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Original Article

Residual Hepatitis B Burden Despite Declining Rates Across 21 Middle East and North Africa Countries, 1990–2023: Age Patterns and a Case Study of Oman

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Abstract

Background and Aims: Across the Middle East and North Africa (MENA), the age-standardized rates (ASRs) of hepatitis B virus (HBV) burden may be declining while the absolute burden rises among middle-aged and older adults. In this study, we aimed to characterize changes in rates, counts, and age distribution across 21 MENA countries, with Oman as a case study. ***Methods:*** We analyzed Global Burden of Disease 2023 estimates for 1990–2023. Disability-adjusted life-years (DALYs) were used to measure the overall HBV-related burden, and acute hepatitis B incidence was examined as a secondary outcome. We compared population-weighted means of country ASRs with aggregated counts, assessed rate-count divergence, and summarized DALYs across four fixed age bands. ***Results:*** The population-weighted mean DALY ASR declined 53.0%, from 624.5 to 293.6 per 100,000 (estimated annual percentage change −2.28%; 95% confidence interval −2.34 to −2.23), while absolute DALYs increased 19.3%, from 1.18 to 1.41 million. Mean burden age increased in 20 countries, by up to 12.4 years, and the 0–34-year DALY share declined in 19 countries. In Oman, DALYs and acute-incidence ASRs declined 38.6% and 49.2%, while DALYs at ages 35–54 increased 2.55-fold and represented 43.3% of national HBV DALYs in 2023. ***Conclusions:*** HBV burden in MENA is shifting toward middle-aged and older adults while absolute DALYs rise despite declining ASRs. Service planning should consider counts and age distribution alongside rates, with sustained vaccination complemented by adult diagnosis, treatment, cirrhosis care, and hepatocellular carcinoma surveillance.

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Introduction

Hepatitis B virus (HBV) infection is a major cause of liver disease and premature death worldwide. In 2022, an estimated 254 million people were living with chronic HBV infection, with more than one million deaths attributed mainly to cirrhosis and hepatocellular carcinoma (HCC) annually.[1–3] Despite major advances in vaccination, HBV still accounts for a substantial share of global cirrhosis and HCC.[4–6] Due to

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the long natural history of chronic HBV infection, reductions in transmission may not lead to immediate reductions in the total disease burden, particularly in regions with large aging populations infected before vaccine introduction.[7–9] The Global Burden of Disease (GBD) 2019 hepatitis B analysis reported this pattern globally, with age-standardized death rates falling while death counts rose, attributed to population growth, aging, and cohort effects.[10]

The Middle East and North Africa (MENA) region is important for examining this epidemiological transition. Most MENA countries introduced universal infant HBV vaccination between the late 1980s and the early 2000s and have subsequently achieved high vaccine coverage. This has been accompanied by a marked decline in HBV prevalence among children.[11] However, these gains have occurred alongside rapid population growth, increasing life expectancy, and population aging.[12,13] Previous GBD analyses have shown that HBV age-standardized rates (ASRs) are declining globally even as absolute disease burden continues to rise because of demographic change. Despite this, little attention has been given to how the age distribution of the HBV burden has changed across the MENA region or how patterns differ between countries. Most studies have focused on overall burden trends, raising an important question about whether the burden is becoming less concentrated among younger age groups and more concentrated among middle-aged and older adults.

Therefore, we analyzed GBD 2023 estimates for 21 MENA countries from 1990 to 2023 to characterize changes in the age distribution of the HBV burden. We examined trends in age-standardized and age-specific incidence and disability-adjusted life-years (DALYs), assessed the divergence between rates and absolute burden, and explored age redistribution across countries. To further explore this dynamic, Oman was included as an embedded case study because its early introduction of HBV vaccination, changing population structure, and relatively high health-system capacity provide a useful setting for examining the coexistence of declining ASRs and persistent adult-centred absolute burden.

Methods

Data source and study design

A longitudinal ecological analysis was conducted using publicly available estimates from the GBD 2023 study retrieved from the Global Health Data Exchange (GHDx) query tool.[14] The GBD framework provides internally comparable estimates of incidence, mortality, and DALYs across countries, age groups, and time periods using standardized modeling methods. Detailed descriptions of the GBD analytical framework have been previously published.[15] This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[16]

This study covered the period from 1990 to 2023 and was restricted to countries within the MENA region, as defined by the GBD framework. These countries included Afghanistan, Algeria, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, the United Arab Emirates, and Yemen. The regional analysis described trends across all included countries, whereas the embedded Oman case study examined country-specific changes in rates, absolute burden, and age distribution. All analyses were performed using the combined data for both sexes to reflect the overall population-level burden.

In line with the GBD cause hierarchy, burden analyses were restricted to the cause category "total burden related to hepatitis B" with DALYs used as the primary measure of total health loss attributable to HBV, including cirrhosis and HCC.[10,15] Incidence analyses were restricted to the cause category "acute hepatitis B" and were interpreted as modeled estimates rather than observed case counts. Acute hepatitis B incidence was examined as a secondary indicator, and age-specific counts and population denominators were obtained for all standard five-year GBD age groups.

Further analyses separately assessed years of life lost (YLLs) and years lived with disability (YLDs). We also evaluated DALYs for the GBD categories "Chronic hepatitis B including cirrhosis" and "Liver cancer due to hepatitis B".

The study was performed in accordance with the Declaration of Helsinki (as revised in 2024). Ethical approval and informed consent were not required because this study used publicly available, aggregate estimates from the GBD study and involved no individual-level data.

Age group classification

Age-specific estimates were summarized into four fixed age bands, including 0–34, 35–54, 55–64, and ≥65 years. These categories were used descriptively to characterize the changing age distribution of burden and should not be interpreted as birth cohorts, vaccination-eligibility groups, or indicators of individual vaccination status because the fixed age bands contain different birth generations in each calendar year and cannot track the same cohort across the time series. Band boundaries were chosen to separate the age range over which chronic HBV sequelae typically emerge. A sensitivity analysis in which all age-band cut-points were shifted upward by five years is presented in Supplementary Table 1. The composition of the fixed age bands in relation to the years of national vaccination introduction is described in Supplementary Tables 2 and 3.

Dependence of GBD hepatitis B estimates on vaccination coverage

The published GBD hepatitis B modeling framework estimated counterfactual hepatitis B surface antigen seroprevalence in the absence of vaccination, applied three-dose hepatitis B vaccine coverage and assumed vaccine efficacy, and then derived the reported estimates; acute hepatitis B incidence was subsequently derived using age-specific probabilities of chronic infection.[10] The GBD 2023 data available for this study included final age-specific estimates, but not counterfactual estimates, vaccination-adjustment components, underlying serosurvey data, or draw-level outputs. Consequently, the contribution of vaccination could not be estimated independently. Therefore, age bands were interpreted descriptively rather than as vaccination cohorts, and acute incidence was not interpreted as a direct measure of observed transmission. The available aggregate estimates did not include individual-level information on metabolic comorbidity, hepatitis D virus coinfection, socioeconomic conditions, healthcare access, nationality, or migration status; therefore, these factors could not be incorporated into the analysis.

Statistical analysis

The analysis proceeded in three stages: first, regional and national DALY and incidence trends were described over time; second, rate-based and count-based indicators were compared to distinguish changes in risk from changes in population size and age structure; and third, age-specific burden

patterns were examined to assess shifts in the distribution of HBV-related health loss.

Regional ASRs were summarized as population-weighted means of country-level ASRs. This measure summarises national rates while giving greater weight to countries with larger populations, but it is not equivalent to the direct standardization of pooled regional age-specific rates. It is therefore referred to as the population-weighted mean of the country's ASRs. Absolute DALY and incidence counts were aggregated across countries to quantify the total burden across the MENA region. To facilitate a direct visual comparison between rate-based indicators and absolute measures, the selected time series were indexed to the baseline year 1990, which was set to 100.

The estimated annual percentage change (EAPC) was derived by regressing the natural logarithm of the rate on the calendar year, with 95% confidence intervals obtained from the regression slope.[17] These intervals reflect the fit of the log-linear model to the GBD point estimates only; they do not incorporate the uncertainty of the underlying GBD estimates and are therefore narrower than the true uncertainty in these quantities.

Continuous piecewise log-linear joinpoint regression was used to identify variations in the trends of the total HBV DALY and acute HBV incidence ASR in the MENA region and Oman from 1990 to 2023. Models with zero to three joinpoints, each with a minimum of five calendar years per segment, were evaluated using the Bayesian information criterion. The stability of the selection was assessed through a moving block bootstrap with 499 replicates, recording the proportion of replicates that selected the same number of joinpoints. A sensitivity analysis was performed, allowing for up to four joinpoints.

To examine the divergence between rates and counts, an approximate log-scale accounting analysis related the EAPC of the absolute count series to the EAPC of the corresponding ASR and the EAPC of the total regional population. The remaining difference after accounting for rate change and population growth was interpreted as an approximate age-structure component. This represents an accounting relationship rather than a formal Das Gupta or Kitagawa decomposition. Because the residual was obtained by subtraction rather than direct estimation, it may also absorb differences that are not captured by the rate and population terms.

For the age-structure analysis, DALYs were categorized into four predefined fixed age bands and expressed as proportional shares of total HBV DALYs within each country-year and regional-year series. The burden-weighted mean age of HBV DALYs was calculated by multiplying each age group's midpoint by its corresponding DALY count, summing these products, and dividing by the total DALYs; the open-ended ≥95-year group was assigned a midpoint of 97 years. The median and 75th percentile of the burden age distribution were obtained from the cumulative distribution of DALYs across five-year age groups, with linear interpolation within the age group containing the percentile. For the embedded Oman case study, temporal changes in ASRs, absolute counts, age-band shares, and burden-weighted mean age were evaluated.

We summarized YLL and YLD counts, shares of total HBV DALYs, and burden-weighted mean ages for the MENA region and Oman for 1990 and 2023. For the two GBD outcome categories, comparisons were made across all 21 countries regarding DALY counts, shares of total HBV DALYs, burden-weighted mean ages, and annual ASR trends. The shares were calculated using the total HBV DALYs for the respective country or region and year.

All statistical analyses were conducted using R programming version 4.6.0.[18] Ethical approval and informed consent were not required because this study used publicly available, aggregate estimates from the GBD study and involved no individual-level data.

Results

Regional decline in age-standardized HBV burden with divergence between rates and absolute burden

Between 1990 and 2023, the population-weighted mean of country-level HBV DALY ASRs in MENA declined from 624.5 to 293.6 per 100,000 people, a 53.0% reduction. The EAPC was −2.28% per year (95% CI −2.34 to −2.23). The decline was progressive across the study period, with rates reaching 554.2 per 100,000 in 1995, 488.4 in 2000, 390.6 in 2010, and 304.4 in 2020 before reaching 293.6 in 2023 (Table 1). The age-standardized incidence rate also declined, although less steeply than the DALY ASR, with an EAPC of −1.48% per year (95% CI −1.56 to −1.39).

The DALY ASRs declined across all 21 countries, although the magnitude of the reduction varied substantially (Table 2). The largest relative reductions were observed in Qatar (−77.4%), the United Arab Emirates (−70.8%), and Jordan (−70.4%). The smallest reductions were observed in Oman (−38.6%), Afghanistan (−31.7%), and Iraq (−24.6%).

These reductions in rates were not accompanied by corresponding reductions in the absolute burden. Indexed to the 1990 baseline, the DALY and acute incidence ASRs reached values of 47 and 62, respectively, in 2023 (Fig. 1). In contrast, the corresponding absolute count indices remained above their 1990 levels, reaching 119 for DALYs and 121 for acute incidence. The total HBV DALYs increased from 1,177,440 in 1990 to 1,405,236 in 2023, an increase of 19.3%, whereas the acute hepatitis B incidence increased from 4,540,194 to 5,479,089 cases, an increase of 20.7%. The divergence between the rates and absolute counts widened after 2000 and remained pronounced until 2023.

Components of the divergence between rates and absolute counts

The total MENA population grew at an EAPC of +1.95% per year (95% CI +1.91 to +2.00) across the study period. For HBV DALYs, the count EAPC was +0.47% per year (95% CI +0.41 to +0.53), compared with a rate EAPC of −2.28% per year, giving a difference of +2.75 percentage points per year. The accounting analysis suggested that population growth accounted for +1.95 points of this difference, leaving a residual of +0.80 points per year consistent with an age-structure component.

For acute hepatitis B incidence, the count EAPC was +0.51% per year (95% CI +0.37 to +0.65) compared with a rate EAPC of −1.48% per year, giving a difference of +1.99 percentage points per year. Population growth accounted for +1.95 points of this difference, leaving a residual of +0.03 points per year consistent with an age-structure component.

Age redistribution of the HBV-attributable burden in the MENA region

The age distribution of HBV-attributable DALYs in the MENA region changed substantially between 1990 and 2023 (Figs. 2 and 3; Supplementary Table 4). The proportional contribution of the 0–34-year age band declined in 19 of the 21 countries examined. This pattern was observed even when the absolute change was relatively modest, such as in Iraq, where the share decreased from 18.3% to 15.1%. The larg-

Table 1. Regional hepatitis B trends in MENA, 1990–2023

Year	HBV DALYs				Acute HBV Incidence			
	ASR	Δ *vs.* 1990	Absolute	Δ *vs.* 1990	ASR	Δ *vs.* 1990	Absolute	Δ *vs.* 1990
1990	624.5	0.0%	1,177,440	0.0%	1,447.2	0.0%	4,540,194	0.0%
1995	554.2	−11.3%	1,192,326	+1.3%	1,390.4	−3.9%	4,964,319	+9.3%
2000	488.4	−21.8%	1,193,121	+1.3%	1,329.9	−8.1%	5,317,954	+17.1%
2005	443.6	−29.0%	1,229,745	+4.4%	1,241.1	−14.2%	5,498,745	+21.1%
2010	390.6	−37.5%	1,251,566	+6.3%	1,150.7	−20.5%	5,681,900	+25.1%
2015	364.0	−41.7%	1,347,654	+14.5%	1,050.8	−27.4%	5,617,257	+23.7%
2020	304.4	−51.3%	1,308,819	+11.2%	942.6	−34.9%	5,463,207	+20.3%
2023	293.6	−53.0%	1,405,236	+19.3%	895.7	−38.1%	5,479,089	+20.7%
EAPC	−2.28% per year		+0.47% per year		−1.48% per year		+0.51% per year	
95% CI	−2.34 to −2.23		+0.41 to +0.53		−1.56 to −1.39		+0.37 to +0.65	
R^2	0.995		–		0.974		–	

ASR represents the population-weighted mean of country-level ASRs across the 21 MENA countries; absolute counts represent the sum across the same countries. The Δ *vs.* 1990 columns show the cumulative percentage change in the adjacent measure relative to its 1990 value. EAPCs were estimated separately for each age-standardized rate and absolute-count series by log-linear regression of the natural logarithm of the corresponding measure on calendar year from 1990 to 2023. EAPC was calculated as 100 × (exp(β) − 1), with 95% confidence intervals derived from the regression slope. R^2 values are reported for the age-standardized rate models only. ASR, age-standardized rate per 100,000; DALYs, disability-adjusted life-years; EAPC, estimated annual percentage change; HBV, hepatitis B virus; CI, confidence interval; R^2, coefficient of determination.

est reduction occurred in Yemen, where the contribution of the 0–34-year age group fell from 38.4% to 16.8%, followed by Sudan, where it declined from 37.6% to 17.0%. Lebanon and Afghanistan were exceptions to this regional pattern. In Lebanon, the proportional share remained essentially unchanged, increasing slightly from 5.6% to 5.7%, whereas in

Table 2. Country-level HBV DALY ASR, 1990 *vs.* 2023 with percentage change

Country	ASR 1990 (95% UI)	ASR 2023 (95% UI)	% Change	Rank
Qatar	500.6 (349.2–659.0)	113.1 (87.7–147.3)	−77.4%	1
United Arab Emirates	406.4 (246.4–597.2)	118.6 (85.4–156.9)	−70.8%	2
Jordan	279.2 (184.3–383.4)	82.6 (64.2–108.0)	−70.4%	3
Kuwait	137.5 (105.4–169.4)	46.2 (35.0–56.5)	−66.4%	4
Saudi Arabia	394.1 (288.9–523.9)	146.4 (112.0–190.9)	−62.8%	5
Iran	298.7 (212.9–400.8)	113.4 (89.8–145.1)	−62.0%	6
Yemen	829.9 (491.2–1,265.4)	318.2 (195.5–446.6)	−61.7%	7
Bahrain	434.3 (322.3–561.5)	169.5 (127.7–227.9)	−61.0%	8
Tunisia	284.8 (184.0–396.4)	118.5 (88.7–158.1)	−58.4%	9
Egypt	1,858.4 (1,427.8–2,381.7)	791.5 (602.8–1,053.1)	−57.4%	10
Palestine	316.3 (219.3–439.8)	138.5 (107.3–178.4)	−56.2%	11
Libya	436.3 (310.4–625.1)	194.3 (136.2–264.8)	−55.5%	12
Turkey	297.2 (200.2–426.6)	143.7 (112.7–177.8)	−51.7%	13
Sudan	842.0 (524.9–1,237.1)	410.3 (253.1–576.9)	−51.3%	14
Lebanon	279.7 (169.6–447.6)	152.7 (115.5–196.3)	−45.4%	15
Algeria	354.8 (228.8–502.5)	194.6 (125.4–267.9)	−45.2%	16
Syria	317.5 (228.8–423.5)	175.7 (123.3–233.1)	−44.6%	17
Morocco	395.1 (257.2–569.6)	235.1 (169.2–320.5)	−40.5%	18
Oman	350.1 (235.2–471.2)	215.0 (159.4–294.8)	−38.6%	19
Afghanistan	242.7 (160.7–351.5)	165.7 (117.4–230.0)	−31.7%	20
Iraq	338.8 (236.8–453.0)	255.3 (188.0–326.2)	−24.6%	21

The rates are per 100,000 people. Countries were ranked by percentage reduction in the DALY ASR between 1990 and 2023. ASR, age-standardized rate; DALYs, disability-adjusted life-years; HBV, hepatitis B virus; UI, 95% uncertainty interval.

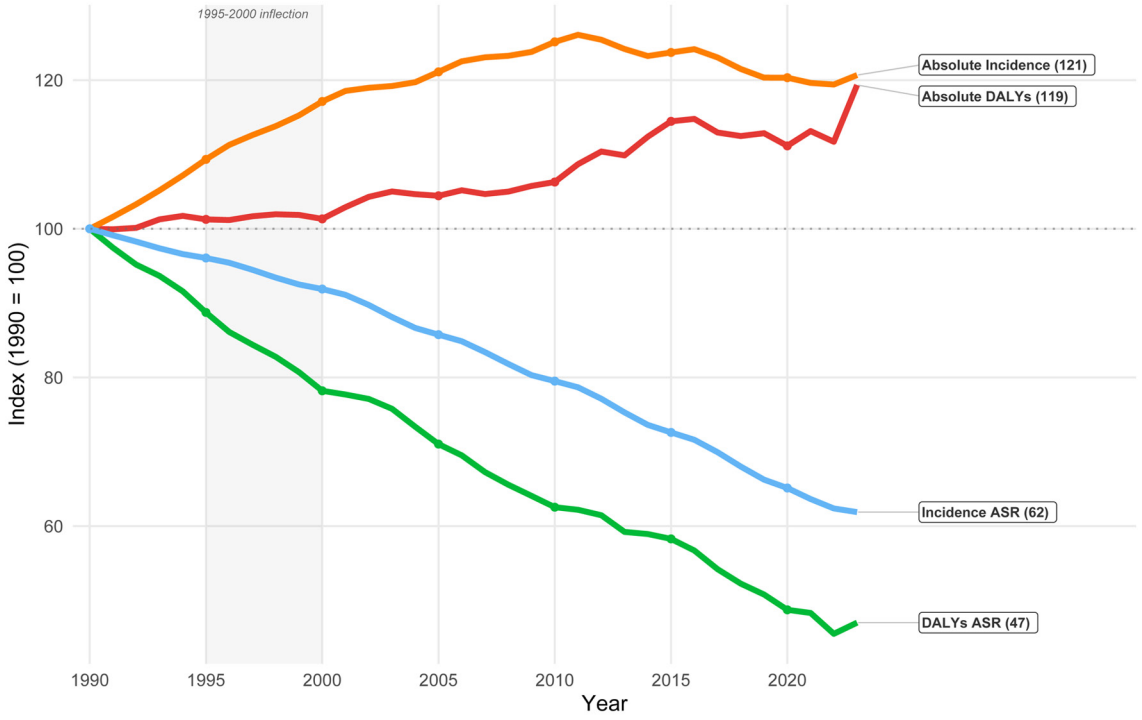


Fig. 1. Diverging indexed trends in absolute counts and age-standardized rates of HBV-related DALYs and acute hepatitis B incidence across 21 MENA countries, 1990–2023. All series were indexed to their corresponding 1990 values set to 100. Absolute counts represent the sum of country-level estimates across the 21 MENA countries. Regional rate series represent population-weighted means of country-level age-standardized rates and are not equivalent to directly standardized pooled regional rates. Acute hepatitis B incidence represents GBD-modeled estimates rather than observed notified cases. Indexed values show relative changes within each measure and should not be used to compare the absolute magnitudes of DALYs and incidence. Lines represent point estimates; uncertainty intervals for the underlying GBD estimates are not displayed. ASR, age-standardized rate; DALYs, disability-adjusted life-years; HBV, hepatitis B virus; GBD, Global Burden of Disease; MENA, Middle East and North Africa.

Afghanistan, it increased from 7.8% to 20.1%.

The burden-weighted mean age of HBV-attributable DALYs increased in 20 of the 21 countries, although the magnitude of the change varied substantially (Fig. 3). Yemen showed the largest increase, rising by 12.4 years from 39.4 to 51.8 years, followed by Sudan, with an increase of 11.6 years from 41.7 to 53.2 years, and Iran, with an increase of 10.3 years. Syria, Algeria, and Kuwait showed intermediate shifts with increases of 5.6, 5.1, and 4.2 years, respectively. In contrast, Lebanon, Qatar, and Oman showed the smallest changes, with increases of 0.3, 0.7, and 0.7 years, respectively. Afghanistan was the only country in which the burden-weighted mean age decreased, falling by 8.2 years from 55.3 to 47.1 years.

Oman embedded case study

Trends in age-standardized and absolute burden: The age-standardized DALY rate attributable to HBV in Oman decreased from 350.1 per 100,000 population in 1990 to 215.0 per 100,000 in 2023, representing a 38.6% relative reduction over the study period (Table 3). The age-standardized acute hepatitis B incidence rate declined more sharply, falling from 1,180.6 to 599.4 per 100,000, corresponding to a 49.2% reduction.

In contrast to the declining rate-based measures, the absolute DALYs and acute incident case estimates were higher in 2023 than in 1990 (Fig. 4). The indexed analysis therefore showed a divergence between declining ASRs and increasing absolute burden over the study period.

Age-specific incidence and DALYs: The absolute acute HBV incidence among people aged 0–34 years declined from 14,778 cases in 1990 to 2,497 in 2023, representing an 83.1% reduction. In contrast, the incidence among people aged 35–54 years increased from 5,747 to 26,390 cases, equivalent to a 4.59-fold increase. Incidence among those aged 55–64 years increased from 700 to 2,926 cases, a 4.18-fold increase, while incidence among those aged ≥65 years rose from 486 to 1,390 cases, a 2.86-fold increase (Supplementary Fig. 1).

Despite the 83.1% decline in acute incidence among people aged 0–34 years, DALYs in this age group increased from 415 in 1990 to 614 in 2023, representing a 1.48-fold increase. DALYs also increased in all three older age groups. The largest absolute increase occurred among people aged 35–54 years, for whom DALYs rose from 1,093 to 2,790, equivalent to a 2.55-fold increase. DALYs among people aged 55–64 years increased from 721 to 1,468, a 2.04-fold increase, while those among people aged ≥65 years rose from 757 to 1,571, a 2.08-fold increase. By 2023, the 35–54-year age group accounted for 43.3% of Oman's total HBV DALY burden (Supplementary Table 5).

Burden-weighted mean age: The burden-weighted mean age of the HBV DALYs in Oman followed a two-phase pattern during the study period (Fig. 5). It initially increased from 52.8 years in 1990 to a peak of 54.7 years in 2010, before declining to 53.6 years in 2023. Over the full study period, this represented a net increase of 0.7 years based on the unrounded estimates. The distributional percentiles followed a different pattern: the median age of the burden distribution remained at 52 years in both 1990 and 2023, whereas the 75th percentile declined from 67 to 62 years.

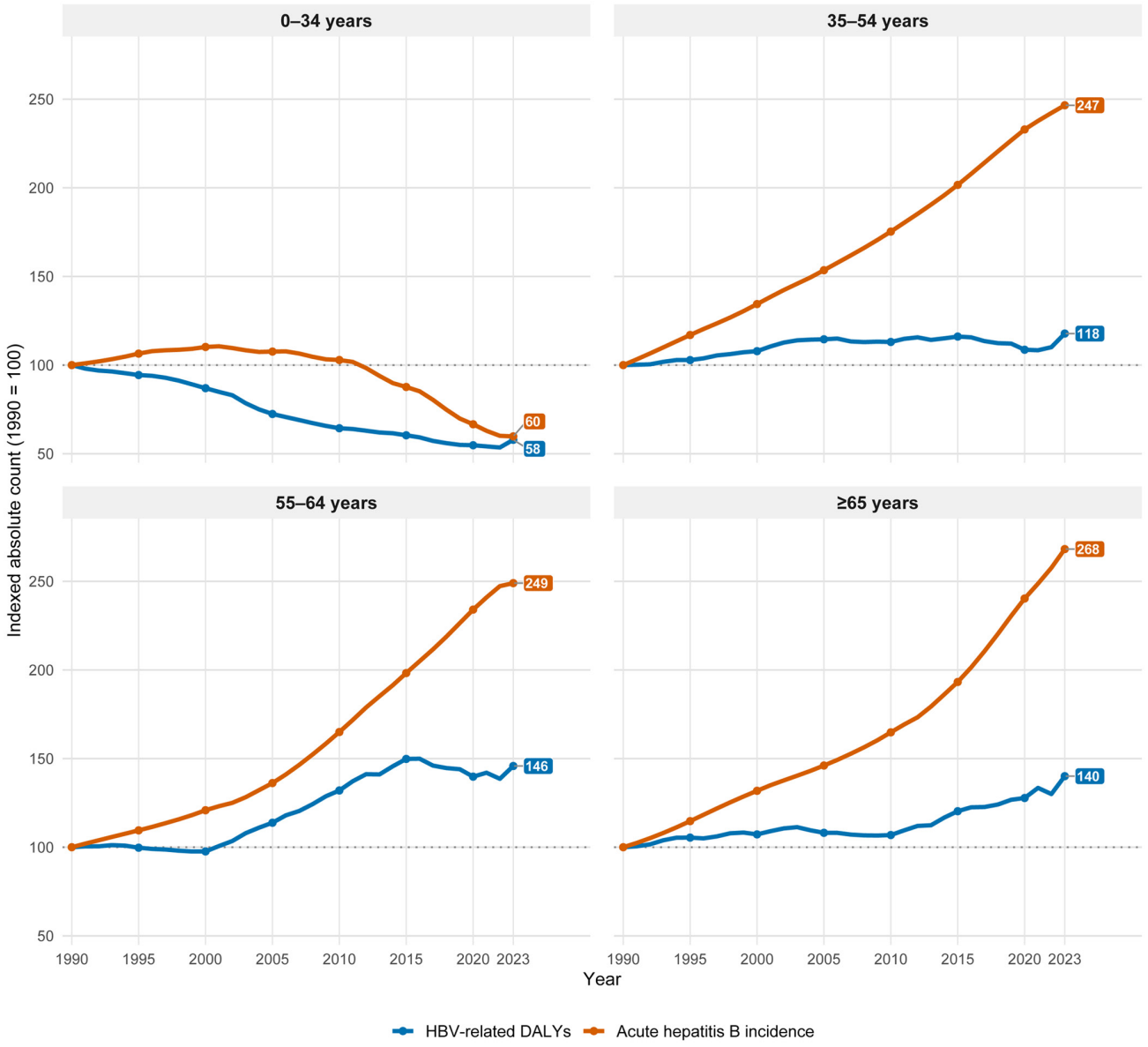


Fig. 2. Indexed changes in absolute HBV-related DALYs and acute hepatitis B incidence by fixed age band across 21 MENA countries, 1990–2023. Absolute estimates were aggregated across the 21 countries and indexed to their corresponding 1990 values, which were set to 100. The fixed age bands are descriptive and do not represent birth cohorts or vaccination eligibility groups. Acute hepatitis B incidence represents GBD-modeled estimates rather than observed notified cases. Indexed trajectories show the relative changes within each measure and do not compare their absolute magnitudes. DALYs, disability-adjusted life-years; GBD, Global Burden of Disease; HBV, hepatitis B virus; MENA, Middle East and North Africa.

YLLs and YLDs

YLLs and YLDs accounted for 97.3% and 2.7% of regional HBV DALYs in 2023, respectively. Between 1990 and 2023, the average age of burden increased from 51.7 to 57.2 years for YLLs and from 47.9 to 52.7 years for YLDs. Specifically, in Oman, these increments were 0.6 years for YLLs and 5.4 years for YLDs, as presented in Supplementary Table 6.

Chronic HBV and liver cancer burden across countries

The regional DALYs increased by 17.5% for "Chronic hepatitis B including cirrhosis" and by 130.3% for "Liver cancer due to hepatitis B". Despite these increases, their ASRs declined by 55.6% and 14.3%, respectively. The proportion of liver cancer due to hepatitis B contributing to total HBV DALYs increased from 10.8% to 20.9%. ASRs for chronic hepatitis B including cirrhosis decreased across all 21 countries, whereas ASRs for liver cancer due to hepatitis B increased in Algeria, Iraq, Lebanon, Morocco, and Tunisia. In Oman, the mean age of burden for chronic hepatitis B including cirrhosis increased from 54.2 to 55.5 years, whereas for liver cancer due to hepatitis B, it decreased from 51.9 to 51.4 years (Supplementary Table 7A and B; Supplementary Fig. 2).

Joinpoint analysis

For the regional DALY ASR, the model identified a joinpoint in 2016, indicating a more rapid proportional decline from

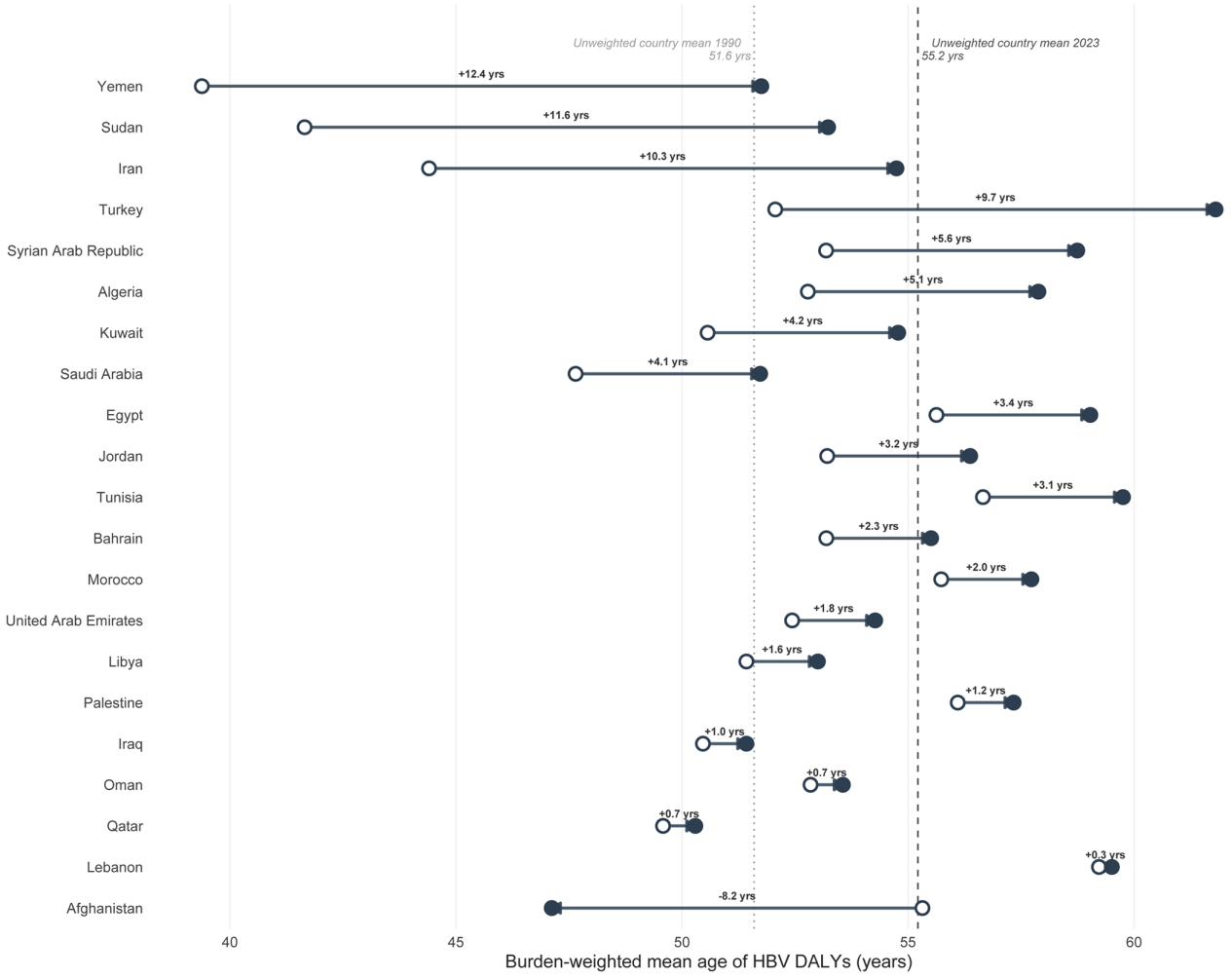


Fig. 3. Shift in burden-weighted mean age of HBV DALYs in MENA region countries, 1990–2023. Open circles represent 1990, and filled circles represent 2023. The connecting arrows show the direction of change, with labels reporting the difference in years between the two time points. The burden-weighted mean age was calculated by multiplying the midpoint of each five-year age group by its corresponding DALY count, summing these values, and dividing by total DALYs; the open-ended ≥95-year group was assigned a midpoint of 97 years. Vertical reference lines represent the unweighted mean of the 21 country-specific burden-weighted mean ages in 1990 and 2023, which are not weighted by population or burden. Values are based on GBD point estimates, and uncertainty intervals are not displayed. DALYs, disability-adjusted life-years; HBV, hepatitis B virus; MENA, Middle East and North Africa.

2016 to 2023 compared to the period from 1990 to 2016. Regarding regional acute HBV incidence ASRs, the model identified joinpoints in 2001 and 2012, with each segment demonstrating progressively faster declines. In Oman, the DALY ASR model identified joinpoints in 1995, 2006, and 2011, with minimal change observed between 2006 and 2011. The

Table 3. Oman HBV burden indicators with regional comparison

Indicator	1990	2023	Change
MENA DALYs ASR, population-weighted mean (per 100,000)	624.5	293.6	−53.0%
Oman DALYs ASR, total HBV (per 100,000)	350.1	215.0	−38.6%
Oman acute HBV incidence ASR (per 100,000)	1,180.6	599.4	−49.2%
Oman burden-weighted mean age (years)	52.8	53.6	+0.7 years
Oman 75th percentile of burden distribution (years)	67	62	−5 years
Oman DALY share, 35–54-year band	36.6%	43.3%	+6.7 pp
Oman DALY share, 0–34-year band	13.9%	9.5%	−4.4 pp

The regional ASR is the population-weighted mean of 21 country ASRs. The change in the burden-weighted mean age was calculated using unrounded estimates; therefore, it may differ slightly from the difference between the displayed values. ASR, age-standardized rate; DALYs, disability-adjusted life-years; HBV, hepatitis B virus; MENA, Middle East and North Africa; pp, percentage points.

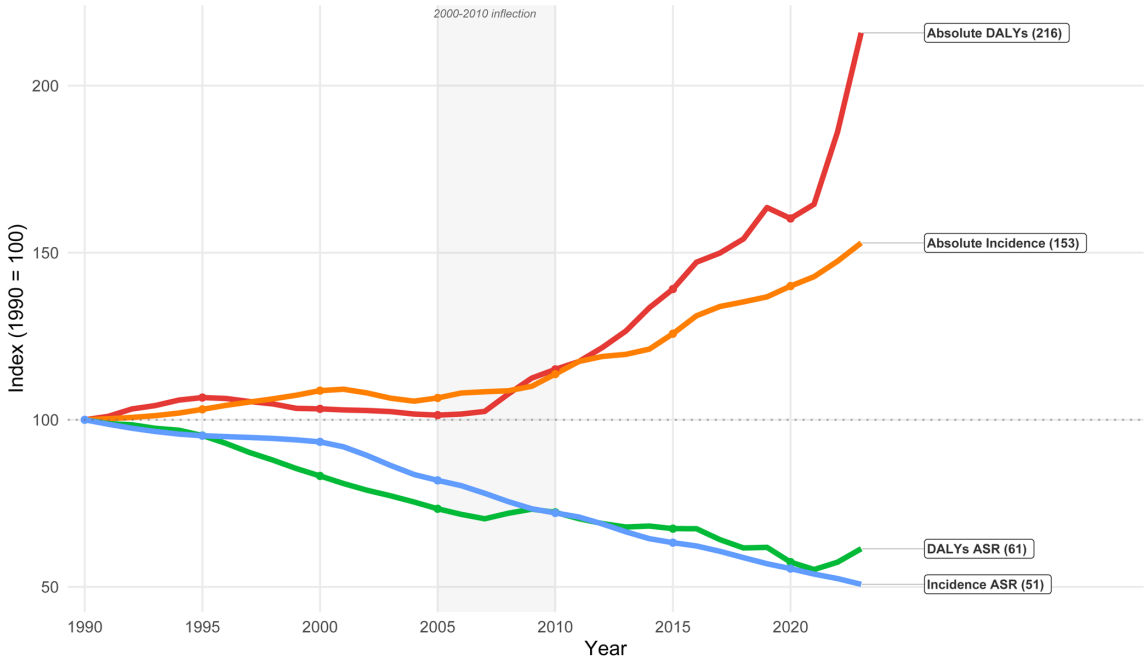


Fig. 4. Diverging indexed trends in absolute counts and ASRs of HBV-related DALYs and acute hepatitis B incidence in Oman, 1990–2023. All series were indexed to their corresponding 1990 values set to 100. The absolute series represent GBD-estimated DALY and acute hepatitis B incidence counts for Oman. Indexed values show relative changes within each measure and should not be used to compare the absolute magnitudes of DALYs and incidence. Acute hepatitis B incidence represents GBD-modeled estimates rather than observed notified cases. Lines represent point estimates; uncertainty intervals for the underlying GBD estimates are not displayed. ASR, age-standardized rate; DALYs, disability-adjusted life-years; HBV, hepatitis B virus.

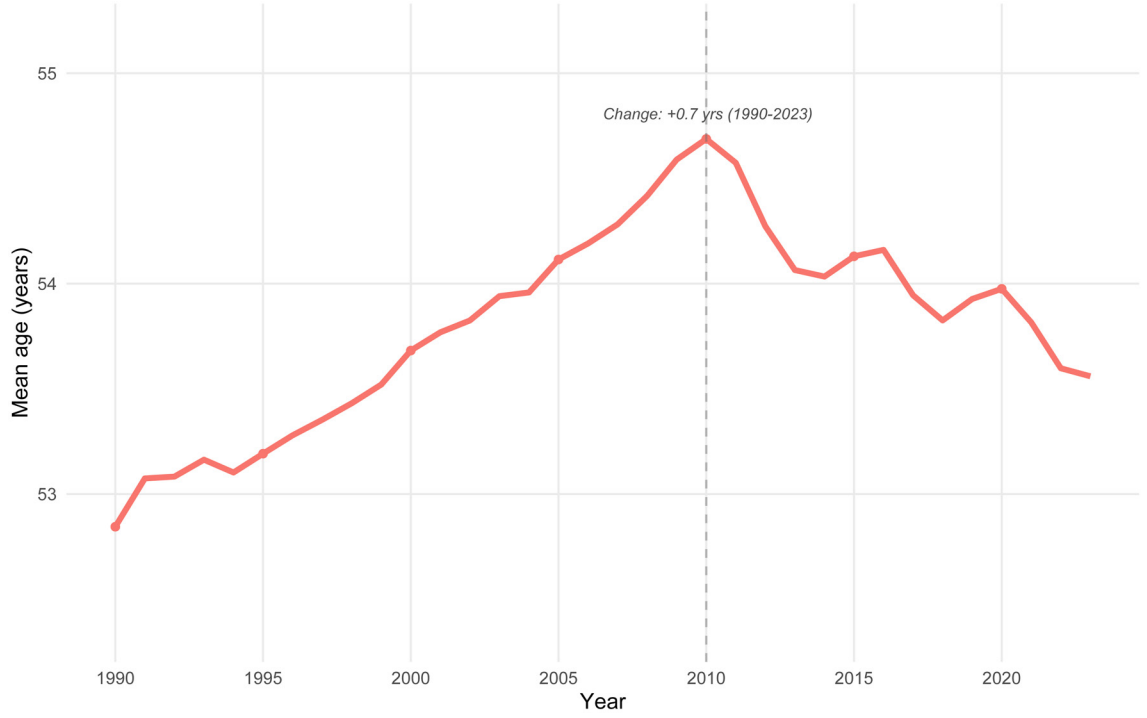


Fig. 5. Burden-weighted mean age of HBV-related DALYs in Oman, 1990–2023. Note: The burden-weighted mean age was calculated annually by multiplying the midpoint of each five-year age group by its corresponding DALY count, summing these values, and dividing by total HBV-related DALYs; the open-ended ≥95-year age group was assigned a midpoint of 97 years. The dashed line marks 2010, when the highest burden-weighted mean age was observed. The reported net change of +0.7 years between 1990 and 2023 was calculated from unrounded estimates and may differ slightly from the difference between displayed rounded values. The annual values are repeated cross-sectional GBD estimates and do not track the same individuals or birth cohorts over time. Values represent point estimates, and uncertainty intervals are not displayed. DALYs, disability-adjusted life-years; HBV, hepatitis B virus.

acute HBV incidence model for Oman identified joinpoints in 1995, 2000, and 2018, with declines noted in all four fitted segments. Both models for Oman selected the maximum of three joinpoints; allowing four joinpoints resulted in the same selected fits. The fitted trends and selected joinpoints are illustrated in Supplementary Figure 3.

Discussion

Across 21 MENA countries, the hepatitis B burden was redistributed toward middle-aged and older adults between 1990 and 2023. The share of DALYs among people aged 0–34 years declined in 19 countries, while the burden-weighted mean age increased in 20. The magnitude of this redistribution was generally greater in countries where the burden was concentrated at younger ages in 1990, showing substantial between-country heterogeneity in the magnitude of change.

Alongside this age redistribution, the population-weighted mean of country DALY ASRs declined by 53.0%, whereas the absolute DALYs increased by 19.3%. The approximate accounting analysis suggested that population growth accounted for most of the divergence between the rate and count trajectories, with a smaller residual interpreted as an approximate age-structure component. For acute hepatitis B incidence, the near-zero residual indicated that within this accounting framework, the difference between count and ASR trajectories was almost entirely accounted for by population growth. This finding should be interpreted cautiously because GBD acute hepatitis B incidence is derived from chronic HBV incidence using age-specific probabilities of progression to chronic infection.[10]

Oman illustrates the practical importance of considering the absolute burden alongside rate trends. Its DALY and acute hepatitis B incidence ASRs declined by 38.6% and 49.2%, respectively. Acute HBV incidence counts among people aged 0–34 years also declined by 83.1%. Nevertheless, the absolute incidence increased 4.59-fold among those aged 35–54 years, 4.18-fold among those aged 55–64 years, and 2.86-fold among those aged ≥65 years. Absolute DALYs increased across all four age groups, with the largest increase among those aged 35–54 years, from 1,093 to 2,790 DALYs, or 2.55-fold. By 2023, this age group accounted for 43.3% of Oman's total HBV DALY burden. These increases are relevant to service planning but should not be interpreted as evidence of increasing transmission, because absolute counts are influenced by population growth and changes in the composition of Oman's resident population, including labor migration.

These findings represent the regional expression of a pattern previously reported globally in the GBD 2019 hepatitis B analysis, in which declining ASRs coexisted with rising absolute burden amid population growth and aging.[10] The contribution of the present analysis is to characterize the age redistribution of HBV burden across MENA, document its considerable between-country heterogeneity, relate the divergence between rates and counts to demographic change, and describe its implications through an Oman case study. Therefore, regional rate trends alone are an incomplete guide for service demand. Planning for adult HBV testing, antiviral treatment, cirrhosis care, and guideline-based HCC surveillance among eligible high-risk patients should consider both absolute burden and its age distribution.

Residual health loss due to HBV was predominantly mortality-related, accompanied by age redistribution in both YLLs and YLDs. The rising impact of HBV-related liver cancer and the varying trajectories across countries underscore the necessity of integrating antiviral treatment and surveillance with advanced liver disease management and suitable palliative care.

In MENA, the age distribution of HBV-attributable DALYs shifted progressively toward adults aged 35 years and older, while the contribution from the 0–34-year age group declined in nearly all countries. This pattern is consistent with the long natural history of chronic HBV infection: infant immunization reduces early life transmission, while infections acquired earlier in life may progress to chronic hepatitis, cirrhosis, and HCC decades later.[19–24]

The magnitude of the country-level shift was highly heterogeneous and appeared partly related to each country's baseline age distribution of burden. The largest increases in burden-weighted mean age occurred in Yemen, Sudan, and Iran, rising by 12.4, 11.6, and 10.3 years, respectively. In 1990, the proportion of DALYs concentrated among people aged 0–34 years was comparatively high in these countries, accounting for 38.4% of total DALYs in Yemen, 37.6% in Sudan, and 30.8% in Iran. Countries with a greater initial concentration of burden at younger ages, therefore, had more scope for subsequent upward age redistribution. Studies from Yemen, Iran, and Saudi Arabia provide a broader context regarding the expansion of hepatitis B vaccination, variations in coverage and immune response, and declining HBV carriage among younger populations.[25–30] The increasing concentration of DALYs among middle-aged and older adults is clinically important because major complications of chronic HBV infection, including cirrhosis and HCC, commonly emerge after prolonged infection.[19,31] Nevertheless, the present analysis uses repeated cross-sectional estimates and does not follow the same birth cohorts over time; therefore, it cannot establish vaccination history as the cause of the observed age redistribution. As described in the Methods section, vaccination effects could not be estimated independently from the available GBD outputs. Therefore, the observed age patterns should not be interpreted as evidence of vaccination impact.

At the other end of the spectrum, Lebanon showed essentially no change in burden-weighted mean age (+0.3 years), consistent with an already older 1990 burden distribution, with a mean age of 59.2 years and therefore little room for further upward shift. This is reflected in the 0–34-year group, which accounted for only 5.6% of DALYs in 1990, a share that remained essentially unchanged in 2023 (5.7%). Qatar and Oman also showed small shifts (+0.7 years each), though from younger and more intermediate 1990 burden profiles with mean ages of 49.6 and 52.8 years, respectively. Afghanistan was the sole country with a distinct shift toward a younger HBV DALY burden, specifically an 8.2-year decrease in the burden-weighted mean age and an increase in the share of the 0–34-year group from 7.8% to 20.1%. Sudan and Yemen did not show rejuvenation, but both retained comparatively high younger age-group shares in 2023 at 17.0% and 16.8%, respectively, despite large declines from their 1990 levels.

The age redistribution observed across most of the MENA region is consistent with patterns reported in East Asia.[32,33] In Taiwan, China, as well as on the Chinese mainland, substantial reductions in HBV transmission and age-standardized disease burden among younger generations have been accompanied by a growing concentration of HBV-related morbidity and mortality among older adults. Similar to the present findings, declines in ASRs have not always translated into proportional reductions in the absolute burden of advanced liver disease, which is consistent with the long natural history of chronic HBV infection and the demographic effects of population growth and aging.

These dynamic contrasts highlight the heterogeneity of

HBV transition across the MENA region. While the burden-weighted mean age effectively captures one critical aspect of population-level age redistribution, national priorities should also consider the baseline age structure and burden magnitude among both younger and older age groups.

Oman provides a national example of the divergence between declining age-standardized rates and changing absolute burden. Between 1990 and 2023, the age-standardized acute hepatitis B incidence rate declined by 49.2%. Over the same period, absolute acute HBV incidence counts among people aged 0–34 years declined by 83.1%, whereas incidence increased 4.59-fold among those aged 35–54 years. DALYs also increased 2.55-fold in the 35–54-year age group and rose across both older age groups. By 2023, people aged 35–54 years accounted for 43.3% of Oman's total HBV DALY burden. The opposing incidence and DALY trajectories are not necessarily inconsistent because acute incidence and DALYs measure different aspects of the disease. DALYs include cumulative health loss associated with chronic HBV sequelae rather than acute incident infection alone.

This mid-adult concentration helps explain the constrained movement in Oman's burden-weighted mean age over time. Although absolute DALYs were higher in 2023 than in 1990 across all age groups, the largest absolute increase occurred among those aged 35–54 years. That increase (1,697 DALYs) exceeded the combined increase in the 55–64-year and ≥65-year groups (1,561 DALYs), producing a relative reconcentration of burden within middle adulthood rather than a uniform shift toward the oldest age groups.

Oman introduced the hepatitis B vaccination nationally in 1990 and has subsequently expanded HBV prevention, screening, and clinical services.[34–37] This context is relevant for interpreting the changing age distribution; however, the present repeated cross-sectional analysis does not track individuals or birth cohorts, and cannot independently attribute the observed differences to vaccination, screening, migration, or changes in case ascertainment. Nevertheless, the concentration of DALYs among middle-aged and older adults indicates an ongoing need for adult HBV testing, linkage to antiviral treatment when indicated, and surveillance for cirrhosis and HCC.[35,38–42]

The regional heterogeneity observed in this study suggests that MENA countries are at different stages of HBV epidemiological transition; therefore, programmatic priorities should be tailored to each country's transition profile. Countries retaining comparatively high proportions of burden among younger age groups, such as Afghanistan, Sudan, Yemen, and Iraq, require continued emphasis on vaccination, timely birth-dose delivery, surveillance, and other measures to prevent new infections. Countries where the burden is concentrated among middle-aged and older adults require parallel investment in adult HBV testing in accordance with national and international guidelines, effective linkage to antiviral treatment, cirrhosis care, and HCC surveillance, an approach that has been cost-effective in appropriate settings.[43–46] As the burden becomes increasingly concentrated in older adults, a major remaining challenge may be the large reservoir of undiagnosed chronic HBV infection among adults. Progress toward the World Health Organisation hepatitis elimination goals will therefore require expanded adult testing, linkage to care, and treatment, alongside sustained routine vaccination coverage, timely birth-dose delivery, and other measures to prevent new infections. Lebanon showed a distinct pattern within the regional analysis: its burden was already concentrated among older age groups in 1990, while the proportion of DALYs among people aged 0–34 years changed only slightly over the study period. This descriptive pattern does not establish gaps in vaccination or other prevention services but highlights the need to consider both younger and older populations when planning HBV services.

The increasing concentration of HBV burden among middle-aged and older adults underscores the necessity for services adept at managing advanced liver disease and acute-on-chronic liver failure (ACLF). Yu and colleagues enhanced the Model for End-Stage Liver Disease (MELD) score by developing the CATCH-LIFE-MELD score, which integrates age, neutrophil count, and hepatic encephalopathy grade. The selection of predictors was guided by a meta-analysis and evaluated in 751 ACLF patients from two prospective cohorts, with 86.4% having HBV infection. The modified score demonstrated greater accuracy in predicting the short-term prognosis of ACLF than other traditional scores.[47] These findings highlight the prognostic value of age in conjunction with markers of inflammation and clinical severity, making the study particularly relevant to an aging HBV population. Consequently, regional service planning should integrate long-term antiviral treatment and HCC surveillance with timely recognition of decompensation, assessment of ACLF severity, and access to specialist management and transplantation evaluation where necessary.

This is an ecological analysis of modeled aggregate estimates and does not support individual-level inference. The analysis of the rate-count divergence described above is an approximate accounting identity on the log scale rather than a formal Das Gupta or Kitagawa decomposition, and the age-structure term is a residual rather than an estimated quantity. Uncertainty was not propagated through derived measures: published country-level uncertainty intervals are reported as given but were not re-estimated for the population-weighted mean of country ASRs, decomposition components, burden-weighted mean age, or age-band shares, all of which would require draw-level GBD data. The chronic HBV category includes cirrhosis but does not separately identify cirrhotic and non-cirrhotic contributions in the extracted estimates, limiting interpretation as cirrhosis-only burden.

As described in the Methods section, the aggregate data did not permit adjustment for several clinical and contextual factors that may have contributed to the observed country heterogeneity. Metabolic comorbidity may accelerate disease progression among people with chronic HBV, while hepatitis D virus coinfection may worsen liver disease in some settings.[48–50] In addition, the estimates did not distinguish citizens from resident non-nationals or quantify labor migration. Therefore, country-level age patterns and absolute counts, particularly in Gulf countries, reflect changing resident populations and should not be interpreted as trends among citizens alone.

Conclusions

Across 21 MENA countries between 1990 and 2023, the population-weighted mean of country HBV DALY age-standardized rates are 53.0% lower, while absolute DALYs are 19.3% higher in 2023 than in 1990. The approximate analysis suggests that population growth accounted for most of this divergence, with a smaller age-structure component for DALYs and a negligible residual for acute hepatitis B incidence. The HBV burden shows a shift toward middle-aged and older adults in 20 of 21 countries, with the magnitude of the shift appearing partly related to baseline age structure. Because countries in the region occupy widely different positions in this transition, regional rate trends alone are an incomplete guide for national service needs. Planning for adult diagnosis, treatment, and hepatocellular carcinoma surveillance should

therefore be based on absolute burden and its age distribution.

Supporting information

Supplementary material for this article is available at https://doi.org/10.14218/JCTH.2026.00740.

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None to declare.

Conflict of interest

MEK has been an Editorial Board Member of *Journal of Clinical and Translational Hepatology* since 2013. The other authors have no conflict of interests related to this publication.

Author contributions

Study concept and design, KMAN, SAB, ZMY; methodology, KMAN, SAB, ZMY; software, KMAN, SAB; formal analysis, SAB; data curation, SAB; investigation, KMAN, SAB; writing – original draft preparation, KMAN, SAB; writing – review and editing, MEK, HA, SAS, SAA, KAA, TB, WKAH, FMS, FA, SAAG, ZMY; visualization, KMAN, SAB; supervision, KMAN, ZMY; project administration, KMAN. All authors reviewed and approved the final manuscript for submission.

Ethical statement

The study was performed in accordance with the Declaration of Helsinki (as revised in 2024). Ethical approval and informed consent were not required because this study used publicly available, aggregate estimates from the GBD study and involved no individual-level data.

Data sharing statement

All data used in this study were derived from the GBD 2023 study and are publicly available through the Institute for Health Metrics and Evaluation Global Health Data Exchange (GHDx). Data can be accessed freely at: https://ghdx.healthdata.org/gbd-results.

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