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Global, regional and national burdens of alcoholic cardiomyopathy among the working-age population, 1990–2021: a systematic analysis

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Abstract

Objectives Alcoholic cardiomyopathy (ACM) results from chronic alcohol misuse and primarily affects the working-age population (15–64 years). The global age-standardized rates (ASRs) of ACM disease burden declined slightly from 1990 to 2021, but the absolute cases increased, especially in high–medium sociodemographic index (SDI) regions such as Eastern Europe. The aim of this study was to inform strategies to combat this preventable yet escalating health issue.

Methods We calculated estimated annual percentage changes (EAPCs) to quantify the dynamics of prevalence, deaths, and disability-adjusted life years (DALYs) for ACM. Decomposition analysis quantifies the contributor of disease burden in ACM. Additionally, we employed a health inequality analysis with two core indicators, the slope index (SI) and the concentration index (CIN), to assess national differences in the burden of ACM in relation to the SDI. Frontier analysis was used to identify preventable burdens with respect to optimized alcohol policies, particularly in high–middle SDI countries. Finally, we applied a Bayesian age–cohort (BAPC) model to project the ACM burden to 2035.

Results This study revealed that the ASRs of prevalence, deaths, and DALYs decreased slightly from 1990 to 2021, whereas absolute cases of ACM continued to increase globally. Global income-based health disparities in ACM have intensified over the past 32 years, with high SDI populations disproportionately favoured. Population growth was the main driver of the increased ACM burden. The global burden of ACM is expected to increase in the future according to the BAPC model.

Conclusions The global burden of ACM continues to rise, primarily due to population ageing and insufficient prevention policies. This burden disproportionately impacts working-age populations, who face heightened

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vulnerability due to alcohol accessibility, premature mortality, and reduced workforce productivity. Moreover, economic growth paradoxically coincides with increased alcohol-related harm in regions with high–middle socioeconomic development—the alcohol control paradox. Projections highlight an urgent need for tailored alcohol control strategies, including stricter regulation and early cardiac screening in high-risk groups, to mitigate workforce productivity loss and align public health priorities with sustainable development goals.

Keywords Alcoholic cardiomyopathy, Global burden of disease, Temporal trends, Sociodemographic index, Health inequality

Introduction

Alcoholic cardiomyopathy (ACM) is an acquired form of dilated cardiomyopathy caused by chronic excessive alcohol consumption [1]. The pathogenesis of ACM involves ethanol-induced oxidative stress, mitochondrial dysfunction, and myocardial fibrosis, which collectively drive progressive cardiac remodelling and systolic/diastolic dysfunction [2]. Although detailed statistics on the global harms of ACM are lacking, ACM poses considerable challenges both to patient health and the global healthcare system. Additionally, ACM imposes a non-negligible economic burden through high medical costs and productivity losses. Despite considerable advances in the prevention, diagnosis and treatment of ACM, its global burden remains significant and varies considerably across regions and socioeconomic groups [3]. Eastern Europe experiences a disproportionately high ACM burden because of deeply entrenched alcohol consumption patterns and differences between socioeconomic groups [4]. Furthermore, ACM markedly affects working-age people, who typically serve as primary economic contributors and have lower healthcare utilization. Because ACM-induced workforce depletion imposes dual burdens of economic loss and increased healthcare resource consumption, this group deserves special attention [5].

Studies have previously investigated the global burden of ACM using data from the Global Burden of Disease (GBD). According to the GBD 2017, despite decreases in the age-standardized rate (ASR), there has been a notable absolute case increase in worldwide prevalence, deaths, years lived with disability (YLD), and years of life lost (YLL) for ACM throughout the preceding decades [6]. The GBD 2019 analysis further demonstrated a continued global increase in the ACM burden, especially in high–middle sociodemographic index (SDI) regions such as Eastern Europe. An examination of gender and age patterns revealed that males bore a heavier burden than females did and that individuals aged 50–69 years were most severely affected [7].

Although prior studies have examined the trends of ACM and identified the correlation between the SDI and regional and country burdens, no study to date has utilized renewed GBD 2021 data to provide a holistic analysis of ACM in the working-age population. This study employed multiple analyses to examine disparities in the associations between socioeconomic, demographic and cultural factors and the ACM burden in the working-age population with the aim of providing a scientific foundation for the formulation of prevention and treatment strategies.

Methods

Data sources and disease definitions

The ACM data analysed in this study were sourced from the GBD 2021, which provides comprehensive epidemiological records of the burden of 371 diseases and injuries for 21 GBD regions and 204 countries and territories from 1990 to 2021. We used de-identified GBD 2021 data with additional privacy safeguards, including anonymization of identifiers, restricted access, and compliance with relevant standards for sensitive variables. All the data are freely available through the Global Health Data Exchange (https://vizhub.healthdata.org/gbd-results/). The GBD 2021 data cleaning framework systematically applies meta-regression with boosted regression trees (MR-BRT) to reconcile gaps in missing data and harmonize heterogeneity across data sources while integrating complementary techniques such as age–gender splitting, regional covariate adjustments, and spatiotemporal smoothing for robust imputation. For clinical datasets, the protocol employs admission-rate calibration, scaling transformations, and standardization protocols to derive population-representative incidence metrics [8]. In this study, we used prevalence, death, and DALY measures in populations aged 15–64 years, which were analysed at the global, 5 SDI regional, 21 regional, and 204 national levels of ACM while excluding other data.

The definition of ACM follows the 2023 European Cardiovascular Society Cardiomyopathy Guidelines, which characterize it as a complex cardiac pathology classified under acquired dilated cardiomyopathy. This condition primarily results from chronic excessive alcohol intake (> 80 g/day for ≥ 5 years) [9].

Data analysis

This study employed a multilevel analytical framework to systematically evaluate the interplay between patterns of sociodemographic development and disease burden. For intuitive changes in the burden of ACM over the past 32 years, we selected absolute values and ASRs for 1990

and 2021 for comparison because of the large amount of data for 1990–2021. Furthermore, we used the estimated annual percentage change (EAPC) in ASRs to evaluate the average change trends over a specified time interval [10].

To assess the relationship between economic status and the burden of ACM, we used the concept of the SDI, a composite metric that integrates fertility rates, educational attainment, and income-adjusted economic capacity and serves as the foundational developmental benchmark [11]. In accordance with this stratification, Spearman's rank correlation analysis was used to quantify directional associations (ρ coefficient) between SDI progression and standardized disease burden metrics to establish baseline societal determinants [12].

To examine the relationship between health inequities and the SDI, dual indices were applied: the slope index (SI) measures gaps in the absolute burden between SDI extremes, whereas the concentration index (CIN) maps the distribution of burden through Lorenz curve dynamics to jointly reveal whether disparities affect low-resource populations disproportionately [13]. Moreover, decomposition analysis variations were decomposed into population growth, ageing, and epidemiological changes using counterfactual modelling to isolate the contribution of each driver while controlling for synergies [14]. Furthermore, frontier analysis was used to benchmark health system efficiency through Euclidean distance calculations between observed burdens and SDI-specific theoretical optima, which helped to identify actionable gaps to guide resource prioritization [15].

Finally, the Bayesian age–period–cohort model (BAPC) was used to integrate these multidimensional insights by leveraging computational optimization through integrated nested Laplace approximations (INLAs). This integration achieved the dual analytical objectives of clarifying historical determinants of disease patterns while establishing a simulation platform for evidence-driven policy design, particularly precise public health interventions [16].

Statistical analysis

To address the confounding effects of disparities in age distribution across populations, this study implemented direct age standardization following the methodological framework of the GBD 2021 study by calculating the ASR using the formula Σ (age-specific rate × corresponding standard population proportion), with standardization weights derived from the GBD 2021 reference population structure. The ASRs for prevalence, deaths, and DALYs are expressed as corresponding numbers per 100,000 people accompanied by 95% uncertainty intervals (UIs) and 95% confidence intervals (CIs). All the statistical analyses and graphical visualizations were conducted using R software (version 4.3.3) and Origin (version 2021) to ensure methodological consistency and reproducibility [3].

Results

Global level

In 2021, the global prevalence, number of deaths, and DALYs for ACM were 368,690.99 (95% UI: 251,183.14 to 515,568.40), 44,540.30 (95% UI: 38,800.98 to 49,311.70), and 1,473,204.12 (95% UI: 1,259,045.21 to 1,649,522.85), respectively, and increased by 31.28%, 44.91%, and 48.37%, respectively, over the past three decades. The global ASPR, ASDR, and ASR of DALYs for ACM were 6.96 (95% UI: 4.73 to 9.74), 0.82 (95% UI: 0.72 to 0.91), and 33.77 (95% UI: 29.61 to 37.32) in 2021, respectively, with EAPCs of -0.74 (95% CI: -0.98-0.50), -1.27 (95% CI: -2.51 to -0.01), and – 1.26 (95% CI: -2.54 to 0.03), respectively, indicating declining trends over 32 years. Both genders presented increasing case numbers but decreasing ASRs. Among males, the population aged 50–54 years reported the highest prevalence and DALY cases, whereas deaths and all ASRs peaked in individuals aged 60–64 years (Fig. 1).

SDI regional level

In 2021, across the five SDI quintiles, high–middle SDI regions presented the highest disease burden in terms of prevalence, deaths, and DALYs. In contrast, low SDI regions presented the lowest values for all three indicators. Specifically, the absolute cases of prevalence, deaths, and DALYs in high–middle SDI regions were 11.34, 107.41, and 97.97 times greater than those in low SDI regions, respectively. With respect to ASRs, the highest ASPR was identified in high SDI regions, and the highest ASDR and ASR of DALYs were reported in high–middle SDI regions. In contrast, the lowest values of the corresponding indicators were found in the low–middle, low, and middle SDI regions, with corresponding EAPCs of 0.39 (95% CI: 0.10 to 0.68), 0.85 (95% CI: -0.80 to 2.53), and 0.83 (95% CI: -0.85 to 2.53), respectively. These results revealed a positive yet nonlinear correlation between the ACM disease burden and the SDI. Notably, high–middle SDI regions presented greater burdens than other SDI categories did, whereas low SDI regions paradoxically presented lower ASPRs and ASRs of DALYs than low–middle SDI regions did, suggesting that transitional health system resource misallocation may disproportionately amplify the stratification of burdens across development phases (Fig. 1).

Regional level

Against the backdrop of an overall rise in the global prevalence, number of deaths and DALY cases of ACM from 1990 to 2021, most regions have shown increasing trends.

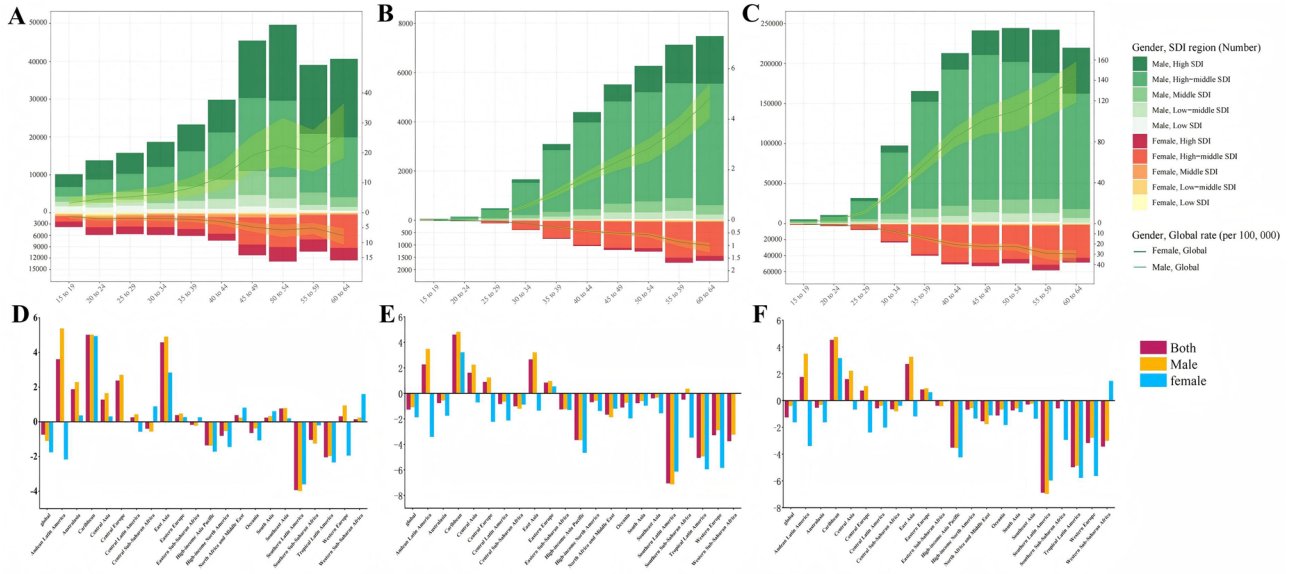

Fig. 1 **A-C**: Age-specific cases and ASR of prevalence **(A)**, deaths **(B)**, and DALYs **(C)** in alcoholic cardiomyopathy of the working-age population by SDI regions, 2021. **D-F**: Changes of EAPC of ASPR **(D)**, ASDR **(E)**, and ASR of DALYs **(F)** in alcoholic cardiomyopathy of the working-age population by GBD regions, 1990–2021

Eastern Europe reported the highest number of cases and ASRs of prevalence, deaths, and DALYs in 2021. This region had the heaviest global ACM burden, accounting for 35.59%, 69.85%, and 70.44% of the global total prevalence, deaths and DALY cases, respectively, and its ASPR, ASDR and ASR of DALY levels were 11.89, 21.57 and 22.35 times higher than the global level, respectively. Although the global ASPR, ASDR, and ASR of DALYs tended to decrease from 1990 to 2021, Eastern Europe still had an increasing trend, with equivalent EAPC values of 0.39 (95% CI: 0.10 to 0.68), 0.85 (95% CI: -0.80 to 2.53), and 0.83 (95% CI: -0.85 to 2.53), respectively. Consistent epidemiological evidence identifies Eastern Europe as bearing the globally predominant ACM burden and demonstrating sustained escalation patterns (Fig. 1).

National level

From 1990 to 2021, 60% of countries experienced increasing trends in prevalence, deaths, and DALYs. The Russian Federation recorded the highest absolute values in all three categories by 2021, contributing 25.73% of the global prevalence, 52.03% of deaths, and 52.16% of worldwide DALYs. In 2021, the Russian Federation had the highest ASPR, whereas Latvia had the highest ASDR and ASR of DALYs. Conversely, Ecuador, Zambia, and Peru exhibited the lowest rates for these three metrics. These results reflect the critical problems faced by the Russian Federation in terms of public health infrastructure and socioeconomic conditions, with connections to uneven access to healthcare, ineffective policies, and disease profile variations. Although Latvia and Ecuador face lower absolute disease burdens, they demand scrutiny because of disproportionately ASDR and ASR of DALYs, indicating potential localized health system vulnerabilities or environmental risks.

Association between ACM and SDI

The ASPR, ASDR, and ASR of DALYs in GBD regions and 204 countries showed weak positive correlations with the SDI. The ACM burden remained stable at an SDI < 0.6, increased to a peak at an SDI of 0.7, and then decreased with increasing SDI. Similarly, national-level analysis revealed a stable ACM burden at an SDI < 0.5, followed by oscillatory increases peaking at an SDI of 0.75 before decreasing. These results suggest that mid-developmental stages require targeted interventions to address transitional health risks (Fig. 2).

Decomposition analysis

Decomposition analysis revealed that the increase in global ACM prevalence over the past 32 years was attributable to population ageing, population growth, and epidemiological changes of 40.52%, 136.01%, and −76.53%, respectively, and that population growth was the major contributor to the increased burden of ACM. This analysis also revealed a greater burden of disease in males and high–middle SDI regions. Between 1990 and 2021, males accounted for 77.11% of the global DALY growth, whereas high–middle SDI regions accounted for 90.65% (Fig. 3).

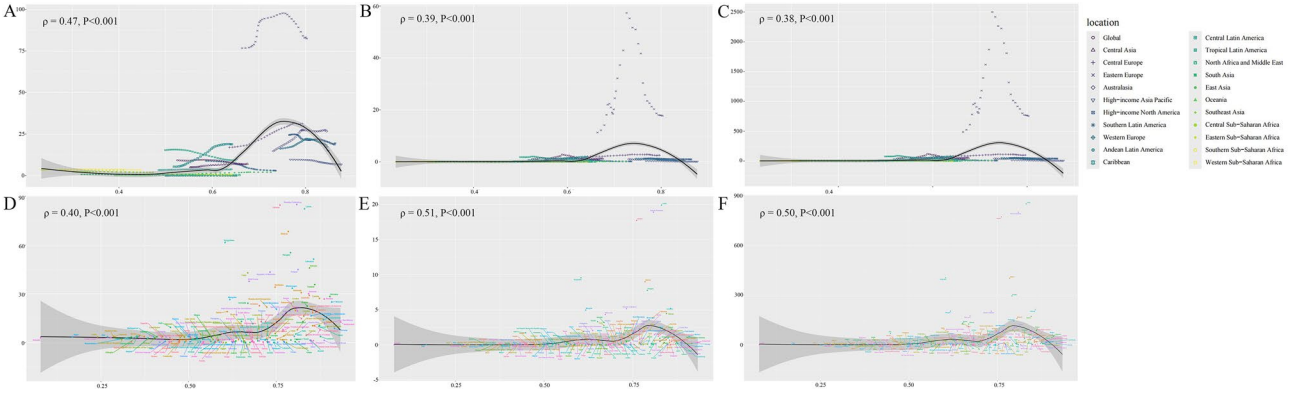

Fig. 2 **A-C**: The association between ASPR **(A)**, ASDR **(B)**, ASR of DALYs **(C)** and SDI in alcoholic cardiomyopathy in the working-age population across 21 GBD regions, 1990–2021. **D-F**: The association between ASPR **(D)**, ASDR **(E)**, ASR of DALYs **(F)** and SDI in alcoholic cardiomyopathy in the working-age population across 204 countries and territories, 1990–2021

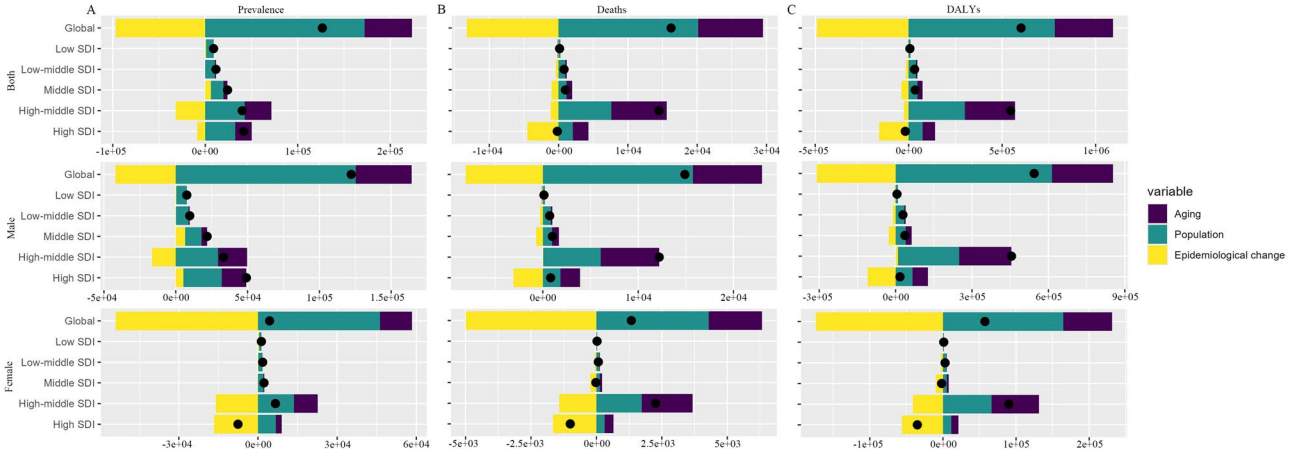

Fig. 3 The changes in prevalence **(A)**, deaths **(B)**, and DALYs **(C)** according to population-level determinants of population growth, aging, and epidemiological change in alcoholic cardiomyopathy of the working-age population at the global level and by SDI regions, 1990–2021 (The black dot represents the overall value of change contributed by all 3 components

Health inequality analysis

Between 1990 and 2021, global income-related inequalities in DALYs associated with ACM significantly intensified. Specifically, the SI for the ASPR between countries with the highest and lowest SDIs nearly doubled, increasing from 6.35 to 12.78, whereas the SI for the ASR of DALYs rose more moderately, from 22.94 to 27.66. In contrast, the SI for the ASDR showed a modest decline, decreasing from 0.60 to 0.53. Concurrently, the CIN increased from 0.62 to 0.64 for the ASDR and from 0.61 to 0.63 for the ASR of DALYs, whereas it decreased from 0.62 to 0.56 for the ASPR. These trends indicate a progressive concentration of health advantages in high SDI populations. Furthermore, absolute disparities in disease burden have widened, underscoring systemic inequities that require targeted policies to address gaps in health resource allocation and mitigate the expansion of health inequalities (Fig. 4).

Frontier analysis

From 1990 to 2021, the ASPR, ASDR, and ASR of DALYs for ACM across 204 countries exhibited distinct trends. ASPR generally increased with increasing SDI values and was marked by gradual shifts in distribution over time, although most countries experienced minor fluctuations. In contrast, the ASDR and DALYs initially increased before declining as the SDI improved, with pronounced peaks observed in select nations.

Frontier analyses in 2021 highlighted stark disparities: ASPR, ASDR, and DALY trends were closely clustered, yet countries such as the Russian Federation, Latvia, and Belarus had significantly higher prevalence rates that diverged sharply from the frontier. Conversely, Somalia, South Sudan, and others aligned more closely to the frontier, reflecting optimal outcomes relative to their SDI (Fig. 5).

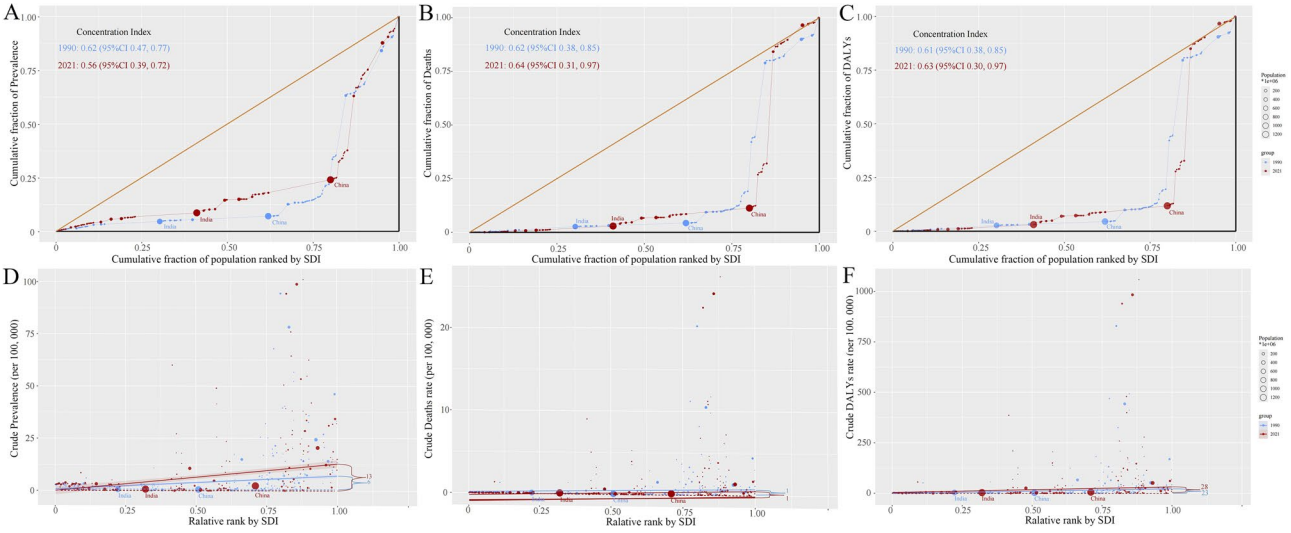

Fig. 4 The health inequality indices for ASPR, ASDR, and ASR of DALYs of alcoholic cardiomyopathy of the working-age population in 1990 and 2019 based on the SDI of 204 countries and territories globally. **A-C**: Concentration indices of ASPR **(A)**, ASDR **(B)**, and ASR of DALYs **(C)**. Each country or territory is represented by a solid dot, with larger dots indicating a higher population. China and India are highlighted for comparative purposes. **D-F**: Slope indices of ASPR **(D)**, ASDR **(E)**, and ASR of DALYs **(F)** (the numbers adjacent to the brackets indicate the slopes)

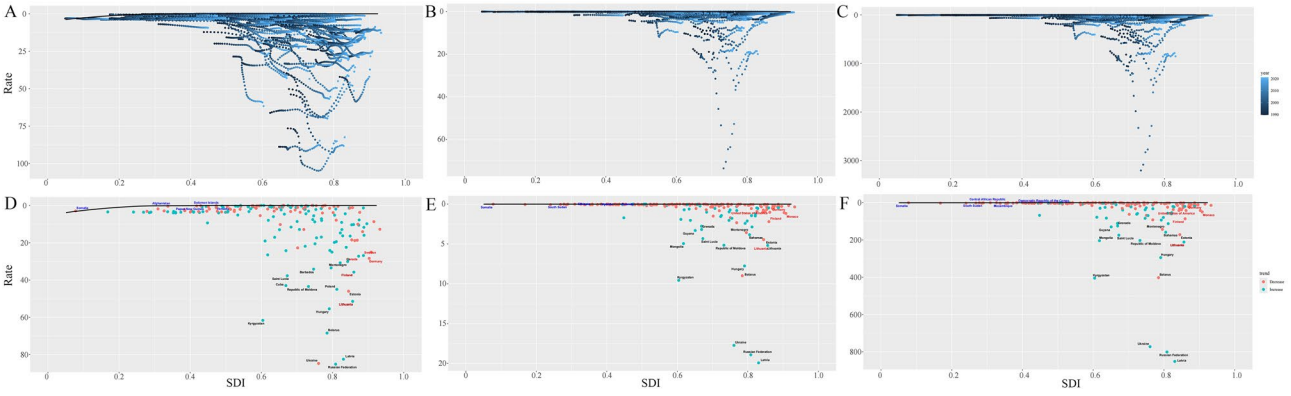

Fig. 5 **A-C**: Trend analysis of ASPR **(A)**, ASDR **(B)**, and ASR of DALYs **(C)** versus the frontier from 1990 to 2021. Each dot represents a country, and the black line denotes the frontier. The gaps between the dots and this line indicate the effective differences. **D-F**: Change in ASPR **(D)**, ASDR **(E)** and ASR of DALYs **(F)** relative to the frontier based on SDI and country data in 2021. Green-blue dots show an increase and orange dots a decrease in these rates from 1990 to 2021. Black font shows countries within the top 15 furthest from the frontier. Red font shows the top 5 countries above the high SDI threshold with the largest distance. The countries in blue are the bottom 5 below the Low SDI threshold with the smallest distance from the frontier

Projections analysis

We projected the cases and ASRs of prevalence, deaths, and DALYs for 10 different age groups from 2021 to 2035 at 5-year intervals and found that all cases will gradually increase in most age groups, whereas the ASPR will continue to decline markedly in all age groups except for the 15–19 and 20–24 age groups, for which it will be relatively flat from 2021 to 2035. Moreover, the ASDR and ASR of DALYs tend to decrease and then increase. Notably, the gap in ACM burden between males and females will narrow and even reverse in a few younger age groups over the next 15 years (Fig. 6).

Discussion

Compared with previous studies, this research introduces significant innovations: it is the first study to incorporate ACM data from the GBD 2021 study, with a specific focus on working-age populations that experience disproportionately high ACM burdens. Through decomposition analysis, we demonstrated that population growth constitutes the primary driver of mortality trends. Frontier analysis further identified substantial potential for improving health outcomes through the adoption of best practices and preventive strategies. Notably, our BAPC modelling projections revealed that the burden of ACM will continue to increase through 2035 and that the gap

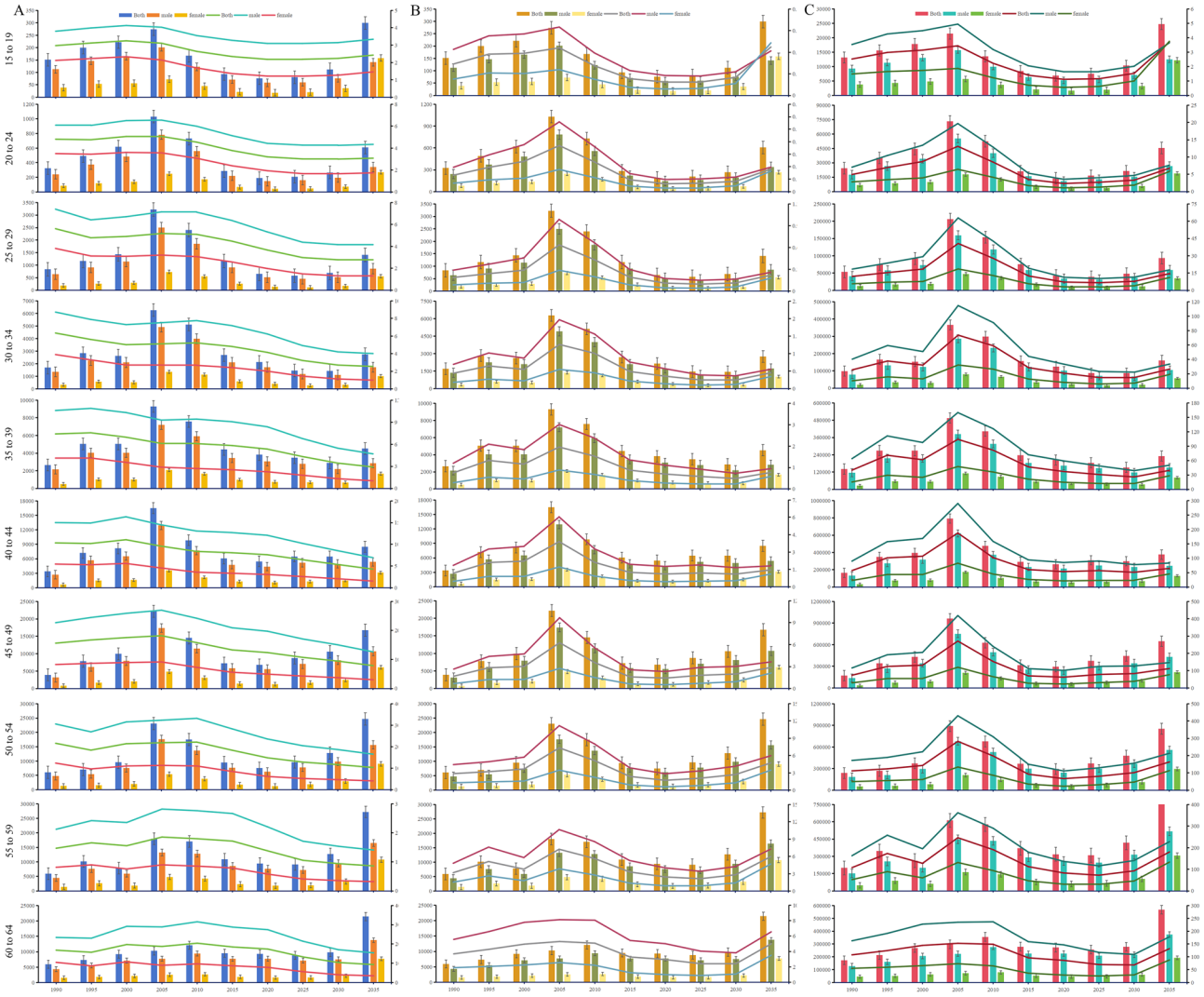

Fig. 6 Previous observations and projection of cases and ASR of prevalence **(A)**, deaths **(B)**, and DALYs **(C)** by Age-specific in alcoholic cardiomyopathy of the working-age population from 2020 to 2035

between the burdens of males and females is projected to narrow.

The Global Action Plan on Alcohol 2022–2030 (GAPA) by the World Health Organization (WHO) outlines a strategy for achieving a 20% reduction in per capita alcohol consumption and a reduction in alcohol-related harm by 2030 [15]. However, the global consumption of alcohol has continued to increase from 5.5 L per capita in 2005 to 6.4 L in 2016 and is projected to increase further to 7.6 L per capita by 2030 [17]. Global alcohol consumption has surged, driven by economic growth, healthcare advancements improving accessibility, and shifting social norms that favour hedonic use. Concurrently, inadequate policy enforcement and counterproductive measures in some nations have exacerbated this trend. Population expansion, urbanization, globalization, and media influence have further amplified consumption patterns, collectively supporting a worldwide upwards trajectory [18]. Alcohol consumption has a paradoxical relationship with socioeconomic status: groups with low socioeconomic status drink less yet endure higher alcohol-related mortality [19].

Previous GBD studies – 70 years as the predominant age range for ACM globally but lack a focus on working-age groups. As both main income providers and key labour force participants, this demographic forms the fundamental socioeconomic structure underlying modern societies. However, the dual pressures of financial provisions and occupational demands frequently correlate with excessive alcohol consumption, increasing the risk of developing ACM [20]. In terms of gender patterns, the ACM burden disproportionately affects males, reflecting their historically higher alcohol intake and sociocultural norms. However, converging consumption

patterns fuelled by progress in gender equality and female occupational stress are reducing this gap. Females are physiologically more vulnerable to ACM at equivalent exposure levels [21]. The projection analysis indicates that the gender gap in the burden of ACM will decrease and may even reverse between males and females in younger age groups over the next 15 years.

This analysis reveals the highest ACM burden in high–middle SDI regions and the lowest in low SDI regions in 2021. Economic development likely exacerbates excessive alcohol consumption in high–middle SDI areas and is compounded by inadequate attention to alcohol-related health issues, uneven medical resource distribution, and cultural norms that promote alcohol use [22]. Although low SDI regions demonstrate lower ACM burdens, this may reflect underdiagnosis due to limited healthcare infrastructure. Notably, low SDI regions experienced sharper ACM growth from 1990 to 2021, which was potentially driven by the expansion of the alcohol industry, poverty, poor sanitation, and increased health risks per alcohol unit consumed [23]. To effectively reduce the global burden of ACM, common but different initiatives should be adopted worldwide, such as universal community screening for early detection, alcohol regulation and health education in high SDI regions, and diagnostic capacity building, infrastructure upgrades, poverty reduction, and alcohol industry control in low SDI regions.

The results of this study reveal that Eastern European countries, including the Russian Federation, Ukraine, and Latvia, bear the highest global ACM burden, which is linked to entrenched drinking cultures marked by frequent irregular consumption of spirits. This stems from the historical prevalence of spirit production and consumption as social norms [24]. Over the past three decades, regional countries such as the Russian Federation have enacted strict alcohol control measures, including raising prices, restricting distribution, banning advertising, and penalizing drunk driving [25]. These policies have successfully reduced alcohol consumption and mortality rates and increased national life expectancy. Despite progress, the impacts of a persistent ACM burden underscore the need for stronger preventive policies [26].

This study has several limitations. First, the ACM risk burden estimates were constrained by incomplete and low-quality raw data, particularly from low-middle income countries with underdeveloped disease registries. Second, data limitations constrained the risk factor analysis of ACM to only alcohol intake and ambient temperature in the GBD 2021 study. Third, sparse data availability for less populated regions requires reliance on projections from neighbouring areas, which potentially decreases accuracy. Additionally, while ACM subtypes (congestive, hypertrophic, restrictive) exhibit distinct pathogenesis and prevalence patterns, the GBD 2021 study limitations preclude subtype-specific statistical differentiation. Lastly, although the GBD data were anonymized, reporting results for very small geographic areas may carry potential re-identification risks.

Conclusion

The health effects of alcohol are complex. Some studies indicate that moderate consumption may actually have benefits, whereas excessive drinking is clearly linked to significant risks [27]. This analysis revealed an increasing global burden of ACM in the working-age population, particularly in high–middle SDI regions and males. Delayed ACM diagnosis persists owing to its complex mechanisms and nonspecific clinical features, which highlights the urgent need for innovative diagnostic tools, therapeutic strategies such as biomarker identification and intervention model validation, and further clarification of alcohol dose–response relationships. Additionally, policymakers and health professionals must prioritize equitable health resource distribution and implement the WHO cooperation framework through coordinated policies, standardized technologies, integrated resources, and improved capacity building to mitigate the alcohol control paradox, especially in high–middle SDI regions.

Abbreviations

ACM	Alcoholic cardiomyopathy
SDI	Socio-demographic index
ASR	Age-standardized rate
GBD	Global Burden of Disease
EAPC	Estimated annual percentage changes
DALYs	Disability-adjusted life years
BAPC	Bayesian age-period-cohort
YLDs	Years lived with disability
YLLs	Years of life lost
ASPR	Age-standardized prevalence rate
ASDR	Age-standardized death rate
SI	Slope index
CIN	Concentration index
UI	Uncertainty interval
CI	Confidence interval
MR-BRT	Meta-Regression with Boosted Regression Trees
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41043-025-00920-4.

Supplementary Material 1

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Author contributions

YZ.P. and RJ.L. conceived the study, ZK.W., CY.W., BQ.Z. were responsible for data collection and data analysis and wrote the paper. H.S., WJ.L., Y.Y., Y.G., LF.P., LH.Z., SL.B., YH.L. reviewed and edited the manuscript. All authors have directly accessed and verified the underlying data reported in the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study used anonymized GBD 2021 data, which complies with the ethical guidelines of the database and established standards for health data sharing. All publicly available GBD data are processed to ensure participant confidentiality. To further protect privacy, contemporary methodologies such as the tiered sensitivity classification system are employed, emphasizing the balance between data accessibility and confidentiality in health research [28]. As this study involved secondary analysis of anonymized data, no additional ethics approval was required. Nevertheless, we adhered strictly to data security protocols throughout the study.

Consent for publication
This study utilized data from publicly available databases, which do not contain identifiable personal information. Therefore, consent for publication is not applicable.

Competing interests
The authors declare no competing interests.

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