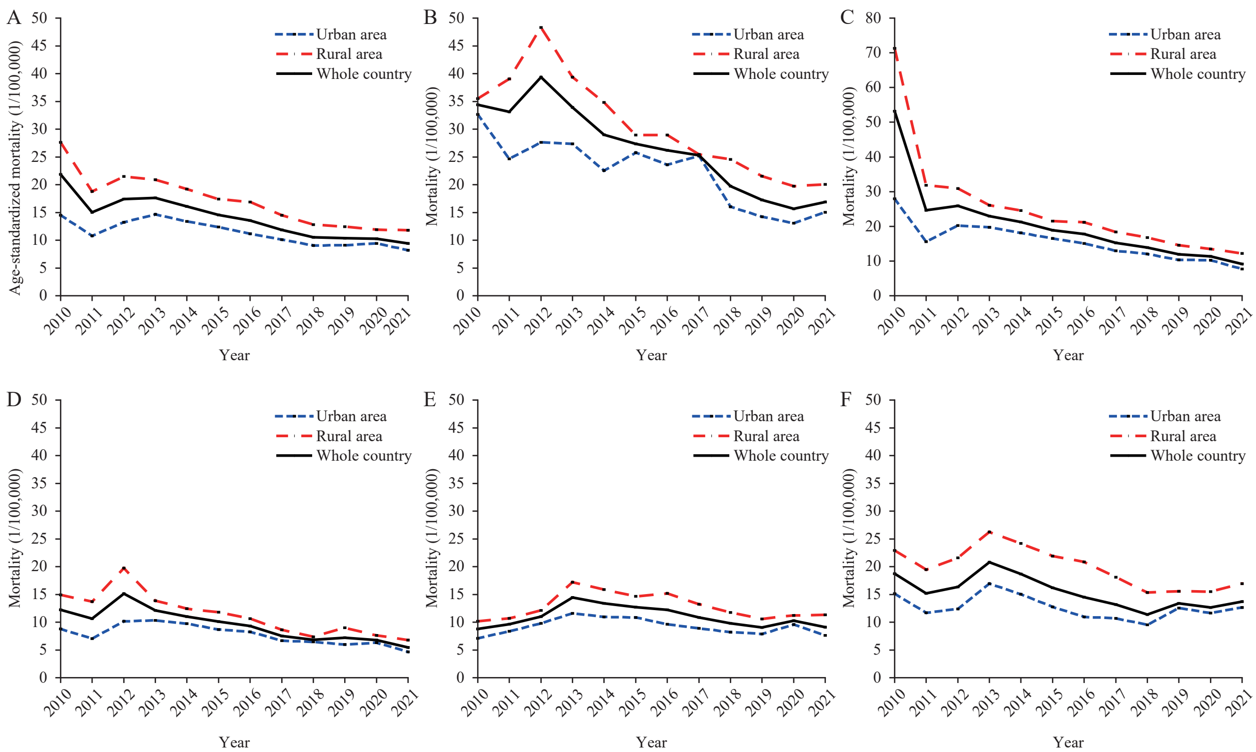


FIGURE 1. Age-standardized and age-specific mortality rates for injuries among children and adolescents in various regions of China, from 2010 to 2021. (A) Age-standardized injury mortality rates in individuals aged 0–19 segmented by area. (B) Mortality caused by injuries in children under 1 year, differentiated by area. (C) Injury-caused mortality in children aged 1–4, broken down by area. (D) Injury-associated mortality in children aged 5–9, classified by area. (E) Mortality due to injuries in adolescents aged 10–14, outlined by area. (F) Injury mortality trends in adolescents aged 15–19, divided by area.

TABLE 1. APC and AAPC in injury mortality among Chinese children and adolescents from 2010 to 2021.

| Age group | Area | Block 1 | | Block 2 | | Block 3 | | AAPC (95% *CI*) |
|---|---|---|---|---|---|---|---|---|
| | | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | |
| All ages | Total | 2010–2021 | −6.7 (−8.2, −5.2)* | | | | | −6.7 (−8.2, −5.2)* |
| | Urban | 2010–2021 | −4.6 (−6.5, −2.6)* | | | | | −4.6 (−6.5, −2.6)* |
| | Rural | 2010–2021 | −6.9 (−8.4, −5.5)* | | | | | −6.9 (−8.4, −5.5)* |
| 0–1 years | Total | 2010–2021 | −7.9 (−9.7, −6.1)* | | | | | −7.9 (−9.7, −6.1)* |
| | Urban | 2010–2021 | −7.2 (−9.7, −4.6)* | | | | | −7.2 (−9.7, −4.6)* |
| | Rural | 2010–2012 | 15.9 (−1.8, 36.8) | 2012–2015 | −14.1 (−27.3, 1.4) | 2015–2021 | −7.0 (−9.5, −4.3)* | −5.3 (−9.0, −1.4)* |
| 1–4 years | Total | 2010–2021 | −11.6 (−14.1, −9.0)* | | | | | −11.6 (−14.1, −9.0)* |
| | Urban | 2010–2021 | −8.8 (−11.1, −6.4)* | | | | | −8.8 (−11.1, −6.4)* |
| | Rural | 2010–2021 | −11.7 (−14.6, −8.6)* | | | | | −11.7 (−14.6, −8.6)* |
| 5–9 years | Total | 2010–2021 | −7.5 (−9.6, −5.3)* | | | | | −7.5 (−9.6, −5.3)* |
| | Urban | 2010–2013 | −9.6 (−9.4, 32.6) | 2013–2021 | −8.6 (−12.3, −4.7)* | | | −3.9 (−8.6, 1.0) |
| | Rural | 2010–2014 | −8.0 (−10.4, −5.6)* | | | | | −8.0 (−10.4, −5.6)* |
| 10–14 years | Total | 2010–2013 | 18.1 (6.7, 30.6)* | 2013–2021 | −5.4 (−7.5, −3.3)* | | | 0.5 (−2.1, 3.2) |
| | Urban | 2010–2013 | 17.0 (2.1, 34)* | 2013–2021 | −4.7 (−7.5, −1.9)* | | | 0.7 (−2.8, 4.4) |
| | Rural | 2010–2013 | 20.1 (8.1, 33.4)* | 2013–2021 | −5.3 (−7.4, −3.1)* | | | 1.1 (−1.7, 3.9) |
| 15–19 years | Total | 2010–2021 | −3.6 (−5.9, −1.3)* | | | | | −3.6 (−5.9, −1.3)* |
| | Urban | 2010–2021 | −2.1 (−4.8, 0.7) | | | | | −2.1 (−4.8, 0.7) |
| | Rural | 2010–2014 | 4.6 (−7.0, 17.7) | 2014–2018 | −11.1 (−26.2, −7.1) | 2018–2021 | 1.5 (−15.7, 22.3) | −2.2 (−8.5, 4.6) |

Abbreviation: APC=annual percent change; AAPC=average annual percent change; *CI*=confidence interval.
* *P*<0.05.

15–19 years: AAPC=–3.6%), while significant decreases only occurred between 2013 and 2021 for the age group of 10–14 years (Figure 1B–F and Table 1).

## Subgroup Injury Mortality by Age Group, Sex, and Area

Between 2010 and 2021, age-standardized injury mortality decreased from 28.52 to 11.24 per 100,000 population for boys, and decreased from 14.34 to 7.30 per 100,000 population for girls. The age-standardized injury mortality for boys was continuously higher than and declined faster than that for girls in both urban and rural areas (Figure 2A and Table 2).

Subgroup analyses showed significant injury mortality decreases in three younger age groups for both sexes in both urban and rural areas (under 1 year, aged 1–4 years and aged 5–9 years, with AAPCs ranging from −12.8% to −4.3%), with exceptions for rural girls under 1 year and for urban boys aged 5–9 years old. Strikingly, overall and subgroup injury mortality by area and sex did not change significantly among early adolescents aged 10–14 years old. Significant reductions appeared only in urban boys (AAPC=–3.5%, 95% *CI*: –6.0%, −1.0%) and rural girls (AAPC=–2.1%, 95% *CI*: –4.0%, –0.1%) for the age group of 15–19 years (Figure 2B–D, Table 2, and Supplementary Tables S1–S3, available at https://weekly.chinacdc.cn/).

## Cause Spectrum of Injury Mortality by Age Group and Area

Supplementary Figure S1 (available at https://weekly.chinacdc.cn/) depicts the distribution of the top six causes of injury-related deaths, segmented by age group and geographical area. Drowning and road traffic crashes were the predominant causes of injury-related mortality for the four older age groups. Among infants under the age of 1 year, suffocation emerged as the primary cause, accounting for 56.0%–76.7% of injury deaths during 2010–2021. Suicide has come to light as a significant cause of injury-related deaths among adolescents aged 10–19 years.

During 2010–2021, significant injury mortality decreases were detected for suffocation among children under 1 year (urban: AAPC=–7.7%, rural: AAPC=–6.8%). Drowning mortality decreased significantly among children and adolescents aged 0–19 years (urban: AAPC=–8.0%, rural: AAPC=–9.5%). The

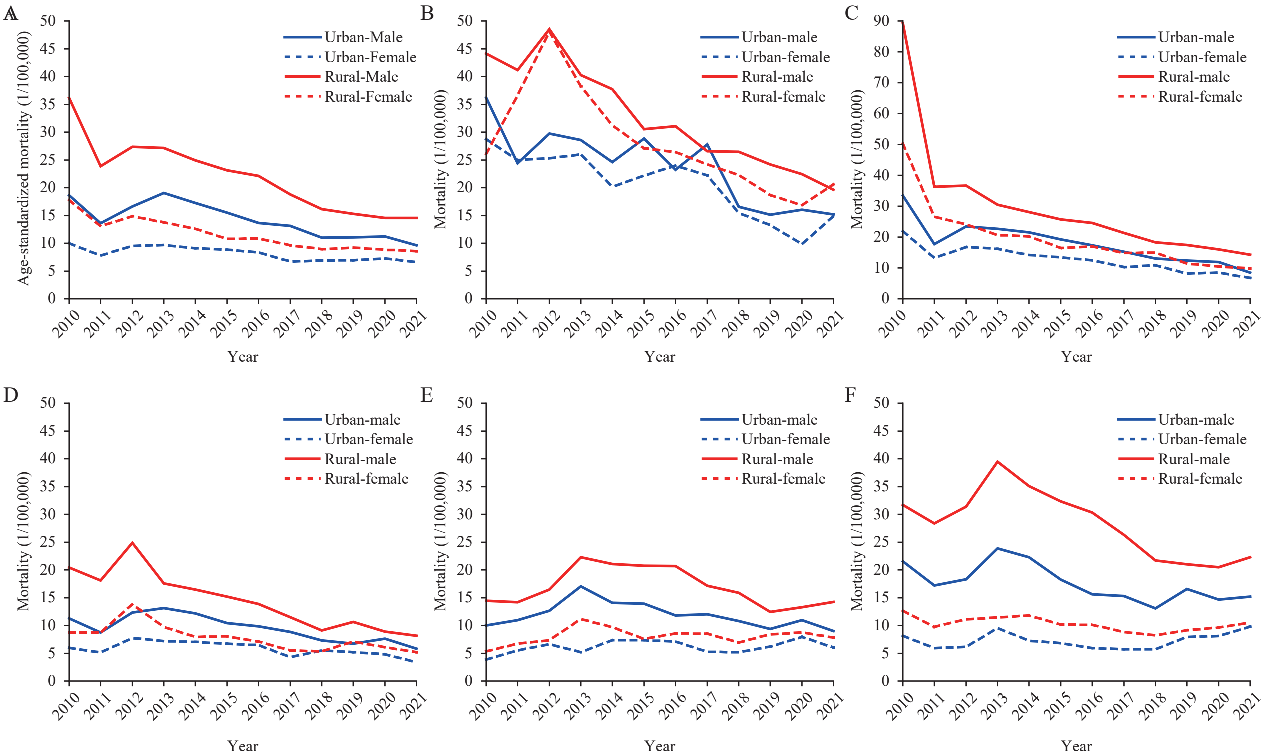


FIGURE 2. Overall age-standardized and age-specific mortality rates due to injury among Chinese children and adolescents, categorized by sex and area, spanning the years 2010–2021. (A) Age-standardized injury mortality in children and adolescents aged 0–19, separated by sex and area. (B) Injury mortality in infants under one year of age, reported by sex and area. (C) Injury mortality in toddlers aged 1–4, delineated by sex and area. (D) Injury mortality in young children aged 5–9, categorized by sex and area. (E) Injury mortality in early adolescents aged 10–14, divided by sex and area. (F) Injury mortality in late adolescents aged 15–19, sorted by sex and area.

overall and age-specific road traffic injury mortality reduced substantially since 2014 (e.g., 0–19 years, urban area: APC=−10.6%, rural area: APC=−10.2%). In contrast, notable suicide mortality increases were observed in the two oldest age groups for both urban and rural areas (with an AAPC changing between 4.7% and 11.5%) (Supplementary Figure S1 and Supplementary Table S4, available at https://weekly.chinacdc.cn/).

## DISCUSSION

This study, using nationally representative data, analyzed current trends in injury mortality among Chinese children aged 0–19 years. The research produced four critical findings: First, the overall age-standardized injury mortality saw a decrease of 57% between 2010 and 2021. Second, the mortality rate due to injuries was comparatively higher in rural areas and among boys, with a faster decline rate than in urban areas and among girls. Third, the predominant cause of injury mortality differed by age groups, where unintentional suffocation was the leading cause of death for infants under one year and drowning was the main cause for the four older age groups. Lastly, suicide emerged as a leading cause of injury mortality among adolescents aged 10–19 years.

The significant decrease in injury mortality rates in Chinese children and adolescents over the past ten years are likely be attributed to two main factors. First, the reduction may symbolize the enormous efforts made by the Chinese government regarding injury prevention. As an instance, the implementation of changes to traffic laws — such as making drunk driving a criminal offense — has decreased traffic crash risks (*10*). Furthermore, the Chinese administration issued a variety of injury prevention guidelines and commenced education programs in schools across the country. These initiatives probably have a positive impact on child injury prevention.

Second, the notable decline in mortality due to injuries might be correlated with the swift urbanization throughout the nation. The percentage of Chinese residents residing in rural areas dropped from 48.17%

TABLE 2. Mortality due to injuries and AAPC among Chinese children and adolescents, categorized by sex, from 2010–2021.

| Age group | Area | Boys | | | Girls | | |
|---|---|---|---|---|---|---|---|
| | | Mortality in 2010 | Mortality in 2021 | AAPC (95% *CI*) | Mortality in 2010 | Motrality in 2021 | AAPC (95% *CI*) |
| All ages | Total | 28.52 | 11.24 | −7.4 (−9.0, −5.7)* | 14.34 | 7.30 | −5.6 (−6.9, −4.2)* |
| | Urban | 18.62 | 9.61 | −5.3 (−7.4, −3.1)* | 9.97 | 6.61 | −3.4 (−5.1, −1.7)* |
| | Rural | 36.14 | 14.53 | −7.4 (−9.1, −5.8)* | 17.75 | 8.56 | −6.0 (−7.4, −4.7)* |
| Under 1 year | Total | 41.05 | 16.82 | −8.0 (−9.4, −6.6)* | 27.15 | 16.96 | −7.7 (−10.5, −4.8)* |
| | Urban | 36.21 | 15.19 | −7.0 (−9.7, −4.2)* | 28.74 | 14.87 | −7.5 (−10.5, −4.5)* |
| | Rural | 44.15 | 19.62 | −7.5 (−8.8, −6.2)* | 26.10 | 20.58 | −3.5 (−13.0, 7.0) |
| 1–4 years | Total | 66.00 | 10.41 | −11.9 (−14.7, −9.0)* | 38.40 | 7.79 | −11.0 (−13.1, −8.8)* |
| | Urban | 33.42 | 8.51 | −9.0 (−11.5, −6.4)* | 21.93 | 6.79 | −8.4 (−10.4, −6.2)* |
| | Rural | 89.24 | 14.28 | −11.9 (−15.2, −8.5)* | 50.31 | 9.82 | −12.8 (−15.9, −9.7)* |
| 5–9 years | Total | 16.45 | 6.65 | −8.3 (−10.3, −6.3)* | 7.53 | 4.05 | −5.9 (−8.7, −2.9)* |
| | Urban | 11.29 | 5.80 | −4.5 (−9.3, 0.6) | 6.00 | 3.41 | −4.3 (−7.6, −0.8)* |
| | Rural | 20.42 | 8.14 | −9.0 (−11.0, −6.9)* | 8.71 | 5.16 | −6.1 (−9.2, −2.8)* |
| 10–14 years | Total | 12.49 | 11.08 | −0.8 (−3.6, 2.1) | 4.67 | 6.75 | 3.0 (−2.0, 8.2) |
| | Urban | 10.02 | 8.99 | −0.6 (−3.5, 2.3) | 3.85 | 6.03 | 2.3 (−1.3, 6.2) |
| | Rural | 14.45 | 14.21 | −0.8 (−4.9, 3.5) | 5.32 | 7.83 | 3.3 (−1.2, 8.0) |
| 15–19 years | Total | 26.26 | 17.03 | −4.8 (−7.1, −2.5)* | 10.22 | 9.96 | −0.9 (−3.8, 2.1) |
| | Urban | 21.54 | 15.19 | −3.5 (−6.0, −1.0)* | 8.17 | 9.79 | 1.1 (−2.6, 5.0) |
| | Rural | 31.67 | 22.28 | −3.6 (−7.2, 0.2) | 12.66 | 10.52 | −2.1 (−4.0, −0.1)* |

Abbreviation: AAPC=average annual percent change; *CI*=confidence interval.
* $P<0.05$.

in 2011 to 35.28% in 2021 (*11*). This could possibly lead to lower exposure to specific injury risks and hazards, such as drowning, for children.

Our results corroborate earlier findings that injury-related death rates are significantly elevated among children in rural regions and boys, compared to their urban and fema counterparts (*5*). The heightened injury mortality rates among young people in China's rural areas are linked to insufficient adult supervision of children who are left behind (*12*), as well as a lack of adequate public facilities including readily accessible medical centers. The higher injury fatality rates among boys could be attributed to their increased physical activity, impulsivity, and heightened energy levels, predisposing them to engage in high-risk behaviors (*5*).

The substantial decrease in injury mortality rates in rural areas between 2010 and 2021 is promising. It may be attributable to accelerated socio-economic advancement experienced in rural China over the past decade. The National Precision Poverty Alleviation Project has seen considerable progress in strengthening rural economic growth and distribution of healthcare resources. From 2010 to 2021, there was an impressive 115.8% rise in the number of health technicians per thousand population in rural sectors, greatly surpassing the 32.9% increase observed in urban sectors (*8*). Furthermore, the count of children left behind in rural primary and middle schools declined from 15.51 million in 2017 to 12.00 million in 2021 (*11*).

Our findings indicate that the reasons for injury-related mortalities vary among the five age groups, reflecting different levels of exposure to certain hazards during various stages of child development. Infants under one-year-old, for instance, are more prone to unintentional suffocation due to underdeveloped respiratory systems, making them susceptible to potentially fatal obstructions while eating, playing, or sleeping (*13*). Older children, on the other hand, are more likely to engage in dangerous activities when left unsupervised, especially near roads or bodies of water (*1*). During adolescence, the rapid maturation of the brain and hormonal changes coupled with increased exposure to internet and social media, may exacerbate interpersonal stress and emotional instability (*14*). Such factors could potentially contribute to a rise in suicide rates among adolescents (*14*). The escalating trend of adolescent suicides that we have observed in China mirrors a global pattern, although the reported rates in China remain lower than in many other countries (*15*).

Our findings have two policy implications. First, the substantial injury mortality reductions suggest that government goals to reduce child and adolescent injury mortality between 2011 and 2020 have been successful in China. Reduced injury mortality gaps between urban and rural areas and between boys and girls indicate slight improvement in reducing disparities and achieving injury mortality equity across population subgroups.

Second, systematic and intensified prevention efforts should continue according to prevention priorities listed by the Child Development Program of China (2021–2030). Priority should be identification of a government department responsible for injury prevention programs in China to lead implementation of proven prevention programs nationwide like the recent adoption of national child safety seat law.

This study has several limitations. First, due to the absence of data on non-fatal injuries, the results for injury morbidity over the past decade may differ. Second, because data were lacking, this research did not study relevant influencing factors. Conducting research to identify associated risk factors is necessary to fully interpret epidemiological data trends, quantify causal relations between influencing factors and injury mortality, and develop prevention programs.

## CONCLUSIONS

From 2010 to 2021, there was a significant decline in child injury mortality in China. Moreover, injury mortality disparities across area (urban vs. rural) and gender (boys vs. girls) diminished during this period. The dramatic injury mortality decrease likely echoes the impact of governmental interventions. Considering the notably high child injury mortality, however, comprehensive and intensified efforts are encouraged to meet the objectives set forth by the Child Development Program of China (2021–2030).

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# SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE S1. APC and AAPC in injury-related mortality among Chinese boys from 2010 to 2021.

| Age group | Area | Block 1 | | Block 2 | | AAPC (95% *CI*) |
|---|---|---|---|---|---|---|
| | | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | |
| 0–19 years | Total | 2010–2021 | −7.4 (−9.0, −5.7)* | | | −7.4 (−9.0, −5.7)* |
| | Urban area | 2010–2021 | −5.3 (−7.4, −3.1)* | | | −5.3 (−7.4, −3.1)* |
| | Rural area | 2010–2021 | −7.4 (−9.1, −5.8)* | | | −7.4 (−9.1, −5.8)* |
| under 1 year | Total | 2010–2021 | −8.0 (−9.4, −6.6)* | | | −8.0 (−9.4, −6.6)* |
| | Urban area | 2010–2021 | −7.0 (−9.7, −4.2)* | | | −7.0 (−9.7, −4.2)* |
| | Rural area | 2010–2021 | −7.5 (−8.8, −6.2)* | | | −7.5 (−8.8, −6.2)* |
| 1–4 years | Total | 2010–2021 | −11.9 (−14.7, −9.0)* | | | −11.9 (−14.7, −9.0)* |
| | Urban area | 2010–2021 | −9.0 (−11.5, −6.4)* | | | −9.0 (−11.5, −6.4)* |
| | Rural area | 2010–2021 | −11.9 (−15.2, −8.5)* | | | −11.9 (−15.2, −8.5)* |
| 5–9 years | Total | 2010–2021 | −8.3 (−10.3, −6.3)* | | | −8.3 (−10.3, −6.3)* |
| | Urban area | 2010–2013 | 8.8 (−10.8, 32.6) | 2013–2021 | −9.1 (−12.9, −5.0)* | −4.5 (−9.3, 0.6) |
| | Rural area | 2010–2021 | −9.0 (−11.0, −6.9)* | | | −9.0 (−11.0, −6.9)* |
| 10–14 years | Total | 2010–2013 | 17.7 (5.5, 31.3)* | 2013–2021 | −6.9 (−9.1, −4.7)* | −0.8 (−3.6, 2.1) |
| | Urban area | 2010–2013 | 17.0 (4.6, 30.8)* | 2013–2021 | −6.5 (−8.7, −4.2)* | −0.6 (−3.5, 2.3) |
| | Rural area | 2010–2014 | 13.1 (0.9, 26.6)* | 2014–2021 | −7.9 (−12.2, −3.4)* | −0.8 (−4.9, 3.5) |
| 15–19 years | Total | 2010–2021 | −4.8 (−7.1, −2.5)* | | | −4.8 (−7.1, −2.5)* |
| | Urban area | 2010–2021 | −3.5 (−6.0, −1.0)* | | | −3.5 (−6.0, −1.0)* |
| | Rural area | 2010–2013 | 8.2 (−6.7, 25.5) | 2013–2021 | −7.6 (−10.6, −4.6)* | −3.6 (−7.2, 0.2) |

Abbreviation: APC=annual percent change; AAPC=average annual percent change; *CI*=confidence interval.
* *P*<0.05.

SUPPLEMENTARY TABLE S2. APC and AAPC in injury-induced mortality among Chinese girls spanning 2010 through 2021.

| Age group | Area | Block 1 | | Block 2 | | Block 3 | | AAPC (95% *CI*) |
|---|---|---|---|---|---|---|---|---|
| | | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | |
| 0–19 years | Total | 2010–2021 | −5.6 (−6.9, −4.2)* | | | | | −5.6 (−6.9, −4.2)* |
| | Urban area | 2010–2021 | −3.4 (−5.1, −1.7)* | | | | | −3.4 (−5.1, −1.7)* |
| | Rural area | 2010–2021 | −6.0 (−7.4, −4.7)* | | | | | −6.0 (−7.4, −4.7)* |
| Under 1 year | Total | 2010–2021 | −7.7 (−10.5, −4.8)* | | | | | −7.7 (−10.5, −4.8)* |
| | Urban area | 2010–2021 | −7.5 (−10.5, −4.5)* | | | | | −7.5 (−10.5, −4.5)* |
| | Rural area | 2010–2012 | 33.8 (−13.1, 105.9) | 2012–2015 | −17.4 (−46.3, 27.2) | 2015–2021 | −6.5 (−13.1, 0.6) | −3.5 (−13.0, 7.0) |
| 1–4 years | Total | 2010–2021 | −11.0 (−13.1, −8.8)* | | | | | −11.0 (−13.1, −8.8)* |
| | Urban area | 2010–2021 | −8.4 (−10.4, −6.2)* | | | | | −8.4 (−10.4, −6.2)* |
| | Rural area | 2010–2012 | −28.9 (−42.8, −11.6)* | 2012–2021 | −8.8 (−10.6, −7.0)* | | | −12.8 (−15.9, −9.7)* |
| 5–9 years | Total | 2010–2021 | −5.9 (−8.7, −2.9)* | | | | | −5.9 (−8.7, −2.9)* |
| | Urban area | 2010–2021 | −4.3 (−7.6, −0.8)* | | | | | −4.3 (−7.6, −0.8)* |
| | Rural area | 2010–2021 | −6.1 (−9.2, −2.8)* | | | | | −6.1 (−9.2, −2.8)* |
| 10–14 years | Total | 2010–2013 | 18.4 (−2.0, 43.1) | 2013–2021 | −2.3 (−6.3, 1.8) | | | 3.0 (−2.0, 8.2) |
| | Urban area | 2010–2021 | 2.3 (−1.3, 6.2) | | | | | 2.3 (−1.3, 6.2) |
| | Rural area | 2010–2013 | 21.0 (2.2, 43.3)* | 2013–2021 | −2.7 (−6.2−1.0) | | | 3.3 (−1.2, 8.0) |
| 15–19 years | Total | 2010–2021 | −0.9 (−3.8, 2.1) | | | | | −0.9 (−3.8, 2.1) |
| | Urban area | 2010–2021 | 1.1 (−2.6, 5.0) | | | | | 1.1 (−2.6, 5.0) |
| | Rural area | 2010–2021 | −2.1 (−4.0, −0.1)* | | | | | −2.1 (−4.0, −0.1)* |

Abbreviation: APC=annual percent change; AAPC=average annual percent change; *CI*=confidence interval.

* *P*<0.05.

SUPPLEMENTARY TABLE S3. AAPC in mortality rates due to injuries among Chinese children and adolescents, segregated by age group and region, from 2010 to 2021.

| Age group | Area | Overall injury mortality | | | Injury mortality for boys | | | Injury mortality for girls | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2010 | 2021 | AAPC (95% *CI*) | 2010 | 2021 | AAPC (95% *CI*) | 2010 | 2021 | AAPC (95% *CI*) |
| All ages | Total | 21.87 | 9.41 | −6.7 (−8.2, −5.2)* | 28.52 | 11.24 | −7.4 (−9.0, −5.7)* | 14.34 | 7.30 | −5.6 (−6.9, −4.2)* |
| | Urban area | 14.50 | 8.21 | −4.6 (−6.5, −2.6)* | 18.62 | 9.61 | −5.3 (−7.4, −3.1)* | 9.97 | 6.61 | −3.4 (−5.1, −1.7)* |
| | Rural area | 27.59 | 11.79 | −6.9 (−8.4, −5.5)* | 36.14 | 14.53 | −7.4 (−9.1, −5.8)* | 17.75 | 8.56 | −6.0 (−7.4, −4.7)* |
| Under 1 year | Total | 34.37 | 16.89 | −7.9 (−9.7, −6.1)* | 41.05 | 16.82 | −8.0 (−9.4, −6.6)* | 27.15 | 16.96 | −7.7 (−10.5, −4.8)* |
| | Urban area | 32.63 | 15.04 | −7.2 (−9.7, −4.6)* | 36.21 | 15.19 | −7.0 (−9.7, −4.2)* | 28.74 | 14.87 | −7.5 (−10.5, −4.5)* |
| | Rural area | 35.50 | 20.07 | −5.3 (−9.0, −1.4)* | 44.15 | 19.62 | −7.5 (−8.8, −6.2)* | 26.10 | 20.58 | −3.5 (−13.0, 7.0) |
| 1–4 years | Total | 53.18 | 9.16 | −11.6 (−14.1, −9.0)* | 66.00 | 10.41 | −11.9 (−14.7, −9.0)* | 38.40 | 7.79 | −11.0 (−13.1, −8.8)* |
| | Urban area | 27.96 | 7.68 | −8.8 (−11.1, −6.4)* | 33.42 | 8.51 | −9.0 (−11.5, −6.4)* | 21.93 | 6.79 | −8.4 (−10.4, −6.2)* |
| | Rural area | 71.29 | 12.18 | −11.7 (−14.6, −8.6)* | 89.24 | 14.28 | −11.9 (−15.2, −8.5)* | 50.31 | 9.82 | −12.8 (−15.9, −9.7)* |
| 5–9 years | Total | 12.24 | 5.44 | −7.5 (−9.6, −5.3)* | 16.45 | 6.65 | −8.3 (−10.3, −6.3)* | 7.53 | 4.05 | −5.9 (−8.7, −2.9)* |
| | Urban area | 8.78 | 4.68 | −3.9 (−8.6, 1.0) | 11.29 | 5.80 | −4.5 (−9.3, 0.6) | 6.00 | 3.41 | −4.3 (−7.6, −0.8)* |
| | Rural area | 14.90 | 6.78 | −8.0 (−10.4, −5.6)* | 20.42 | 8.14 | −9.0 (−11.0, −6.9)* | 8.71 | 5.16 | −6.1 (−9.2, −2.8)* |
| 10–14 years | Total | 8.80 | 9.10 | 0.5 (−2.1, 3.2) | 12.49 | 11.08 | −0.8 (−3.6, 2.1) | 4.67 | 6.75 | 3.0 (−2.0, 8.2) |
| | Urban area | 7.08 | 7.62 | 0.7 (−2.8, 4.4) | 10.02 | 8.99 | −0.6 (−3.5, 2.3) | 3.85 | 6.03 | 2.3 (−1.3, 6.2) |
| | Rural area | 10.15 | 11.32 | 1.1 (−1.7, 3.9) | 14.45 | 14.21 | −0.8 (−4.9, 3.5) | 5.32 | 7.83 | 3.3 (−1.2, 8.0)* |
| 15–19 years | Total | 18.72 | 13.73 | −3.6 (−5.9, −1.3)* | 26.26 | 17.03 | −4.8 (−7.1, −2.5)* | 10.22 | 9.96 | −0.9 (−3.8, 2.1) |
| | Urban area | 15.14 | 12.67 | −2.1 (−4.8, 0.7) | 21.54 | 15.19 | −3.5 (−6.0, −1.0)* | 8.17 | 9.79 | 1.1 (−2.6, 5.0) |
| | Rural area | 22.90 | 16.91 | −2.2 (−8.5, −4.6) | 31.67 | 22.28 | −3.6 (−7.2, 0.2) | 12.66 | 10.52 | −2.1 (−4.0, −0.1)* |

Abbreviation: APC=annual percent change; AAPC=average annual percent change; *CI*=confidence interval.
* *P*<0.05.

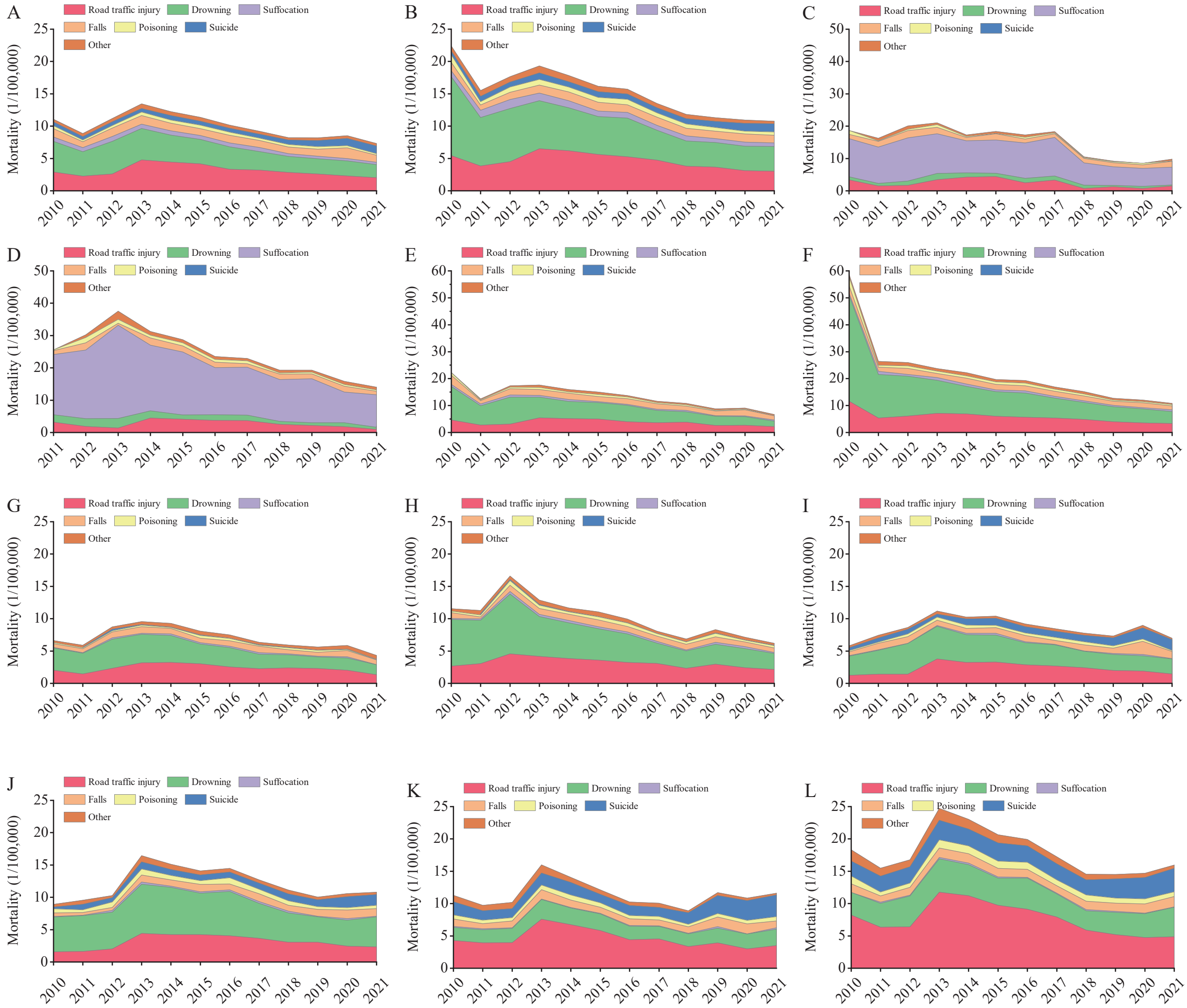
SUPPLEMENTARY TABLE S4. APC and AAPC in cause−specific injury mortality among Chinese children and adolescents from 2010 to 2021.

| Injury cause | Age group | Area | Block 1 | | Block 2 | | Block 3 | | AAPC (95% *CI*) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | |
| Road traffic injury | 0–19 years | Urban area | 2010–2014 | 17.3 (−1.5, 39.6) | 2014–2021 | −10.6 (−16.9, −3.7)* | | | −1.3 (−7.5, −5.4) |
| | | Rural area | 2010–2014 | 9.1 (−6.3, 27.0) | 2014–2021 | −10.2 (−15.8, −4.3)* | | | −3.6 (−9.0, 2.0) |
| | Under 1 year | Urban area | 2010–2021 | −8.9 (−18.0, 1.3) | | | | | −8.9 (−18.0, 1.3) |
| | | Rural area | 2010–2021 | −5.6 (−13.3, 2.7) | | | | | −5.6 (−13.3, 2.7) |
| | 1–4 years | Urban area | 2010–2021 | −4.3 (−8.9, 0.7) | | | | | −4.3 (−8.9, 0.7) |
| | | Rural area | 2010–2021 | −7.7 (−10.8, −4.5)* | | | | | −7.7 (−10.8, −4.5)* |
| | 5–9 years | Urban area | 2010–2014 | 19.0 (−2.0, 44.5) | 2014–2021 | −9.7 (−16.8, −1.9)* | | | −0.1 (−7.2, 7.4) |
| | | Rural area | 2010–2012 | 32.2 (−1.0, 76.5) | 2012–2021 | −7.5 (−9.9, −5.0)* | | | −1.3 (−5.8, 3.5) |
| | 10–14 years | Urban area | 2010–2014 | 35.4 (10.8, 65.5)* | 2014–2021 | −11.3 (−18.5, −3.5)* | | | 3.4 (−4.1, 11.5) |
| | | Rural area | 2010–2014 | 36.0 (16.2, 59.1)* | 2014–2021 | −9.3 (−15.1, −3.1)* | | | 5.1 (−0.9, 11.5) |
| | 15–19 years | Urban area | 2010–2013 | 21.3 (−1.0, 48.7) | 2013–2021 | −9.0 (−12.9, −4.9)* | | | −1.6 (−6.7, 3.8) |
| | | Rural area | 2010–2014 | 13.7 (−6.3, 38.0) | 2014–2021 | −12.4 (−19.3, −5.0)* | | | −3.7 (−1.04, 3.6) |
| Drowning | 0–19 years | Urban area | 2010–2021 | −8.0 (−10.1, −5.8)* | | | | | −8.0 (−10.1, −5.8) * |
| | | Rural area | 2010–2021 | −9.5 (−11.4, −7.5)* | | | | | −9.5 (−11.4, −7.5)* |
| | Under 1 year | Urban area | 2010–2017 | 3.6 (−11.8, 21.7) | 2017–2021 | −31.1 (−52.9, 0.9)* | | | −10.7 (−22.6, 3.1) |
| | | Rural area | 2010–2021 | −13.5 (−17.2, −9.6)* | | | | | −13.5 (−17.2, −9.6)* |
| | 1–4 years | Urban area | 2010–2021 | −12.9 (−15.4, −10.0)* | | | | | −12.9 (−15.4, −10.0)* |
| | | Rural area | 2010–2012 | −37.4 (−45.3, −28.3)* | 2012–2021 | −11.4 (−12.5, −10.3)* | | | −16.8 (−18.6, −15.0)* |
| | 5–9 years | Urban area | 2010–2013 | 9.6 (−9.2, 32.3) | 2013–2021 | −12.8 (−16.3, −9.2)* | | | −7.2 (−11.7, −2.5)* |
| | | Rural area | 2010–2012 | 32.2 (−1.0, 76.5) | 2012–2021 | −7.5 (−9.9, −5.0)* | | | −10.8 (−13.3, −8.1)* |
| | 10–14 years | Urban area | 2010–2012 | 32.5 (4.0, 68.8)* | 2012–2021 | −9.1 (−11.1, −7.1)* | | | −2.7 (−6.4, 1.2) |
| | | Rural area | 2010–2014 | 11.0 (−2.4, 26.2) | 2014–2019 | −12.2 (−22.8, −0.2)* | 2019–2021 | 5.7 (−29.5, 58.6) | −1.1 (−8.2, 6.5) |
| | 15–19 years | Urban area | 2010–2013 | 15.0 (3.0, 28.5)* | 2013–2017 | −9.2 (−18.7, 1.4) | 2017–2021 | 6.6 (−0.6, 14.3) | 2.7 (−1.3, 6.8) |
| | | Rural area | 2010–2013 | 16.9 (−4.6, 43.2) | 2013–2018 | −9.9 (−20.8, 2.4) | 2018–2021 | 10.6 (−9.7, 35.4) | 2.3 (−4.5, 9.6) |

Continued

| Injury cause | Age group | Area | Block 1 | | Block 2 | | Block 3 | | AAPC (95% *CI*) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | Time period | APC (95% *CI*) | |
| Suffocation | 0–19 years | Urban area | 2010–2021 | −6.2 (−8.5, −3.8)* | | | | | −6.2 (−8.5, −3.8)* |
| | | Rural area | 2010–2012 | 18.4 (−7.1, 50.9) | 2012–2021 | −9.6 (−11.6, −7.6)* | | | −5.1 (−8.8, −1.3)* |
| | Under 1 year | Urban area | 2010–2021 | −7.7 (−10.8, −4.5)* | | | | | −7.7 (−10.8, −4.5)* |
| | | Rural area | 2010–2012 | 14.1 (−15.1, 53.2) | 2012–2021 | −10.9 (−13.3, −8.5)* | | | −6.8 (−11.2, −2.2)* |
| | 1–4 years | Urban area | 2010–2021 | −8.7 (−13.1, −4.0)* | | | | | −8.7 (−13.1, −4.0)* |
| | | Rural area | 2010–2021 | −6.0 (−9.3, −2.6)* | | | | | −6.0 (−9.3, −2.6)* |
| | 5–9 years | Urban area | 2010–2017 | 17.3 (−3.5, 42.6) | 2017–2021 | −31.9 (−57.1, 8.1) | | | −3.7 (−19.1, 14.5) |
| | | Rural area | 2010–2021 | −2.0 (−8.7, 5.2) | | | | | −2.0 (−8.7, 5.2) |
| | 10–14 years | Urban area | 2010–2021 | 4.1 (−6.0, 15.1) | | | | | 4.1 (−6.0, 15.1) |
| | | Rural area | 2010–2021 | −0.6 (−10.5, 10.5) | | | | | −0.6 (−10.5, 10.5) |
| | 15–19 years | Urban area | 2010–2021 | 0.7 (−8.0, 10.3) | | | | | 0.7 (−8.0, 10.3) |
| | | Rural area | 2010–2021 | NA | | | | | NA |
| Suicide | 0–19 years | Urban area | 2010–2017 | 1.7 (−2.3, 5.8) | 2017–2021 | 19.9 (9.2, 31.8)* | | | 8.0 (4.2, 11.8)* |
| | | Rural area | 2010–2013 | 13.6 (−5.1, 36.1) | 2013–2018 | −3.1 (−13.5, 8.7) | 2018–2021 | 18.9 (−0.7, 42.3) | 7.0 (0.7, 13.8)* |
| | 10–14 years | Urban area | 2010–2021 | 11.5 (7.5, 15.7)* | | | | | 11.5 (7.5, 15.7)* |
| | | Rural area | 2010–2021 | 11.0 (4.8, 17.6)* | | | | | 11.0 (4.8, 17.6)* |
| | 15–19 years | Urban area | 2010–2017 | −2.3 (−9.3, 5.3) | 2017–2021 | 25.8 (5.5, 50.0)* | | | 7.1 (0.3, 14.4)* |
| | | Rural area | 2010–2013 | 7.8 (0.0, 16.2)* | 2013–2018 | −3.2 (−7.7, 1.5) | 2018–2021 | 15.8 (7.4, 24.8)* | 4.7 (2.1, 7.4)* |

Note: NA: Because the initial value is 0, we cannot calculate the APC and AAPC.
Abbreviation: APC=annual percent change; AAPC=average annual percent change; *CI*=confidence interval; NA=not applicable.
* $P<0.05$.




SUPPLEMENTARY FIGURE S1. Distribution of injury-related mortality by area and age group in Chinese children and adolescents, from 2010 to 2021. (A) Injury-related mortality distribution in children and adolescents aged 0–19 in urban areas. (B) Injury-related mortality distribution in children and adolescents aged 0–19 in rural areas. (C) Injury-related mortality distribution in children under 1 year in urban areas. (D) Injury-related mortality distribution in children under 1 year in rural areas. (E) Injury-related mortality distribution in children aged 1–4 in urban areas. (F) Injury-related mortality distribution in children aged 1–4 in rural areas. (G) Injury-related mortality distribution in children aged 5–9 in urban areas. (H) Injury-related mortality distribution in children aged 5–9 in rural areas. (I) Injury-related mortality distribution in adolescents aged 10–14 in urban areas. (J) Injury-related mortality distribution in adolescents aged 10–14 in rural areas. (K) Injury-related mortality distribution in adolescents aged 15–19 in urban areas. (L) Injury-related mortality distribution in adolescents aged 15–19 in rural areas.

Perspectives

# State of the Art of Lifecourse Cohort Establishment

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The global rise in non-communicable diseases (NCDs) presents significant public health challenges. Effectively managing and preventing NCDs necessitates a thorough understanding of their causes and progression, which can be achieved through a lifecourse approach to determine past exposures' impact before NCD onset. However, this approach requires robust backing from data, specifically lifecourse cohort data, which are generally insufficient. To overcome this obstacle, three primary strategies have been employed to establish such cohorts: active follow-up cohorts, registry-based datasets, and technology-based data collection and simulation methods.

## ACTIVE FOLLOW-UP COHORTS

Continuous health and behavior monitoring in active follow-up cohorts is essential for early identification and management of risk factors. Despite being resource-intensive, collaboration among global epidemiologists has facilitated access to extensive long-term follow-up cohorts, enhancing lifecourse epidemiological research capabilities.

The UK Biobank is an exemplary population-based prospective cohort study focused on the genetic and non-genetic factors influencing diseases in adults and the elderly (*1*). It aimed for an extensive evaluation of exposures, meticulous follow-up, and detailed characterization of various health outcomes. By 2010, the UK Biobank had recruited 500,000 participants ranging from 40 to 69 years old, amassing an extraordinary array of baseline data and biological samples. Subsequently, three follow-up surveys were conducted in 2012–2013, 2014, and 2019. The database has been continually enhanced since 2012 with additional types of data, including monthly blood samples and nuclear magnetic resonance spectroscopy data, among others. To date, the UK Biobank has compiled a comprehensive dataset featuring details on over 8,500 deaths, upward of 75,000 cancer cases, and more than 600,000 hospital admissions.

The China Kadoorie Biobank (CKB) has made significant progress (*2*). The baseline survey, conducted from 2004 to 2008, covered 10 specific regions and included questionnaire data, physical measurements, and blood samples. In 2013–2014, a second survey was conducted with 25,091 participants aged 30–79 years, followed by a third survey in 2020–2021 with 25,087 participants (*3*). Importantly, a substantial cohort of over 22,000 individuals participated in at least two follow-ups, forming a crucial basis for future longitudinal analyses. The availability of multiple waves of data collected at different time points will enable detailed investigations into the trends of risk factors related to major diseases.

Cohort studies that integrate the lifecourse perspective have significantly enhanced our comprehension of the ramifications of exposures during the early stages of life. The Human Early-Life Exposome (HELIX) project exemplifies such research endeavors, focusing on delineating the spectrum of environmental exposures during prenatal and early childhood phases. The project investigates the associations between these exposures and critical pediatric health outcomes, such as growth patterns, obesity prevalence, neurodevelopmental progress, and respiratory health. To achieve its aims, the HELIX project utilizes an array of investigative tools, including biomarker assessments, omics technologies, geospatial analyses, monitoring through wearable devices, and sophisticated statistical methodologies (*4*). Operating within the framework of a "lifecourse exposome" model, HELIX aggregates data from six established birth cohort studies spanning various regions in Europe. It is undertaking the development of comprehensive exposure models for its entire cohort, which embraces over 32,000 mother-child pairs, specifically concentrating on children within the 6–11 year age bracket.

Cohort studies focusing on specific NCDs have been instrumental in advancing lifecourse epidemiology. A notable example is the Framingham Heart Study (FHS), a pioneering intergenerational longitudinal study that began in 1948 with the goal of enhancing our understanding of cardiovascular disease epidemiology in the United States (*5*–*6*). To date, the FHS has followed up with a total of 15,447 participants, with more than 9,000 followed until death as of 2019. The study population encompasses six cohorts: the Original Cohort (*n*=5,209, ages 28–74 in 1948), Offspring Cohort (*n*=5,124, ages 5–70 in 1971), Omni Generation 1 Cohort (*n*=506, ages 27–78 in 1994), Third Generation Cohort (*n*=4,095, ages 19–72 in 2002), New Offspring Spouse Cohort (*n*=103, ages 47–85 in 2003), and Omni Generation 2 Cohort (*n*=410, ages 20–80 in 2003). The study is known for its detailed participant characterization, regular follow-up examinations, and comprehensive surveillance of both cardiovascular and non-cardiovascular endpoints, providing a solid basis for research into various health outcomes.

The establishment of cohorts focused on detailed occupational experiences is a growing trend in lifecourse epidemiology. A preeminent example is the Nurses' Health Study, a comprehensive prospective cohort that investigates risk factors for major chronic diseases in women (*7*). Initiated in 1976, the Nurses' Health Study is an ongoing project that now includes both male and female nurses. This project has enrolled more than 275,000 participants across three generations: the inaugural cohort from 1976 (ages 30–55), the second cohort from 1989 (ages 25–42), and the third cohort from 2010 (ages 19–46). It conducts active follow-up and gathers lifestyle data every four years. Additionally, the study has collected blood samples and DNA from buccal cell extractions. This cohort also integrates tumor sample information from participants who are part of other databases, thereby providing foundational data for more comprehensive analysis.

## REGISTRY-BASED DATASETS

The utilization of lifecourse cohort studies leverages readily accessible information from various governmental databases, including those related to residency, education, housing, taxes, driver's licenses, insurance, and medical records. While this method may not always capture specialized data such as behavioral and psychological factors necessary for rigorous epidemiological investigations, it is a cost-effective alternative to the creation and maintenance of active follow-up cohorts over the long term. As a feasible method for building lifecourse cohorts in the present context, it offers a practical solution when compared to other methods. In certain European nations, merging residency with medical records facilitates the efficient collection of baseline demographic and health information from broad administrative registries. This process simplifies the establishment of cohorts that encompass extensive time periods. For instance, the Nordic countries — comprising Denmark, Finland, Norway, and Sweden — operate comprehensive registries that cover all citizens, enabled by unique personal identification numbers which allow for the cross-referencing of multiple information systems. By interconnecting various medical record databases, which include data from the Danish healthcare system, the Swedish Medical Birth Registries, the Nordic Cancer Registries, Prescription Registries, Medical Birth Registries, and Patient Registries, with residency records, these countries have created registry-based datasets that span almost 40 years. Such datasets are highly beneficial for diverse health-related research projects. For example, these datasets have been used to study the association between adult stress and atrial fibrillation risk (*8*), assess the real-world effectiveness of medications like liraglutide in the clinical management of cardiovascular diseases (*9*), and probe the potential link between prenatal antibiotic exposure and childhood leukemia incidence (*10*). Another exemplary registry-based dataset is within the UK's National Health Service. Utilizing medical record data from national registers that cover patients who were hospitalized for their first acute ischemic stroke or primary intracerebral hemorrhage in England from 2013 to 2016, which included a total of 145,324 individuals, studies have investigated socioeconomic differences in initial stroke hospitalization rates, evaluated care quality, and assessed post-stroke survival rates among the adult populace in England (*11*). In Australia, a cohort of 85,547 individuals was developed by integrating data from the National Diabetes Services Scheme — which supports patients by providing diabetes-related products at subsidized rates and disseminating essential information — and the National Death Index to track mortality rates among Australians diagnosed with type 1 diabetes (*12*).

Governmental resources beyond healthcare, such as those related to insurance, education, and taxation, are increasingly recognized as valuable for constructing registry-based datasets to tackle multifaceted issues in lifecourse epidemiology. For instance, in Sweden, the amalgamation of longitudinal health insurance and labor market data with registry information about the resident population produced a comprehensive dataset covering 1990–2007, which included over 6 million individuals (6.04 million). This extensive dataset was leveraged to explore the association between individual socioeconomic factors — insurance, education, taxation — and mortality rates throughout the adults' life span (*13*). In Norway, a distinct registry-based dataset was assembled, containing data on 3.1 million individuals aged 18–69. It integrated information from the national road accident registry with the Norwegian prescription database to assess the risk of road traffic accidents in relation to prescription medication usage among drivers (*14*). Most registry-based datasets are constructed with the resident population as a foundation, linked to medical records, and further enriched by integrating additional governmental resources.

## TECHNOLOGY-BASED DATA COLLECTION AND SIMULATION METHODS

To enhance the caliber of existing cohorts beyond the capabilities of traditional survey methods and linkages, it is imperative to incorporate technology-based data collection and simulation techniques. Such methods leverage sophisticated, interactive devices to gather real-time, uninterrupted data that are more detailed in both spatial and temporal aspects compared to conventional epidemiological data collection. For instance, advancements in internet communication technology have underscored the growing relevance of technology-based data collection simulations in developing lifecourse cohorts. A notable example is the UK Biobank initiative, where Axivity AX3 tri-axial wrist physical activity monitors were distributed to 100,000 participants, capturing high-frequency (100 Hz) triaxial acceleration over a week. This yielded a pivotal dataset for an in-depth analysis of daily physical activities and exposure to real-world environments (*15*). Additionally, cutting-edge fiber technology has facilitated the integration of wearable devices into clothing, conveniently tracking behaviors and health status. A recent study introduced a mechanical design for semiconductor fibers, functioning as sensors, actuators, energy harvesters and storages, displays, and healthcare devices (*16*).

Environmental factors persistently influence both individual behaviors and health outcomes. They can be comprehensively monitored using remote sensing technology, utilizing sensors aboard satellites for broad environmental surveillance globally. Direct measurement or straightforward calculation of certain environmental variables is possible using spectral information obtained from these sensors (*17–19*). For instance, airborne sensors on aircraft and unmanned aerial vehicles, such as drones, can directly capture urban built environment features including building outlines, road widths, and traffic density (*20–21*). Vegetation coverage, indicated by parameters like greenness from trees and grasslands, can be quantified through spectral data collected by both airborne sensors and high-resolution satellites (*22–23*). Additionally, certain environmental factors require more complex algorithms and supplementary data for accurate retrieval. For example, the concentrations of fine particulate matter with a diameter of ≤2.5 μm ($PM_{2.5}$), nitrogen dioxide ($NO_2$), sulfur dioxide ($SO_2$), and ozone ($O_3$), as well as the chemical compositions of $PM_{2.5}$, at different temporal resolutions (e.g., daily, monthly) can be derived through a combination of satellite-derived, ground-based monitoring, and other auxiliary data (e.g. meteorological and land use data) (*24*).

## FUTURE PERSPECTIVES FOR LIFECOURSE COHORT DEVELOPMENT

Each of the three discussed methodologies has its advantages and disadvantages. Active follow-up cohort studies are highly effective for exploring specific public health concerns, yet they are limited by significant time and financial demands, and they do not provide a comprehensive perspective on overall human health. Registry-based datasets, by contrast, offer greater cost efficiency due to pre-existing governmental funding, eliminating the need for additional cohort establishment. However, their reliance on medical and death records means they might not fully capture the entire scope of health issues throughout an individual's life, potentially limiting their ability to offer a complete picture of public health trends. While innovative, technology-based data collection and simulation methods have the potential to fill many of the voids inherent in traditional models, the interdisciplinary nature of these new approaches poses challenges to conventional sectors and professionals, necessitating increased cross-disciplinary collaboration to be successfully implemented.

The advancement of lifecourse cohort studies should consider three key aspects, informed by current strategic efforts. Firstly, while active follow-up cohorts typically emphasize the health of adults due to the higher incidence of NCDs in this group, there is a need to shift the baseline of future cohorts to earlier life stages, such as initiating at birth. This approach will enable the tracking of health trajectories from infancy, through positive child development studies (*22*), and across the entire lifespan, allowing for a more comprehensive understanding of health evolution. Secondly, the scope of existing registry-based datasets is often limited in the variety and quantity of data they encompass, and frequently fail to integrate medical records. Consequently, it is essential to establish (real-time) data platforms that can amalgamate diverse information sources while rigorously safeguarding data confidentiality. Thirdly, the current application of cutting-edge technologies in the collection and simulation of technology-based data is restricted. The field of spatial lifecourse health, which has evolved from spatial lifecourse epidemiology (*23*) and lies at the confluence of spatial science and public health, leverages sophisticated technologies and methodologies. These include geoinformatics, remote sensing, global navigation satellite systems, the Internet of Things, artificial intelligence, mathematical statistics, bioinformatics, systems science, data science, and augmented, virtual, and mixed reality. These tools enable highly precise assessments of environmental, behavioral, psychological, physiological, and biological risk factors affecting health, while also examining their long-term impacts and underlying causal mechanisms. This domain has significantly contributed to the research of NCDs, infectious diseases, public health monitoring, and 'one health', collecting diverse sets of data in novel ways that address significant data deficiencies present in traditional fields and sectors (*24*). Therefore, it possesses considerable potential to drive the integration of efforts in establishing authentic lifecourse cohort studies.

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