Global disease burden and trends of leukemia attributable to occupational risk from 1990 to 2019: An observational trend study

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Background: Leukemia caused by occupational risk is a problem that needs more attention and remains to be solved urgently, especially for acute lymphoid leukemia (ALL), acute myeloid leukemia (AML), and chronic lymphoid leukemia (CLL). However, there is a paucity of literature on this issue. We aimed to assess the global burden and trends of leukemia attributable to occupational risk from 1990 to 2019.

Methods: This observational trend study was based on the Global Burden of Disease (GBD) 2019 database, the global deaths, and disability-adjusted life years (DALYs), which were calculated to quantify the changing trend of leukemia attributable to occupational risk, were analyzed by age, year, geographical location, and socio-demographic index (SDI), and the corresponding estimated annual percentage change (EAPC) values were calculated.

Results: Global age-standardized DALYs and death rates of leukemia attributable to occupational risk presented significantly decline trends with EAPC [−0.38% (95% CI: −0.58 to −0.18%)] for DALYs and [−0.30% (95% CI: −0.45 to −0.146%)] for death. However, it was significantly increased in people aged 65–69 years [0.42% (95% CI: 0.30–0.55%)] for DALYs and 0.38% (95% CI: 0.26–0.51%) for death]. At the same time, the age-standardized DALYs and death rates of ALL, AML, and CLL were presented a significantly increased trend with EAPCs (0.78% (95% CI: 0.65–0.91%), 0.87% (95% CI: 0.81–0.93%), and 0.66% (95% CI: 0.51–0.81%) for DALYs, respectively, and 0.75% (95% CI: 0.68–0.82%), 0.96% (95% CI: 0.91–1.01%), and 0.55% (95% CI: 0.43–0.68%) for death], respectively. The ALL, AML, and CLL were shown an upward trend in almost all age groups.
Introduction

Cancer has the highest mortality rate among all human diseases (1). The World Health Organization (WHO) classifies tumors based on evidence that tumors occur in various organ systems. It is the global standard for diagnosis, research, cancer registration, and public health monitoring (2). Some kinds of cancer grow rapidly, while others grow slowly. Most kinds of leukemia progress quickly. Hematological tumors can be divided into three different categories, namely, leukemia, lymphoma, and myeloma (3). Among them, leukemia can be further divided into acute myeloid leukemia (AML), acute lymphoid leukemia (ALL), chronic lymphoid leukemia (CLL), chronic myeloid leukemia (CML), and other leukemia (4). In this study, we found that AML and ALL had higher DALY rates and death rates compared with other kinds.

Acute myeloid leukemia is the most common in elderly patients, but the incidence rate in young people is also increasing every year (5), with an incidence of over 20,000 cases per year in the United States alone (6). It has been estimated that ~21,450 adults (11,650 men and 9,800 women) will be diagnosed with AML in 2019 (7). Of all subtypes of leukemia, AML has the highest mortality rate (62%) (7). The excessive accumulation of immature hematopoietic cells in blood and bone marrow, gene mutations, genetics, and other factors will lead to the occurrence of tumors (8). ALL is the most common subtype of childhood leukemia. ALL have a high mortality rate due to excessive accumulation of immature lymphocytes in the peripheral blood and bone marrow (9, 10).

Occupational exposure has been related to higher risks of several kinds of cancer (11, 12). It has brought tremendous health and economic burden for people all over the world (13). However, insufficient attention has been paid to the detection, diagnosis, and monitoring of occupational exposure and its associated diseases, especially leukemia. It is well-accepted that occupational exposure to formaldehyde and benzene causes leukemia (14, 15). The researchers compared occupational exposure to formaldehyde with the risk of leukemia in community-based case-control studies. The proportion of leukemia in occupationally exposed cohorts will increase significantly (16). In 2009, the International Agency for Research on Cancer (IARC) regarded formaldehyde as a risk factor for leukemia (17, 18). Researchers often focus on the relationship between formaldehyde and general lymphohematopoietic cancer or leukemia, but the issue of occupational exposure has not attracted their attention (16, 19, 20).

The Global Burden of Disease (GBD) study was originally authorized by the World Bank and added to the landmark World Development Report 1993 (21). Since 1990, GBD has made the most comprehensive efforts to systematically monitor and master the world’s health problems (22). We used the GBD database to analyze leukemia attributable to occupational risk incidences and deaths in the general population by sex, social development index (SDI), and reason for the 1990–2019 period at regional and global levels. We aimed to provide valuable insights into data-based healthcare regimens and provide a better understanding of the global burden of leukemia attributable to occupational risk as an important complement to previous GBD studies.

Methods

Data sources

Data on the burden of leukemia attributable to occupational risk were downloaded from the Global Health Data Exchange GBD Results Tool (http://ghdx.healthdata.org/gbd-results-tool), including death rates and disability-adjusted life years (DALYs). GBD values were reported as estimated values with 95% uncertainty intervals (UIs), and a posterior distribution was used to calculate the 25th and 975th ranked estimates from random 1,000 draws (23).

Conclusion: We observed a substantial reduction in leukemia due to occupational risks between 1990 and 2019. However, the people aged 65–69 years and burdens of ALL, AML, and CLL had a significantly increased trend in almost all age groups. Thus, there remains an urgent need to accelerate efforts to reduce leukemia attributable to occupational risk-related death burden in this population and specific causes.

KEYWORDS

leukemia, AML, ALL, global burden disease, death rate
| Age group | 1990 | 2019 |
|-----------|------|------|
| DALYS (95% UI) | Number | Age-standardized rate | Number | Age-standardized rate | EAPC (95% CI) | Number | Age-standardized rate | Number | Age-standardized rate | EAPC (95% CI) |
| Global | 80,359 | 1.5609 | 113,715 | 1.3986 | −0.38% | (95% CI: −0.58 to −0.18%) | 1,612 | 0.0326 | 2,455 | 0.0299 | −0.3% |
| Gender | | | | | (792−2,369) | | (1,181−3,645) | | | (95% CI: −0.45 to −0.14%) |
| Male | 46,410 | 1.7925 | 66,189 | 1.6267 | −0.33% | (54,505–167,831) | (0.669–2.0648) | (0.0161–0.0481) | (1,181–3,645) | (0.0144–0.0445) |
| Female | 33,949 | 1.3279 | 47,526 | 1.1703 | −0.44% | (22,691–68,190) | (0.7944–2.4214) | (0.0186–0.0557) | (699–2,131) | (0.0172–0.0524) |
| Age group | 50–69 year | 9,616 | 1.4097 | 18,828 | 1.3654 | −0.11% | (29,299–98,550) | (0.7944–2.4214) | (0.0186–0.0557) | (699–2,131) | (0.0172–0.0524) |
| 70+ year | 1,517 | 0.7528 | 4,365 | 0.9413 | 0.79% | (17,064–51,519) | (0.5417–1.7683) | (0.0167–0.0379) | (1,181–3,645) | (0.0166–0.0379) |
| SDI region | | | | | (Continued) | | | | | | |
### TABLE 1 (Continued)

| Type of cause              | 1990 Number | Age-Standardized rate | 2019 Number | Age-Standardized rate | EAPC (95% CI) | 1990 Number | Age-Standardized rate | 2019 Number | Age-Standardized rate | EAPC (95% CI) |
|----------------------------|-------------|-----------------------|-------------|-----------------------|---------------|-------------|-----------------------|-------------|-----------------------|---------------|
| **Chronic lymphoid leukemia** | 15,418      | 0.3035                | 31,670      | 0.3891                | 0.87%         | 321         | 0.0066                | 712         | 0.0087                | 0.96%         |
| **Acute myeloid leukemia**  | 2,637       | 0.0572                | 5,710       | 0.0687                | 0.66%         | 70          | 0.0016                | 155         | 0.0019                | 0.55%         |
| **Acute lymphoid leukemia** | 12,017      | 0.223                 | 22,397      | 0.2788                | 0.78%         | 218         | 0.0042                | 419         | 0.0052                | 0.75%         |
| **Other leukemia**          | 39,933      | 0.7709                | 40,483      | 0.4969                | −1.51%        | 787         | 0.0158                | 884         | 0.0108                | −1.33%        |
| **Southeast Asia, east Asia, and Oceania** | 8,013 | 1.8404                | 14,872      | 2.0371                | 0.36%         | 153         | 0.0377                | 310         | 0.043                 | 0.47%         |
| **Sub-Saharan Africa**      | 1,301       | 0.8085                | 3,323       | 0.9098                | 0.11%         | 26          | 0.0187                | 65          | 0.0195                | 0.14%         |
| **Eastern Sub-Saharan Africa** | 1,892       | 1.3829                | 4,615       | 1.4389                | 0.14%         | 37          | 0.03                   | 92          | 0.0323                | 0.26%         |
| **Southern Sub-Saharan Africa** | 693       | 1.5077                | 698         | 0.8289                | −2.14%        | 13          | 0.0309                | 13          | 0.0165                | −2.11%        |
| **Central Sub-Saharan Africa** | 456       | 1.0614                | 1,122       | 1.0326                | −0.09%        | 9           | 0.0223                | 21          | 0.0216                | −0.1%         |
| **Western Sub-Saharan Africa** | 1,301       | 0.8085                | 3,323       | 0.9098                | 0.11%         | 26          | 0.0187                | 65          | 0.0195                | 0.14%         |
| **Other Sub-Saharan Africa** | 456        | 1.0614                | 1,122       | 1.0326                | −0.09%        | 9           | 0.0223                | 21          | 0.0216                | −0.1%         |
| **Southeast Asia**          | 8,013       | 1.8404                | 14,872      | 2.0371                | 0.36%         | 153         | 0.0377                | 310         | 0.043                 | 0.47%         |
| **South Asia**              | 1,301       | 0.8085                | 3,323       | 0.9098                | 0.11%         | 26          | 0.0187                | 65          | 0.0195                | 0.14%         |
| **East Asia**               | 28,451      | 2.1654                | 29,187      | 1.7044                | −0.83%        | 543         | 0.0432                | 616         | 0.034                 | −0.84%        |
| **Oceania**                 | 84          | 1.4493                | 206         | 1.6147                | 0.39%         | 2           | 0.0292                | 4           | 0.033                 | 0.43%         |
| **South America**           | 213–275     | 0.5170                | 720–923     | 0.8289                | −2.14%        | 13          | 0.0309                | 13          | 0.0165                | −2.11%        |
| **North America**           | 316–1,063   | (0.6848–2.3022)       | 304–1,109   | (0.3623–1,2965)       | (−2.61 to −1.67)%* | (6–20)       | (0.0143–0.47)         | (6–21)       | (0.0072–0.0256)       | (−2.6 to −1.63)%* |
| **Sub-Saharan Africa**      | 693         | 1.5077                | 698         | 0.8289                | −2.14%        | 13          | 0.0309                | 13          | 0.0165                | −2.11%        |
| **Central Sub-Saharan Africa** | 456        | 1.0614                | 1,122       | 1.0326                | −0.09%        | 9           | 0.0223                | 21          | 0.0216                | −0.1%         |
| **Western Sub-Saharan Africa** | 1,301       | 0.8085                | 3,323       | 0.9098                | 0.11%         | 26          | 0.0187                | 65          | 0.0195                | 0.14%         |
| **Other Sub-Saharan Africa** | 456        | 1.0614                | 1,122       | 1.0326                | −0.09%        | 9           | 0.0223                | 21          | 0.0216                | −0.1%         |
| **North America**           | 213–275     | 0.5170                | 720–923     | 0.8289                | −2.14%        | 13          | 0.0309                | 13          | 0.0165                | −2.11%        |

(Continued)
| Region                          | 1990 | 2019 | DALYS (95% UI) | Age-Standardized rate | 1990 | 2019 | EAPC (95% CI) | Deaths (95% UI) | Age-Standardized rate | 1990 | 2019 | EAPC (95% CI) |
|--------------------------------|------|------|---------------|----------------------|------|------|--------------|------------------|----------------------|------|------|--------------|
| South Asia                     | 7,959| 16,167| 0.8775        | 0.17%                | (3,829–11,931) | 158 | 0.0176       | (76–237) | 0.0085–0.0266 | 0.019 | 0.25% | (-0.01–0.51%) |
| Latin America and Caribbean    |      |      |               |                      |      |      |              |                  |                      |      |      |              |
| Tropical Latin America         | 2,759| 16,167| 0.8775        | -0.26%               | (1,283–4,032) | 54 | 0.0397       | (25–79) | 0.0187–0.0583 | 0.0378 | 0.15% | (-0.1–0.3%)   |
| Caribbean                      | 548 | 990 | 1.76          | 0.76%                | (262–816) | 11 | 0.0342       | (5–16) | 0.0164–0.051 | 0.0431 | 0.82% | (-0.02–0.04%) |
| Andean Latin America           | 863 | 2,123| 3.2553        | 0.81%                | (405–1,355) | 17 | 0.0528       | (8–26) | 0.0248–0.0825 | 0.0683 | 0.86% | (-0.1–0.5%)   |
| Central Latin America          | 3,386| 7,057| 2.6878        | 0.61%                | (1,654–4,978) | 63 | 0.0457       | (31–93) | 0.0225–0.0672 | 0.0548 | 0.64% | (-0.08–0.89%) |
| North Africa and Middle        | 4,688| 10,081| 1.5789       | -0.17%               | (2,220–7,329) | 94 | 0.0359       | (44–145) | 0.0169–0.0555 | 0.0346 | -0.13% | (-0.21–0.04%) |
| East                           |      |      |               |                      |      |      |              |                  |                      |      |      |              |
| Central Europe, eastern Europe, and central Asia |      |      |               |                      |      |      |              |                  |                      |      |      |              |
| Central Europe                 | 1,275| 1,252| 0.9031        | -0.27%               | (374–2,116) | 29 | 0.0213       | (8–48) | 0.0062–0.0535 | 0.0211 | -0.04% | (-0.19–0.12%) |
| Central Asia                   | 1,443| 1,936| 1.9269        | -0.41%               | (653–2,159) | 27 | 0.0432       | (12–41) | 0.0195–0.0646 | 0.0388 | 0.35% | (-0.61–0.09%) |
| Eastern Europe                 | 3,077| 2,297| 0.965         | -0.83%               | (830–5,227) | 66 | 0.0263       | (18–113) | 0.007–0.0447 | 0.0205 | 0.77% | (-0.12–0.29%) |
| High-income regions            |      |      |               |                      |      |      |              |                  |                      |      |      |              |
| High-Income North America      | 4,526| 4,584| 1.0589        | -1.03%               | (1,240–7,650) | 108 | 0.0336       | (29–182) | 0.0091–0.0566 | 0.0261 | 0.83% | (-0.95 to 0.07%) |
| High-Income Asia Pacific       | 2,576| 1,868| 0.8374        | -1.65%               | (742–4,313) | 56 | 0.0284       | (16–94) | 0.0081–0.0476 | 0.0186 | 1.45% | (-1.63 to 1.28%) |
| Australasia                    | 220 | 301 | 0.8674        | -0.43%               | (63–370) | 5 | 0.0232       | (1–9)  | 0.0066–0.0392 | 0.0125 | 0.24% | (-0.4 to 0.07%) |
| Western Europe                 | 4,925| 4,950| 0.9437        | -0.68%               | (1,365–8,254) | 116 | 0.0254       | (32–196) | 0.007–0.0427 | 0.022 | -0.52% | (-0.64 to 0.4%) |
| Southern Latin America         | 1,225| 1,743| 2.4186        | -0.17%               | (1,365–8,254) | 26 | 0.0541       | (13–38) | 0.0261–0.0795 | 0.0526 | -0.12% | (-0.22 to 0.01%) |

The asterisks represent statistically significant.
Age-standardized DALY and death rates in 2019 for leukemia attributable to occupational risk. (A) Age-standardized disability-adjusted life years rate. (B) Age-standardized death rates. (C) Estimated annual percent change of disability-adjusted life years rate. (D) Estimated annual percent change of death rates.

The SDI values range between 0 and 1, which reflect the degree of social development. Our research is compliant with the Guidelines for Accurate and Transparent Health Estimates Reporting.

**Definitions**

The occupational risk was defined as patients’ long-term exposure to carcinogenic factors in the working environment. These kinds of occupational carcinogenic factors include chemical, physical, and biological (27). The DALYs by age, sex, year, and region were collected from GBD 2019. The DALYs is a summary measure that quantifies the overall burden of disease (28, 29).

**Statistical analysis**

We estimated the number of deaths or DALYs, age-standardized rate DALYs, and deaths to quantify leukemia attributable to occupational risk by age, year, and region. The estimated annual percentage change (EAPC) was calculated to quantify the trends of burdens of leukemia attributable to occupational risk from 1990 to 2019. The regression model was used to fit the age-standardized rate (ASR), that is, \( \ln(\text{ASR}) = \alpha + \beta X + \epsilon \), where \( y \) stands for the burden rate and \( x \) for the calendar year. EAPC was calculated by 100 \* [\( \exp(\beta) - 1 \)], and its 95% confidence interval (CI) could also be calculated from the model (24, 25, 30). With the EAPC value and its 95% CI above zero, the corresponding age-standardized rate (ASR) was in an upward trend and vice versa (31). Moreover, to gain a better understanding of the relationship between the EAPC of ASR and possible facts, a local weighted scatter plot smoothing regression was used to display more detailed information (24, 25). All statistical analyses were done using R (version 3.6.0).

**Results**

The distribution and its change trend of leukemia attributable to occupational risk

The global age-standardized DALYs and death rates of leukemia attributable to occupational risk were 1.5609, 95% UI: 0.7676–2.2942 for DALYs and 0.0326, 95% UI: 0.0161–0.0481 for deaths in 1990 and 1.3986, 95% UI: 0.669–2.0648 for DALYs and 0.0299, 95% UI: 0.0144–0.0445 for deaths in 2019. Male individuals had higher age-standardized rates than female individuals in leukemia attributable to occupational risk. Global age-standardized DALYs and death rates presented significantly decline trends with EAPCs \([-0.38\% \text{ (95\% CI: } -0.58 \text{ to } -0.18\%)]\)
Differences in types of leukemia are attributable to occupational risk. (A) Acute lymphoid leukemia. (B) Acute myeloid leukemia. (C) Chronic lymphoid leukemia. (D) Chronic myeloid leukemia. (E) Other leukemia.

Impact of occupational risk on each leukemia

In 2019, ALL and AML were the leading causes of leukemia attributable to occupational risk-related DALYs and death rates. Both ALL and AML attributable to occupational risk were heavy in Central Latin America, Andean Latin America, and Southern Latin America (Figure 2, Supplementary Table 1). Globally, the age-standardized DALYs and death rates of ALL, AML, and CLL were presented a significantly increase trends with EAPCs [0.78% (95% CI: 0.65–0.91%), 0.87% (95% CI: 0.81–0.93%), and 0.66% (95% CI: 0.51–0.81%) for DALYs, respectively, and
The DALY and death rates of leukemia were attributable to occupational risk among different age groups between 1990 and 2019. Red asterisks represent an uptrend, blue asterisks represent a decline, and black asterisks represent a steady trend. (A) DALYs and (B) Deaths.

0.75% (95% CI: 0.68–0.82%), 0.96% (95% CI: 0.91–1.01%), and 0.55% (95% CI: 0.43–0.68%) for death, respectively, whereas the age-standardized DALYs and death rates of CML and other leukemia were significantly decreased. For SDI quintiles, except for the high SDI level region, the ALL, AML, and CLL were significantly increased in other SDI levels region (Figure 3, Supplementary Table 2).

Leukemia attributable to occupational risk age distribution structure

We analyzed the DALYs and death rates of leukemia attributable to occupational risk in three different age groups. The results indicated that most DALYs and deaths occurred in 25–29 years in the globe. Overall, the leukemia attributable to occupational risk was significantly increased in people aged 65–69 years [0.42% (95% CI: 0.30–0.55%) for DALYs and 0.38% (95% CI: 0.26–0.51%) for death]. The burdens of ALL, AML, and CLL were increased in almost all age groups while decreased in CML and other leukemia (Figure 4).

Relationship between SDI and the burdens of leukemia attributable to occupational risk

In 2019, the highest age-standardized rates of leukemia attributable to occupational risk-related deaths and DALYs were observed in countries in the Middle-SDI [1.6778 (95% UI: 0.7894–2.4881) DALYs per 100,000 people and 0.0348 (95% UI: 0.0164–0.052) deaths per 100,000 people]. Figure 5 and Supplementary Figure 1 show the changes in age-standardized DALYs and death rates across the SDI by region from 1990 to 2019. Five regions with the highest SDI exhibited a decline in the age-standardized rate of leukemia attributable to occupational risk-related DALYs and deaths, whereas five regions with the lowest SDI experienced an increasing trend. The regions with
Age-standardized DALY and death rates were attributable to leukemia attributable to occupational risk across 21 GBD regions by the socio-demographic index for both sexes combined in 1990–2019. (A) Age-standardized DALY’s rates. (B) Age-standardized death rates.

middle SDI show greatly varied. The associations between age-standardized DALYs and death rates and SDI across countries in 2019 are shown in Supplementary Figure 1.

Discussion

In this study, we reported the disease burden of leukemia attributable to occupational risk-related deaths and their trends from 1990 to 2019 at the global, regional, and country levels. Our findings showed several key points. Changes between different countries and regions in the burden and trends in total and particular leukemia attributable to occupational risk-related deaths across the globe were found in our research. In general, regions of Andean Latin America, Central Latin America, and the Caribbean were the so-called hotspot regions with the highest age-standardized rates of total leukemia attributable to occupational risk-related deaths in 2019. Overall, most countries and regions showed a decrease in age-standardized DALYs and death rates. The DALYs and deaths of leukemia caused by occupational risk in elderly people is higher than that in other age groups, and the burdens are on the rise.

We analyzed the epidemiological trends of leukemia attributable to occupational risk by calculating the EAPC values from 1990 to 2019. As everyone knows, aging is an important factor contributing to leukemogenesis. Accompanied by aging gene mutations, changes in internal environmental homeostasis and mitochondrial dysfunction make the risk of leukemia higher in the elderly than in the young people (32–35). The marked increase in leukemia attributable to occupational risk in Latin America in terms of deaths and DALYs can be partially explained by the fact that humans in these countries and regions are mostly engaged in physical labor and have more opportunities to come into contact with toxic substances such as formaldehyde and...
benzene. Besides, long-term poverty, poor access to healthcare, a lower awareness regarding occupational risk, inadequate prevention measures and screening, and a lower proportion of treatment together make low-income countries more susceptible to leukemia attributable to occupational risk than high-income countries (36–38). Therefore, in the subsequent campaign to eliminate leukemia attributable to occupational risk, more attention and health resources were warranted in developing countries and low-income regions.

Of note, our research found that, among all leukemia caused by occupational risk, the age-standardized DALYs and death rates were particularly observed in ALL and AML. The possible reasons can be listed as follows. First, the standard of leukemia classification has changed. For example, the World Health Organization (WHO) classification (2, 39), recognized as a standard for disease diagnosis and public health monitoring worldwide, has been revised from the primary to the 5th edition during the past 60 years (2). French-American-British (FAB) classification (40) and MICM classification (Morphology, Immunology, Cytogenetics, and Molecular) classification (41). Meanwhile, the diagnostic criteria for leukemia have also changed (42, 43). In terms of the countries and regions’ distribution of these two kinds of leukemia, in Mexico and Latin America, the age-standardized DALYs and death rates were the highest, possibly because of the most common of these two types of leukemia in young adults and regional economic development. Thus, accurate surveillance data were important for developing a prevention-and-control program and providing valuable countermeasures to estimate the impact of those programs (44, 45). Elderly people were found to have disproportionately high DALYs and death rates in total leukemia attributable to occupational risk-related deaths, which might be due to age factors. For one thing, the DALYs and death rates of leukemia will increase with age, so the DALYs and death rates of the elderly will be higher than that of young adults. For another, if the elderly were exposed to toxic and harmful substances such as formaldehyde and benzene during adolescence, these substances will not immediately cause reactions after exposure but will slowly accumulate in the body, and symptoms will slowly emerge with age (46, 47). Our findings call for an urgent need to accelerate efforts to reduce leukemia attributable to occupational risk burden in elderly people. Male individuals generally had higher age-standardized DALYs and death rates than female individuals for leukemia attributable to occupational risk-related deaths, possibly because men were the main part of social labor and were more engaged in heavy physical labor, thus, they had more chances to contact toxic and harmful substances. In addition, the burden of leukemia itself is higher in men than in women (48, 49).

Most countries had a decrease in age-standardized rates of DALYs and death rates for leukemia attributable to occupational risk-related deaths, whereas the absolute DALYs and death cases increased from 1990 to 2019. Leukemia attributable to occupational risk-related deaths still represents a global public health challenge, especially in Latin America and other developing countries, where more attention and health prevention services are warranted. Our study also suggested an upward trend of leukemia attributable to occupation risk among elderly people. ALL, AML, and CLL showed an upward trend in almost all age groups. Thus, there remains an urgent need to accelerate efforts to reduce leukemia attributable to occupational risk-related death burden in this population and specific causes.

Data availability statement
The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author(s).

Author contributions
WX designed the study, DX, CC, HS, YY, and YX accessed and verified the data. XY, HT, AL, and JJ analyzed the data and interpreted the results. YS, YH, XT, and DC wrote the manuscript. All authors revised the manuscript from the preliminary draft to submission.

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Conflict of interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1015861/full#supplementary-material

SUPPLEMENTARY FIGURE 1
Age-standardized DALY and death rates were attributable to leukemia attributable to occupational risk across countries and territories by the socio-demographic index for both sexes combined in 2019. (A) Age-standardized DALY rates. (B) Age-standardized death rates.

SUPPLEMENTARY TABLE 1
Differences in types of leukemia attributable to occupational risk in 21 GBD regions.

SUPPLEMENTARY TABLE 2
The trends of different types of leukemia attributable to occupational risk among SDI quintiles between 1990 and 2019.

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