

Burden, Temporal Trends, and Projections of Hodgkin Lymphoma in South Asia, 1990–2040: A Systematic Analysis of the Global Burden of Disease Study 2023

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Abstract

Background

Hodgkin lymphoma (HL) is a highly curable malignancy, yet its burden and trajectory in South Asia remain poorly characterized. We quantified the burden, temporal trends, and future projections of HL across South Asia and its five constituent countries.

Methods

Using Global Burden of Disease (GBD) 2023 estimates, we extracted age-standardized rates and absolute counts of HL incidence, prevalence, mortality, and disability-adjusted life years (DALYs) for 1990–2023. Joinpoint regression estimated average annual percentage changes (AAPCs); Kitagawa decomposition partitioned crude-rate changes into epidemiological and demographic components; and autoregressive integrated moving average (ARIMA) models projected burden to 2040.

Results

Between 1990 and 2023, regional age-standardized incidence (AAPC – 1.35%), mortality (– 2.12%), and DALY rates (– 2.15%) all declined significantly, while prevalence remained stable. Bangladesh, Nepal, and India achieved the largest improvements, whereas Pakistan showed the slowest progress and, by 2023, the highest incidence (1.09), mortality (0.74), prevalence (3.61), and DALY (36.31 per 100,000) rates in the region. Despite falling rates, absolute incident and prevalent cases rose across South Asia, driven predominantly by population growth and ageing, as confirmed by decomposition. ARIMA projections indicate continued declines in mortality and DALYs through 2040, with Pakistan retaining a disproportionately high burden.

Conclusions

HL burden has declined substantially across South Asia over three decades, but marked cross-country disparities persist, with Pakistan lagging. Strengthening cancer registries, promoting early diagnosis, and expanding equitable access to treatment—particularly in Pakistan—are priorities for further reducing the regional burden.

Introduction

Hodgkin lymphoma (HL) is an uncommon B-cell lymphoid malignancy defined histologically by the presence of malignant Hodgkin and Reed–Sternberg cells embedded within a reactive inflammatory microenvironment (1,2). It follows a characteristically bimodal age distribution, with incidence peaks among young adults aged 20–34 years and again in older adults aged ≥ 55 years (1,2). Although rare, HL is one of the most curable human malignancies and accounts for a distinct and clinically important share of the lymphoma burden (3). The therapeutic revolution of the 1960s and 1970s—combining multi-agent chemotherapy with radiotherapy—

transformed HL from a near-uniformly fatal disease into a highly treatable one, driving sustained declines in mortality across high-income settings in the following decades (4).

Globally, HL accounts for a small fraction of cancer incidence and mortality, representing approximately 0.4% of new cancer cases and 0.2% of cancer deaths in 2020 (5), but its distribution varies markedly by age, sex, and geography, with a consistent male predominance and the heaviest burden falling on adolescents and young adults (6). Established risk factors include infectious exposures—most notably Epstein–Barr virus and HIV/AIDS—alongside environmental and lifestyle determinants such as tobacco smoking and air pollution (7–9), together with host and social factors including socioeconomic status, family size, and immune-related conditions (10).

The epidemiology of HL is shaped by a pronounced transition gradient: high-income countries tend to report higher recorded incidence, partly reflecting greater diagnostic capacity and more complete case ascertainment, whereas low- and middle-income countries bear a disproportionate share of mortality owing to late-stage presentation, fragmented referral pathways, and constrained access to multi-modal therapy (11,12). South Asia is of particular interest, as its young population age structure, high infectious burden including endemic EBV exposure, and heterogeneous, resource-limited health systems may jointly reshape both the level and trajectory of HL burden (12,13). Yet contemporary evidence remains fragmented—largely single-centre, cross-sectional, or methodologically inconsistent—with few long-term, internally comparable, cross-country estimates. Using Global Burden of Disease (GBD) 2023 estimates, we characterize HL incidence, prevalence, mortality, and disability-adjusted life years (DALYs) across South Asia and its five constituent countries (Pakistan, India, Bangladesh, Nepal, and Bhutan) from 1990 to 2023, apply joinpoint regression and Kitagawa decomposition, and use autoregressive integrated moving average (ARIMA) modelling to project burden to 2040, to inform equitable cancer-control planning.

Methods

2.1 Study Design and Data Source

This secondary analysis used Global Burden of Disease (GBD) 2023 estimates produced by the Institute for Health Metrics and Evaluation (IHME) (14), which provides internally consistent estimates across 204 countries. Data for HL were extracted from the public IHME GBD Results Tool (<https://vizhub.healthdata.org/gbd-results/>) for South Asia and its five countries (Pakistan, India, Bangladesh, Nepal, and Bhutan) for 1990–2023.

2.2 Outcome Measures

We extracted incidence, prevalence, mortality, and DALYs (the sum of years lived with disability and years of life lost), each as absolute counts and age-standardized rates per 100,000 (ASIR, ASPR, ASDR, and ASR-DALYs), using the GBD world standard population and direct standardization across 5-year age groups. Analysing rates and counts in parallel distinguishes demographic change from change in per-population risk. Sex-specific and age-specific rates for 2023 were also extracted to characterize the sex and age distribution.

2.3 GBD Estimation

GBD estimates were generated with the DisMod-MR 2.1 Bayesian meta-regression tool [15], integrating vital registration, cancer registries, hospital data, surveys, verbal autopsy, and published literature, and borrowing statistical strength across ages, periods, and comparable locations where data were sparse. Estimates are reported with 95% uncertainty intervals derived from 1,000 posterior draws.

2.4 Joinpoint Regression

Temporal trends in each age-standardized rate were analysed with the U.S. National Cancer Institute Joinpoint Regression Program (version 5.4), a piecewise log-linear model that identifies statistically significant changes in slope. Models used log-transformed rates, permitted up to four joinpoints, and were selected by permutation testing (4,499 replicates; $\alpha = 0.05$; Bonferroni-corrected) [16]. Segment annual percentage changes (APCs) and full-period average annual percentage changes (AAPCs, the duration-weighted geometric mean of the APCs) were computed with 95% confidence intervals on the log scale, with significance assessed by a two-sided test.

2.5 Decomposition

To separate epidemiological from demographic drivers, we compared age-standardized rates with absolute counts and applied Kitagawa decomposition to the change in crude rates between 1990 and 2023, partitioning it into a rate effect (change in age-specific risk) and a structure effect (change in population size and age composition), expressed in absolute terms and as a percentage of the total change; a rate effect exceeding 100% indicates epidemiological improvement partially offset by an opposing demographic effect.

2.6 Forecasting

Crude rates were projected to 2040 using automated ARIMA models fitted to each measure–jurisdiction series (1990–2023), with orders selected by the corrected Akaike Information Criterion (AICc) and residuals assessed by the Ljung–Box test. Out-of-sample performance was evaluated by training on 1990–2016 and testing on 2017–2023 (RMSE, MAE, MAPE, and 95% prediction-interval coverage). The best model for each series was refitted to the full period to generate forecasts with 95% prediction intervals (24 models in total).

2.7 Statistical Software and Ethics

Analyses used the Joinpoint Regression Program and R version 4.5.0 ('forecast' package), with significance defined as two-sided $p < 0.05$. As the study used only publicly available, aggregated, de-identified GBD data, no ethical approval was required, consistent with IHME guidelines and the Declaration of Helsinki.

Results

Absolute Burden and Temporal Trends

Between 1990 and 2023, the absolute burden of Hodgkin lymphoma diverged sharply across South Asia. Regional absolute deaths were largely stable, edging from 5,996 (95% UI 3,766–8,900) to 6,172 (3,964–9,181), but this masked opposing national trends: deaths fell 29% in Bangladesh (763 to 539) and 6% in India (4,222 to 3,981), with modest declines in Nepal and Bhutan, whereas Pakistan's rose 75% (890 to 1,555). Total DALYs

fell 36% in Bangladesh (42,004 to 26,870), 32% in Bhutan, 22% in India (225,164 to 175,500), and 31% in Nepal, but rose 73% in Pakistan (51,265 to 88,556). Absolute incidence and prevalence rose across the region, with incident cases up 31% (7,723 to 10,103) and prevalent cases up 96% (19,723 to 38,678). Pakistan drove much of this growth—incidence + 111% (1,185 to 2,505) and prevalence + 187% (3,214 to 9,230)—while India also rose (incidence + 18%, 5,408 to 6,409; prevalence + 77%, 13,638 to 24,165), largely reflecting demographic shifts. Detailed country-specific estimates for burden metrics in 1990 and 2023 are presented in Table 2.

Age-Standardized Incidence Rate (ASIR)

Age-standardized incidence declined in every country, though the magnitude varied (Table 1). The steepest reductions were in Bangladesh (1.15 to 0.60 per 100,000; AAPC – 1.98%, 95% CI – 2.15% to – 1.80%) and Nepal (0.90 to 0.48; –1.88%), with India falling to 0.44 (– 1.59%) and the region from 0.83 to 0.54 (– 1.35%). Pakistan improved slowest (AAPC – 0.41%), its 2023 rate (1.09, down from 1.23) roughly double the regional average. Joinpoint analysis showed that India, Pakistan, and the region shared a three-phase pattern—a prolonged decline (e.g., India – 2.00%, 1998–2018), a non-significant 2018–2021 plateau (India + 2.66%; Pakistan + 1.36%), and a sharp 2021–2023 drop (India – 5.64%; Pakistan – 7.32%)—whereas Bangladesh, Nepal, and Bhutan declined more continuously (Supplementary Table S1).

Age-Standardized Prevalence Rate (ASPR)

Prevalence trends were mixed (Table 1). Nepal fell (1.98 to 1.52; AAPC – 0.89%) and Pakistan rose significantly (+ 0.55%), while Bangladesh (2.60 to 2.57), Bhutan (1.75 to 1.87), India (1.68 to 1.59), and the region (1.90 to 1.95) showed no significant net change; by 2023 Pakistan's ASPR (3.61) was nearly double India's and more than double Nepal's. Joinpoint analysis showed Pakistan sustained continuous prevalence growth (+ 0.63% annually) from 1994 to 2021, with significant late-period increases in Bhutan (+ 2.13%, 2018–2023), India (+ 1.46%, 2016–2023), the region (+ 1.33% from 2016), and Bangladesh (+ 7.74% from 2021) (Supplementary Table S1).

Age-Standardized Death and DALY Rates (ASDR, ASR-DALYs)

Age-standardized mortality fell significantly in every country (Table 1), roughly halving in Bangladesh (0.97 to 0.34; AAPC – 3.15%, 95% CI – 3.39% to – 2.90%) and Nepal (0.76 to 0.32; –2.62%), with Bhutan (0.64 to 0.32; –2.02%), India (to 0.29; –2.34%), and the region (– 2.12%; –2.48% to – 1.76%) also achieving roughly 50% reductions. Pakistan improved slowest (– 0.92%), retaining the region's highest 2023 rate (0.74, down from 0.99). DALY-rate trends mirrored mortality, the region falling from 31.39 to 15.38 per 100,000 (AAPC – 2.15%), with the largest reductions in Bangladesh (– 3.12%, 95% CI – 3.31% to – 2.93%), Nepal (– 2.71%), India (– 2.56%), and Bhutan (– 1.96%); Pakistan's decline was weakest (– 0.85%), leaving its 2023 DALY rate (36.31) more than double any other country's. Joinpoint models showed accelerating declines—for example, Bangladesh's ASDR fell faster over successive segments (– 3.01% in 1990–2010 to – 5.06% in 2019–2023) and India's DALY rate accelerated from – 1.50% (1990–1998) to – 3.76% (2011–2018)—followed by a shared terminal 2021–2023 contraction (ASDR: India – 6.26%; Pakistan – 8.06%), with Pakistan's early-period stagnation delaying progress (Supplementary Table S1).

Sex and Age Distribution

Across all four measures, burden was consistently higher in males. In 2023, regional male-to-female ratios were 1.79 for incidence (0.69 versus 0.38 per 100,000), 2.00 for mortality (0.46 versus 0.23), 1.59 for prevalence, and 1.86 for DALYs, with the male excess greatest for mortality in every country (1.83–2.13, highest in Bhutan and India; Supplementary Table S5). Age-specific incidence was bimodal, peaking in young adults (25–29 years: 0.71 per 100,000) and, more prominently, older adults (80–84 years: 1.24), with a relative midlife trough (45–49 years: 0.45); age-specific mortality rose monotonically with age (0.34 at 25–29 to 1.52 at 80–84), concentrating deaths among older adults (Supplementary Figure S5).

Demographic Decomposition

Kitagawa decomposition (Table 3) showed that epidemiological improvement (the rate effect) drove the regional declines in DALYs, mortality, and incidence, explaining over 100% of net reductions, while population growth and ageing (the structure effect) partly offset these gains. The regional crude DALY rate fell 47.86% (29.97 to 15.62 per 100,000; rate effect 110.13%, structure – 10.13%), with national reductions in Bangladesh (– 59.86%; rate 114.56%), Nepal (– 56.62%; 107.84%), India (– 54.35%; 111.13%), Bhutan (– 44.00%; 112.44%), and Pakistan (– 21.15%; 111.56%). Regional crude mortality fell 40.95% (0.55 to 0.33; rate 136.40%), with structural offsets ranging from – 24.14% in Pakistan (0.80 to 0.64) to – 69.38% in Bhutan (0.48 to 0.32), indicating that ageing substantially masked clinical progress. Regional crude incidence fell 24.96% (0.71 to 0.53; rate 145.49%, structure – 45.49%); rate effects exceeded 130% in Bangladesh, Bhutan, India, and Nepal, but in Pakistan a large negative structure effect (– 123.82%) nearly neutralized a 223.82% rate effect, limiting the reduction to 3.48% (1.06 to 1.03). Crude prevalence rose regionally (+ 12.49%; 1.82 to 2.04), structure-driven in India (1.61 to 1.67; where prevalence rose 3.77% despite a – 72.70% rate effect) and Bangladesh (2.29 to 2.74), but rate-driven in Pakistan (+ 31.09%; 2.89 to 3.78; 90.04% rate), while Nepal recorded the only net contraction (– 14.90%; 1.88 to 1.60, entirely rate-driven).

ARIMA Projections (2024–2040)

All 24 ARIMA models showed white-noise residuals (Ljung–Box $p > 0.05$), with higher-order specifications for Pakistan to accommodate volatility [deaths ARIMA(2,2,0); incidence ARIMA(2,1,1); DALYs ARIMA(0,2,4)] (Table 4). Because the models were fitted to crude rates, projections are crude and not directly comparable to the age-standardized trends above. Regional crude mortality is projected to fall from 0.326 (2023) to 0.216 (95% CI 0.160–0.273) by 2035 and 0.163 (0.096–0.231) by 2040, led by India (to 0.162 by 2035), while Pakistan remains highest (0.350 by 2035). Regional crude incidence declines from 0.534 to 0.427 (0.336–0.518) by 2035 in all countries except Pakistan, where it fluctuates near 1.12–1.21. Crude prevalence diverges—rising in Pakistan (3.78 to 4.01 by 2035 and 4.13 by 2040) and Bangladesh (2.93 by 2035) but plateauing in India near 1.56, stabilizing regional estimates at 1.84–1.86. Regional crude DALYs fall from 15.62 to 9.56 (6.67–12.45) by 2035 and 7.13 (3.69–10.58) by 2040, led by India (6.03 by 2035), while Pakistan stays highest (25.62 by 2035; 19.58 by 2040). Out-of-sample validation showed acceptable point accuracy (MAPE 3–11%) but below-nominal 95%-interval coverage for several series, especially prevalence (South Asia 28.6%; Nepal 57.1%) and regional incidence (57.1%), so prevalence projections warrant particular caution; widening

intervals with zero lower bounds at the 2040 horizon reflect forecasting uncertainty rather than elimination of disease. Among the smaller-burden countries, crude mortality is projected to reach 0.142 per 100,000 in Bangladesh, 0.108 in Nepal, and 0.204 in Bhutan by 2035, falling further to 0.06 in Bangladesh and 0.11 in India by 2040; crude incidence is projected to decline to 0.502 in Bangladesh and 0.328 in India by 2035, and crude DALYs to 8.19 in Bangladesh and 10.04 in Nepal over the same horizon. Collectively, these projections indicate a continued regional decline in mortality and DALY burden through 2040, driven chiefly by India and Bangladesh, while Pakistan persistently retains the highest burden across all four measures. Full model specifications, diagnostics, validation metrics, and complete forecast trajectories are provided in Supplementary Tables S2–S4 and Figures S1–S4.

Table 1
Average Annual Percentage Change (AAPC) in Age-Standardized Hodgkin Lymphoma Rates by Country, 1990–2023

Location	ASIR AAPC (95% CI)	ASPR AAPC (95% CI)	ASDR AAPC (95% CI)	ASR-DALYs AAPC (95% CI)
South Asia	-1.35* (- 1.71 to - 0.98)	0.13 (- 0.08 to 0.33)	-2.12* (- 2.48 to - 1.76)	-2.15* (- 2.52 to - 1.78)
Bangladesh	-1.98* (- 2.15 to - 1.80)	0.02 (- 0.37 to 0.40)	-3.15* (- 3.39 to - 2.90)	-3.12* (- 3.31 to - 2.93)
Bhutan	-1.14* (- 1.31 to - 0.98)	0.24 (- 0.06 to 0.53)	-2.02* (- 2.16 to - 1.89)	-1.96* (- 2.15 to - 1.78)
India	-1.59* (- 2.06 to - 1.13)	-0.10 (- 0.46 to 0.26)	-2.34* (- 2.85 to - 1.83)	-2.56* (- 3.09 to - 2.03)
Nepal	-1.88* (- 2.07 to - 1.69)	-0.89* (- 1.08 to - 0.71)	-2.62* (- 2.76 to - 2.48)	-2.71* (- 2.93 to - 2.49)
Pakistan	-0.41* (- 0.67 to - 0.15)	0.55* (0.25 to 0.86)	-0.92* (- 1.16 to - 0.68)	-0.85* (- 1.16 to - 0.53)

* Indicates that the AAPC is statistically significant ($P < 0.05$). ASIR = Age-Standardized Incidence Rate; ASPR = Age-Standardized Prevalence Rate; ASDR = Age-Standardized Death Rate; ASR-DALYs = Age-Standardized Disability-Adjusted Life Years Rate.

Table 2
Magnitude of Hodgkin Lymphoma Burden Metrics by Country in 1990 and 2023

Metric (Unit)	Location	Year	Estimate	95% Uncertainty Interval (UI)
Absolute Deaths (Cases)	South Asia	1990	5,996	3,766–8,900
		2023	6,172	3,964–9,181
	Bangladesh	1990	763	474–1,193
		2023	539	297–946
	Bhutan	1990	3	2–5
		2023	2	1–4
	India	1990	4,222	2,502–6,158
		2023	3,981	2,567–5,791
	Nepal	1990	117	73–183
		2023	95	52–169
	Pakistan	1990	890	583–1,309
		2023	1,555	945–2,242
Age-Standardized Incidence Rate (per 100,000)	South Asia	1990	0.83	0.53–1.24
		2023	0.54	0.35–0.79
	Bangladesh	1990	1.15	0.71–1.80
		2023	0.6	0.34–1.05
	Bhutan	1990	0.78	0.46–1.24
		2023	0.53	0.29–0.94
	India	1990	0.75	0.44–1.10
		2023	0.44	0.28–0.64
	Nepal	1990	0.9	0.57–1.38
		2023	0.48	0.26–0.85
	Pakistan	1990	1.23	0.81–1.83
		2023	1.09	0.67–1.55
Age-Standardized Prevalence Rate (per 100,000)	South Asia	1990	1.9	1.19–2.83
		2023	1.95	1.27–2.91
	Bangladesh	1990	2.6	1.64–4.50

Metric (Unit)	Location	Year	Estimate	95% Uncertainty Interval (UI)
Age-Standardized Death Rate (per 100,000)	Bhutan	2023	2.57	1.40–4.68
		1990	1.75	1.08–2.95
	India	2023	1.87	0.95–3.62
		1990	1.68	0.99–2.52
	Nepal	2023	1.59	1.03–2.34
		1990	1.98	1.23–3.28
	Pakistan	2023	1.52	0.85–2.79
		1990	2.98	1.87–4.59
	South Asia	2023	3.61	2.27–5.28
		1990	0.7	0.44–1.04
	Bangladesh	2023	0.34	0.22–0.51
		1990	0.97	0.59–1.51
	Bhutan	2023	0.34	0.18–0.60
		1990	0.64	0.38–1.02
Age-Standardized DALYs Rate (per 100,000)	India	2023	0.32	0.18–0.57
		1990	0.63	0.37–0.92
	Nepal	2023	0.29	0.19–0.41
		1990	0.76	0.48–1.16
	Pakistan	2023	0.32	0.17–0.57
		1990	0.99	0.66–1.48
	South Asia	2023	0.74	0.45–1.07
		1990	31.39	19.64–46.36
	Bangladesh	2023	15.38	9.75–22.70
		1990	43.35	26.88–67.95
	Bhutan	2023	15.23	8.40–26.83
		1990	29.16	17.27–46.46
	India	2023	14.98	8.24–27.35
		1990	27.89	16.56–40.69

Metric (Unit)	Location	Year	Estimate	95% Uncertainty Interval (UI)
		2023	11.86	7.53–17.07
	Nepal	1990	36.08	22.42–56.13
		2023	14.78	8.12–26.45
	Pakistan	1990	47.47	31.18–69.93
		2023	36.31	22.26–52.50

Table 3
Kitagawa Decomposition of Crude Disease Burden Metrics (1990–2023)

Metric	Jurisdiction	Crude Rate 1990	Crude Rate 2023	Total Change (%)	Rate Effect (%)	Structure Effect (%)
DALYs	South Asia	29.967	15.623	-47.86%	110.13%	-10.13%
	Bangladesh	38.506	15.455	-59.86%	114.56%	-14.56%
	Bhutan	27.735	15.532	-44.00%	112.44%	-12.44%
	India	26.635	12.159	-54.35%	111.13%	-11.13%
	Nepal	34.956	15.163	-56.62%	107.84%	-7.84%
	Pakistan	46.036	36.301	-21.15%	111.56%	-11.56%
Deaths	South Asia	0.552	0.326	-40.95%	136.40%	-36.40%
	Bangladesh	0.699	0.31	-55.69%	132.49%	-32.49%
	Bhutan	0.479	0.319	-33.49%	169.38%	-69.38%
	India	0.499	0.276	-44.79%	138.49%	-38.49%
	Nepal	0.601	0.306	-49.15%	132.17%	-32.17%
	Pakistan	0.799	0.638	-20.22%	124.14%	-24.14%
Incidence	South Asia	0.711	0.534	-24.96%	145.49%	-45.49%
	Bangladesh	0.895	0.596	-33.42%	146.21%	-46.21%
	Bhutan	0.638	0.543	-14.97%	205.58%	-105.58%
	India	0.64	0.444	-30.60%	143.62%	-43.62%
	Nepal	0.77	0.48	-37.65%	130.90%	-30.90%
	Pakistan	1.064	1.027	-3.48%	223.82%	-123.82%
Prevalence	South Asia	1.816	2.043	12.49%	59.23%	40.77%
	Bangladesh	2.288	2.744	19.97%	48.32%	51.68%
	Bhutan	1.649	1.982	20.21%	79.55%	20.45%
	India	1.613	1.674	3.77%	-72.70%	172.70%
	Nepal	1.877	1.597	-14.90%	136.00%	-36.00%
	Pakistan	2.886	3.784	31.09%	90.04%	9.96%

Table 4
ARIMA Mathematical Models and Predictive Projections for Crude Burden Rates (per 100,000 population)
through 2040

Metric	Jurisdiction	ARIMA Model Order	2035 Forecasted Mean (95% CI)	2040 Forecasted Mean (95% CI)
Deaths	South Asia	ARIMA(0,1,0)	0.217 (0.160–0.273)	0.163 (0.096–0.231)
	Bangladesh	ARIMA(0,2,1)	0.142 (0.000–0.295)	0.060 (0.000–0.293)
	Bhutan	ARIMA(0,1,0)	0.204 (0.141–0.266)	0.155 (0.081–0.229)
	India	ARIMA(0,1,0)	0.162 (0.099–0.225)	0.110 (0.035–0.186)
	Nepal	ARIMA(0,2,3)	0.108 (0.000–0.392)	0.018 (0.000–0.513)
	Pakistan	ARIMA(2,2,0)	0.350 (0.000–0.825)	0.194 (0.000–0.959)
Incidence	South Asia	ARIMA(0,1,0)	0.427 (0.336–0.518)	0.382 (0.273–0.490)
	Bangladesh	ARIMA(0,2,1)	0.502 (0.302–0.702)	0.463 (0.157–0.769)
	Bhutan	ARIMA(0,1,0)	0.435 (0.345–0.524)	0.397 (0.290–0.504)
	India	ARIMA(0,1,0)	0.328 (0.227–0.429)	0.281 (0.161–0.402)
	Nepal	ARIMA(2,2,0)	0.394 (0.169–0.619)	0.354 (0.000–0.717)
	Pakistan	ARIMA(2,1,1)	1.150 (0.997–1.303)	1.153 (0.975–1.331)
Prevalence	South Asia	ARIMA(3,0,0)	1.837 (1.727–1.947)	1.854 (1.743–1.966)
	Bangladesh	ARIMA(0,2,1)	2.933 (1.994–3.873)	3.085 (1.754–4.417)
	Bhutan	ARIMA(1,0,0)	1.768 (1.638–1.897)	1.762 (1.632–1.892)
	India	ARIMA(0,1,2)	1.555 (1.275–1.836)	1.555 (1.215–1.895)
	Nepal	ARIMA(0,2,1)	1.470 (0.860–2.080)	1.449 (0.510–2.388)
	Pakistan	ARIMA(2,1,0)	4.012 (3.681–4.343)	4.129 (3.747–4.511)
DALYs	South Asia	ARIMA(0,1,0)	9.559 (6.667–12.452)	7.134 (3.691–10.577)
	Bangladesh	ARIMA(0,2,1)	8.194 (0.629–15.759)	5.264 (0.000–17.046)
	Bhutan	ARIMA(0,1,3)	10.183 (5.446–14.920)	8.139 (2.360–13.918)
	India	ARIMA(0,1,0)	6.030 (2.876–9.185)	3.601 (0.000–7.355)
	Nepal	ARIMA(2,2,0)	10.037 (0.387–19.686)	7.923 (0.000–23.499)
	Pakistan	ARIMA(0,2,4)	25.617 (9.382–41.851)	19.578 (0.000–46.695)

**Note: All 24 final autoregressive integrated moving average (ARIMA) models were evaluated for diagnostic adequacy using the Ljung-Box Q test. Across all specifications, the residual autocorrelations were statistically non-significant ($p > 0.05$), confirming that the model residuals represent white noise and indicating an adequate model fit to the historical data series.*

Discussion

This analysis of GBD 2023 data shows substantial declines in age-standardized incidence, mortality, and DALY rates for Hodgkin lymphoma across South Asia between 1990 and 2023, alongside marked cross-country variation. Bangladesh, Nepal, and India achieved the greatest reductions, yet absolute incidence and prevalence rose—particularly in India and Pakistan—reflecting population growth, ageing, and improved survival. Demographic decomposition confirmed that epidemiological improvement, rather than demographic change, drove the rate declines, although demographic shifts offset part of these gains. Pakistan was a consistent outlier, with the slowest declines in incidence, mortality, and DALY rates and the largest increases in absolute cases, deaths, and prevalence. Overall, the regional HL burden remains shaped by healthcare disparities and limited diagnostic and treatment infrastructure, challenges compounded by the COVID-19 pandemic, underscoring the need for policies that improve access to care and clinical outcomes across the region [17–19].

Falling age-standardized incidence across all countries suggests reduced risk-factor exposure, while stable-to-rising prevalence—significant in Pakistan—likely reflects ongoing incidence together with improved survival, producing a growing population living with HL. Regional patterns also reflect differences in risk profiles, access to care, and genetic predisposition [5]. Health-system heterogeneity is relevant: traditional medical systems such as Ayurveda and Siddha remain important in India and Nepal [20, 21], and cancer-care resources are markedly unequal—India has roughly one oncologist per 1,600 cancer patients versus one per 10,000 in Sri Lanka [22, 23]—while in Pakistan nearly 70% of the population lives in rural areas yet only about 20% of health facilities are located there [23, 24].

The pronounced mortality and DALY reductions in Bangladesh and Nepal likely reflect gradual improvements in cancer-care delivery, including earlier diagnosis, better referral pathways, and greater access to chemotherapy and supportive care [25], with recent regional series reporting favourable treatment outcomes and survival despite resource constraints [26, 27, 28]. Pakistan, by contrast, retained the highest mortality burden, consistent with a clinico-epidemiological profile characterized by advanced-stage presentation and B symptoms that indicate delayed diagnosis and limited access to timely care [24, 29]; unlike high-income settings where most patients present with early-stage disease, delayed presentation is common, and socioeconomic and gender disparities may further compound this pattern, particularly among women and children [30, 31, 32].

Because years of life lost constitute the largest component of HL DALYs, these mortality gains largely explain the parallel DALY declines, echoing global trends driven by advances in chemotherapy, risk-adapted strategies, and improved healthcare access [33, 34]; declining rates despite rising absolute case counts indicate that clinical gains outweighed the upward pressure of population growth and ageing, especially in Bangladesh, Nepal, and India [35]. Decomposition reinforced that epidemiological improvement was the principal driver of reduced burden, partly counterbalanced by demographic change—most evident in India and Pakistan, where rising prevalence was largely demographic rather than a reflection of higher disease risk. ARIMA projections suggest continued mortality and DALY reductions through 2040, led by India and Bangladesh, but with Pakistan retaining a comparatively higher burden, underscoring the need for targeted investment in treatment access and healthcare infrastructure [36].

The consistent male predominance (male-to-female ratio approximately 1.8 for incidence and 2.0 for mortality) and the bimodal age distribution—with a prominent older-adult peak and mortality concentrated among the elderly, who often tolerate intensive therapy poorly—suggest that outcomes in older patients are an important and potentially modifiable contributor to regional mortality. Future work should prioritize strengthening population-based cancer registries and surveillance for accurate burden estimation and policy planning, evaluating ongoing government cancer-control initiatives [37–41], and pursuing subnational and age-specific studies. Partnerships among governments, cancer societies, and non-governmental organizations may further improve screening, referral pathways, and treatment delivery, ultimately reducing the Hodgkin lymphoma burden across the region [42–44].

Limitations:

Several limitations apply. GBD estimates depend on the quality and completeness of the underlying data sources, which vary across South Asian countries; countries with limited cancer-registry coverage carry greater uncertainty even after statistical adjustment, and estimates for small populations and sparse-registry settings—most notably Bhutan, where annual deaths number only two to three—are especially unstable, so country- and year-specific percentage changes there should be interpreted with corresponding caution. Because the analysis relied on national-level data, it could not capture differences between central and peripheral areas in healthcare access and outcomes. We also lacked information on histological subtypes, disease stage, treatment patterns, and individual-level risk factors, and therefore could not explore the underlying drivers of the observed trends. The ARIMA projections extrapolate historical trends and do not account for future policy changes, evolving health systems, or unexpected shocks. Finally, trends in the most recent years of any GBD series—including the terminal joinpoint segments spanning the COVID-19 period—are particularly sensitive to modelling assumptions and may be revised in future GBD cycles.

Conclusion

This study highlights Hodgkin lymphoma burden and its substantial reduction across South Asia between 1990 and 2023. Significant declines in age-standardised incidence, mortality, and DALY rates are documented. However, important disparities remain across countries. Bangladesh, Nepal, and India demonstrated the greatest improvements, while Pakistan continued to experience a disproportionately higher burden and slower overall progress. Furthermore, the forecasts suggest continued trends of reduction in mortality and DALY burden through 2040. Strengthening cancer surveillance, promoting early diagnosis, and improving equitable access to treatment can further reduce the regional burden.

Declarations

Conflicts of Interest

The authors declare that they have no competing interests.

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Author Contribution

FNU Sawaira: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Writing - original draft, Visualization. Sarim Hassan Shahab: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Writing - original draft, Visualization. Madho Mal: Data curation, Validation, Writing - review & editing. Hasan Ahmed: Data curation, Validation, Writing - review & editing. Malik Saad Saud Haider: Data curation, Validation, Writing - review & editing. FNU Kritika: Data curation, Validation, Writing - review & editing. Shariq Hayat: Data curation, Validation, Writing - review & editing. Muhammad Shahzaib: Data curation, Validation, Writing - review & editing. Muhammad Osama: Data curation, Validation, Writing - review & editing. Qazi Muhammad Farooq Wahab: Data curation, Validation, Writing - review & editing. Muhammad Yasir: Data curation, Validation, Writing - review & editing. Hadia Ghazala Masood: Data curation, Validation, Writing - review & editing. Muhammad Junaid: Data curation, Validation, Writing - review & editing. Sana Khurram: Data curation, Validation, Writing - review & editing. Dileep Raja Kuraku: Investigation, Validation, Writing - review & editing, Project administration, Correspondence. Krishna Sai Sakalabaktula: Validation, Supervision, Writing - review & editing. Owais Gul: Supervision, Validation, Writing - review & editing. All authors critically reviewed the manuscript, approved the final version for publication, and agree to be accountable for all aspects of the work in accordance with ICMJE authorship criteria.

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Data Availability

All data analysed in this study are publicly available from the Institute for Health Metrics and Evaluation (IHME) Global Health Data Exchange GBD Results Tool (<https://vizhub.healthdata.org/gbd-results/>). Derived estimates generated during the analysis are available from the corresponding author on reasonable request. The statistical code used for the joinpoint, decomposition, and ARIMA analyses is available from the corresponding author on reasonable request.

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