# Macroeconomic burden of colorectal cancer in low- and middle-income countries: estimates and projections to 2050

Wenwen Lv[1], Shihan Wang[1], Lei Duan[2], Yu Zhong[3], Yejun Wu[1], Shenshen Gao[4,5], Bingshun Wang[1]*

[1]Institute of Clinical Medicine, Ruijin Hospital Luwan Branch, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[2]National Institute of Parasitic Diseases, Chinese Center for Disease Control and Prevention (Chinese Center for Tropical Diseases Research), Shanghai, China
[3]Department of nephrology, Southwest Hospital Jiangbei Area (The 958th Hospital of Chinese People's Liberation Army), Chongqing, China
[4]Departments of Pediatric, Ruijin Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, China
[5]Clinical Research and Development Center of Shanghai Municipal Hospitals, Shanghai Hospital Development Center, Shanghai, China

***Corresponding author:**
Wang Bingshun
School of Medicine
Shanghai Jiao
Tong University
China
E-mail: wangbingshun@sjtu.edu.cn

**Submitted:** 8 June 2026; **Accepted:** 16 October 2026
**Online publication:** 26 November 2026

Arch Med Sci
DOI: https://doi.org/10.5114/aoms/241835
Copyright © 2026 Termedia & Banach

## Abstract

**Introduction:** Colorectal cancer (CRC) is an increasing health challenge in low- and middle-income countries (LMICs), where demographic transition, population ageing, and limited access to screening and treatment amplify both health and economic consequences. However, the macroeconomic burden of CRC across LMICs remains insufficiently characterised.
**Material and methods:** We conducted a cross-country macroeconomic valuation study across 122 LMICs using data from the Global Burden of Disease 2023 study. CRC-attributable disability-adjusted life years (DALYs) were monetised using a value of a statistical life year (VSLY) approach to estimate the value of lost welfare (VLW). Country-specific DALY series from 1990 to 2023 were projected to 2050 using exponential smoothing state space models and incorporated into the VLW framework. Results were reported in absolute terms and relative to gross domestic product (GDP). Sensitivity analyses tested alternative income-elasticity assumptions.
**Results:** In 2023, total discounted VLW attributable to CRC across LMICs was Int$1.03 trillion (1.07% of GDP), increasing to Int$1.51 trillion (1.57% of GDP) when undiscounted. By 2050, DALYs are projected to reach 46.73 million, with discounted and undiscounted VLW rising to Int$2.42 trillion and Int$3.51 trillion, respectively. Absolute economic losses were concentrated in upper-middle-income countries, whereas relative burdens were higher in some lower-income and smaller economies. GDP per capita was positively associated with relative economic burden in 2023, with no significant association observed in the 2050 projections. Aggregate welfare losses across LMICs were higher among men than among women.
**Conclusions:** CRC imposes a substantial and uneven macroeconomic burden across LMICs, with divergence between absolute and relative impacts. Macroeconomic valuation may improve priority setting and support context-specific cancer control.

**Key words:** colorectal cancer, low- and middle-income countries, value of lost welfare, economic burden, health economics.

Creative Commons licenses: This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY -NC -SA 4.0). License (http://creativecommons.org/licenses/by-nc-sa/4.0/).

## Introduction

Colorectal cancer (CRC) is a major contributor to the global cancer burden and ranks among the most commonly diagnosed malignancies and the leading causes of cancer-related mortality worldwide [1, 2]. Although CRC is not the leading cancer in terms of incidence or mortality in every setting, its burden has increased steadily over recent decades, driven by population growth, ageing, urbanisation, lifestyle changes, and ongoing epidemiological transitions [3].

These challenges are particularly important in low- and middle-income countries (LMICs), which are experiencing a growing share of the global CRC burden while facing disproportionate challenges in prevention, diagnosis, and treatment [4–6]. At the same time, constrained health-care resources and limited system capacity restrict early detection and effective treatment, amplifying both the clinical and societal consequences of CRC. The convergence of rising disease burden and restricted health-system capacity makes CRC an increasingly important public health and economic challenge and highlights the need for macroeconomic burden assessment in LMICs.

Existing research on CRC has largely focused on epidemiological indicators such as incidence, mortality, and disability-adjusted life-years (DALYs), as well as on screening effectiveness, treatment costs, and individual-level economic burden [3, 7, 8]. These studies provide essential evidence for disease prevention and clinical decision-making. However, clinical and epidemiological measures alone do not fully capture the broader societal welfare losses and macroeconomic pressure associated with CRC. Although previous studies have estimated the global economic impact of CRC, global-level estimates may obscure substantial heterogeneity across countries and income groups and provide limited information on the future economic burden specifically within LMICs. This evidence gap is particularly relevant in resource-constrained settings, where competing health priorities require a clearer understanding of both the absolute magnitude of economic losses and their scale relative to national economic capacity [9].

In recent years, the value of a statistical life year (VSLY) framework and the associated value of lost welfare (VLW) have been increasingly applied to quantify the macroeconomic burden of diseases such as stroke, breast cancer, and dementia [10, 11]. By translating health losses into monetary terms, this approach enhances policy relevance, enables cross-country comparisons, and provides a more comprehensive assessment of societal impact. For LMICs, this framework is especially valuable, as it allows simultaneous evaluation of absolute economic losses and their relative burden in relation to national income.

Building on this approach, and using data from the Global Burden of Disease (GBD) 2023 study alongside health-adjusted life expectancy (HALE) and World Bank macroeconomic indicators, this study aims to estimate the welfare-based economic burden of CRC across 122 LMICs. In addition to current estimates, we provide projections to 2050 under alternative scenarios to capture future trends. Generating such evidence is essential for LMICs, where rising disease burden, constrained resources, and competing priorities necessitate more evidence-based and forward-looking health policy decisions.

## Material and methods

### Study design

We conducted a macroeconomic valuation study with cross-sectional and forecasting components to estimate the economic burden of CRC across LMICs in 2023. We estimated DALYs attributable to CRC using a VSLY framework and expressed the results as VLW. This welfare-based approach follows the full-income framework, which values health losses in monetary terms rather than estimating direct medical costs alone [7, 10–12].

### Data sources

Country-specific CRC DALYs and corresponding 95% uncertainty intervals (UIs) were obtained from the GBD 2023 study. Estimates were extracted for both sexes combined and stratified by sex. HALE was also obtained from GBD and used to approximate remaining healthy life-years for economic valuation [13].

Macroeconomic data were obtained from the World Bank, including gross domestic product (GDP) per capita and total GDP, both expressed in purchasing-power-parity (PPP)-adjusted international dollars. GDP per capita was used to transfer the reference-country value of a statistical life (VSL) to each country, whereas total GDP was used to express welfare losses relative to national economic output.

### Study population

Countries were classified according to the World Bank FY2025 income-group classification (based on 2023 income data) as low-, lower-middle-, upper-middle-, or high-income economies [14, 15]. In this study, LMICs were defined as countries classified as low-, lower-middle-, or upper-middle-income [16, 17]. Country names were harmonised across the GBD and World Bank datasets before merging. Countries without valid macroeconomic

data after harmonisation were excluded. The final analytic sample comprised 122 LMICs.

### Projection of DALYs to 2050

To estimate future burden, we modelled annual CRC DALYs for each country and sex using the historical GBD 2023 time series from 1990 to 2023 and generated forecasts to 2050. Because DALYs are non-negative and annual series do not contain seasonal structure, projections were based on non-seasonal exponential smoothing state space models (ETS) implemented in the forecast package in R [18, 19]. Before model fitting, DALY values were log-transformed after lower-bounding at 1 to avoid undefined values for zero counts and to improve stability of long-horizon forecasts. Forecasts were generated on the log scale and back-transformed to the original scale for reporting.

The optimal model was selected automatically from candidate models with additive or multiplicative errors and no, additive, or damped trends, using the corrected Akaike information criterion (AICc) [19, 20]. If automatic model selection failed to converge, a simple exponential smoothing model was used as a fallback. For each country–sex series, we generated 27 annual forecasts for 2024–2050 and extracted point estimates and 95% prediction intervals (PIs) from the fitted state space model.

Projected DALYs for 2050 were subsequently used in the economic valuation analysis. To isolate changes attributable to disease burden, PPP-adjusted GDP per capita, total GDP, HALE, and the US reference VSL were held constant at their 2023 values.

### Economic valuation framework

Economic burden was estimated using a VSLY-based approach. The US reference VSL was transferred to each country according to differences in PPP-adjusted GDP per capita. Income elasticity (IE), which reflects the responsiveness of VSL to income differences, was set at 1.0 in the base-case analysis and varied to 0.5 and 1.5 in sensitivity analyses. Country-specific VSL estimates were then converted to VSLY by dividing by remaining healthy life expectancy, approximated as one-half of HALE [12].

### Estimation of economic burden

For each country, total welfare loss attributable to CRC was estimated by multiplying DALYs by country-specific VSLY: $VLW = DALYs \times VSLY$.

Relative economic burden was defined as VLW-to-GDP ratio (%), calculated as follows:

$$\text{Relative economic burden (\%)} = \frac{VLW}{GDP} \times 100\%.$$

We estimated both undiscounted and discounted VLW. A 3% annual discount rate was applied. Discounted VLW represents the present value of future health losses, whereas undiscounted VLW reflects the full lifetime welfare loss without discounting.

### Aggregation and stratification

Country-level estimates were aggregated across all LMICs and stratified by World Bank income group (low, lower-middle, and upper-middle income) and sex. Group-level VLW-to-GDP ratios were calculated using aggregated VLW and GDP values to preserve macroeconomic interpretability.

### Uncertainty and sensitivity analyses

Uncertainty intervals for 2023 VLW were derived by propagating the 95% UIs of DALYs through the valuation framework. For the projection analysis, 95% PIs for DALYs were obtained directly from the ETS models and were propagated into projected VLW estimates. Sensitivity analyses were conducted by varying the IE parameter (0.5–1.5). Increasing elasticity reduced absolute VLW estimates but did not materially change the relative ranking of countries or income groups [10].

### Correlation analysis

As an exploratory cross-country analysis, associations between PPP-adjusted GDP per capita and discounted or undiscounted VLW-to-GDP ratio were assessed using two-sided Spearman rank correlations. Analyses were conducted separately for 2023 and 2050 across all 122 LMICs and stratified by sex. Both-sex analyses were also performed within each World Bank income group. The 95% percentile confidence intervals (CIs) were estimated using 2,000 nonparametric bootstrap resamples with country as the resampling unit. *P*-values for the 24 correlation tests were adjusted using the Benjamini–Hochberg (BH) procedure.

### Statistical analysis

All analyses were performed using R version 4.5.2. Data harmonisation, ETS model fitting, forecasting, economic valuation, aggregation, and visualisation were performed using reproducible workflows [19]. The forecast package was used for time-series modelling and projection. Reporting followed the Consolidated Health Economic Evaluation Reporting Standards (CHEERS 2022) [21].

## Results

### Overall welfare-based economic burden of CRC in LMICs

In 2023, the total discounted VLW attributable to CRC across LMICs was Int$1.03 trillion (95% UI: 0.88–1.22), representing 1.07% of GDP,

while the undiscounted VLW reached Int$1.51 billion (1.57% of GDP) (Table I, Figure 1). By 2050, DALYs are projected to increase to 46.73 million, accompanied by a rise in discounted VLW to Int$2.42 trillion and undiscounted VLW to Int$3.51 trillion. Overall, DALYs and discounted VLW are expected to increase by 2.89-fold and 2.35-fold, respectively, driven primarily by projected increases in DALYs (Table I, Supplementary Figure S1).

## Welfare-based economic burden of CRC in LMICs by income group

Substantial variation in CRC-related health and economic burden was observed across income groups. Upper-middle-income countries bore the greatest economic burden, with a discounted VLW of Int$0.85 trillion, accounting for 1.30% of GDP, markedly higher than in lower-middle-income countries (Int$0.17 trillion, 0.58% of GDP) and low-income countries (Int$0.005 trillion, 0.46% of GDP). Under the undiscounted scenario, the corresponding VLW values were Int$1.26 trillion (1.92% of GDP) for upper-middle-income countries, Int$0.25 trillion (0.83%) for lower-middle-income countries, and Int$0.007 trillion (0.64%) for low-income countries. By 2050, upper-middle-income countries are projected to maintain the largest absolute burden, with 22.38 million DALYs, an

**Table I.** CRC-related DALYs, discounted and undiscounted VLW, and VLW-to-GDP ratios across LMICs by sex and World Bank income group in 2023 and 2050 under the IE = 1.0 scenario

| IE = 1.0 | 2023 | | | | | 2050 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Discounted VLW, Int$ trillion (95% UI) | Discounted VLW-to-GDP ratio (%) | Undiscounted VLW, Int$ trillion (95% UI) | Undiscounted VLW-to-GDP ratio (%) | DALYs (million) | Discounted VLW, Int$ trillion (95% PI) | Discounted VLW-to-GDP ratio (%) | Undiscounted VLW, Int$ trillion (95% PI) | Undiscounted VLW-to-GDP ratio (%) | DALYs (million) |
| Both sexes | 1.03 (0.88, 1.22) | 1.07 | 1.51 (1.29, 1.79) | 1.57 | 16.15 | 2.42 (1.35, 32.74) | 2.51 | 3.51 (1.97, 45.76) | 3.64 | 46.73 |
| Sex | | | | | | | | | | |
| Women | 0.40 (0.32, 0.52) | 0.42 | 0.59 (0.47, 0.77) | 0.61 | 6.73 | 1.15 (0.4, 209.4) | 1.19 | 1.66 (0.58, 293.37) | 1.72 | 27.12 |
| Men | 0.64 (0.52, 0.77) | 0.66 | 0.93 (0.76, 1.12) | 0.96 | 9.42 | 1.32 (0.74, 39.35) | 1.37 | 1.91 (1.09, 55.64) | 1.99 | 22.53 |
| World Bank income group | | | | | | | | | | |
| Low income | 0.01 (0, 0.01) | 0.46 | 0.01 (0.01, 0.01) | 0.64 | 0.53 | 0.05 (0.01, 0.55) | 4.32 | 0.07 (0.01, 0.76) | 5.93 | 5.02 |
| Women | 0 (0, 0) | 0.24 | 0 (0, 0.01) | 0.33 | 0.28 | 0.03 (0, 1.47) | 3.07 | 0.05 (0, 2.03) | 4.23 | 3.89 |
| Men | 0 (0, 0) | 0.22 | 0 (0, 0.01) | 0.31 | 0.25 | 0.01 (0, 0.14) | 1.34 | 0.02 (0, 0.2) | 1.83 | 1.42 |
| Lower middle income | 0.17 (0.13, 0.22) | 0.58 | 0.25 (0.19, 0.31) | 0.83 | 4.62 | 0.69 (0.29, 6.5) | 2.33 | 0.98 (0.42, 9.07) | 3.32 | 19.32 |
| Women | 0.08 (0.06, 0.11) | 0.28 | 0.12 (0.08, 0.16) | 0.4 | 2.25 | 0.51 (0.08, 65.98) | 1.71 | 0.72 (0.12, 91.96) | 2.43 | 14.61 |
| Men | 0.09 (0.06, 0.12) | 0.31 | 0.13 (0.09, 0.18) | 0.44 | 2.36 | 0.32 (0.16, 1.33) | 1.10 | 0.46 (0.23, 1.87) | 1.56 | 8.56 |
| Upper middle income | 0.85 (0.75, 1) | 1.3 | 1.26 (1.1, 1.47) | 1.92 | 11.01 | 1.68 (1.05, 25.68) | 2.57 | 2.46 (1.54, 35.93) | 3.75 | 22.38 |
| Women | 0.32 (0.26, 0.41) | 0.48 | 0.47 (0.38, 0.6) | 0.71 | 4.2 | 0.61 (0.31, 141.96) | 0.93 | 0.89 (0.46, 199.38) | 1.36 | 8.62 |
| Men | 0.54 (0.46, 0.64) | 0.83 | 0.8 (0.67, 0.94) | 1.21 | 6.8 | 0.98 (0.58, 37.87) | 1.50 | 1.43 (0.86, 53.57) | 2.18 | 12.56 |

*CRC – colorectal cancer, DALYs – disability-adjusted life years, GDP – gross domestic product, IE – income elasticity, PI – prediction interval, UI – uncertainty interval, Int$ – international dollars at constant 2023 prices, VLW – value of lost welfare.*

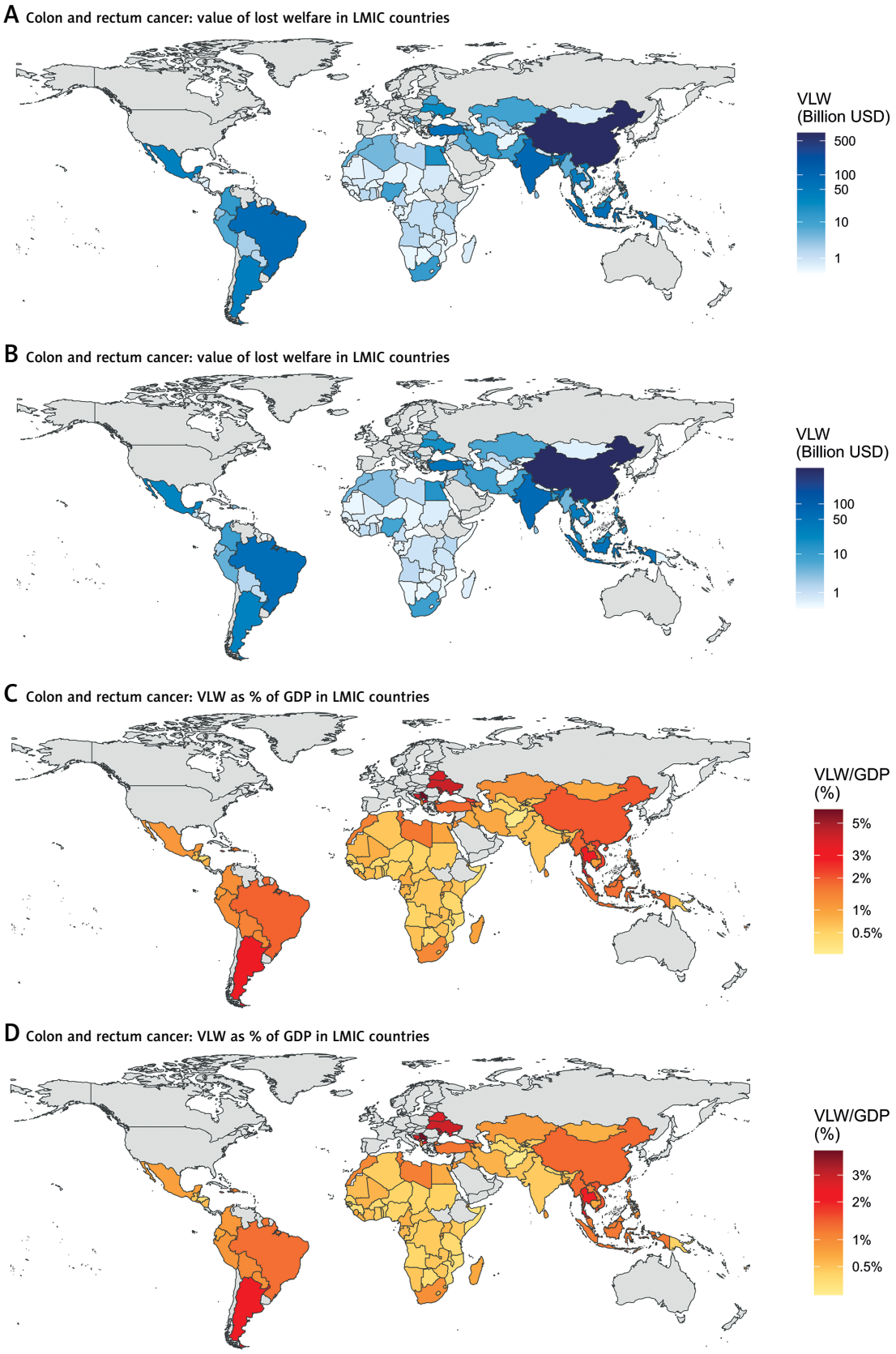


**Figure 1.** Geographic distribution of discounted and undiscounted VLW and VLW-to-GDP ratios for CRC across 122 LMICs in 2023, IE = 1.0. The colour gradient reflects the range of values, with darker colours indicating higher burdens. **A** – undiscounted VLW; **B** – discounted VLW; **C** – undiscounted VLW-to-GDP ratio; **D** – discounted VLW-to-GDP ratio. The maps present country-level point estimates, with corresponding 95% UIs provided in Supplementary Table SI

undiscounted VLW of Int$2.46 trillion (3.75% of GDP), and a discounted VLW of Int$1.68 trillion (2.57% of GDP). Although low-income countries are expected to have lower absolute VLW (undiscounted: Int$66.41 billion; discounted: Int$48.32 billion), they are projected to experience the steepest relative increases: the VLW-to-GDP ratio is expected to rise from 0.64% to 5.93% (undiscounted) and from 0.46% to 4.32% (discounted) (Figure 2, Table I).

## Welfare-based economic burden of CRC in LMICs by sex

In 2023, aggregate VLW across LMICs was higher among men than among women, although this pattern varied by income group. Discounted VLW was Int$0.64 billion among men, corresponding to 0.66% of GDP, compared with Int$0.40 billion and 0.42% of GDP among women. Undiscounted VLW was Int$0.93 trillion among men and Int$0.59 trillion among women (Supplementary Figures S2–S4, Table I). In 2023, sex differences were most pronounced in upper-middle-income countries, where discounted VLW was Int$0.54 trillion among men and Int$0.32 trillion among women, corresponding to 0.83% and 0.48% of GDP, respectively. Smaller differences were observed in lower-middle-income countries, whereas discounted VLW was similar between men and women in low-income countries (Figure 3, Table I). By 2050, aggregate VLW across LMICs was projected to remain higher among men than among women. However, sex-specific patterns varied across income groups: projected VLW was higher among women in low- and lower-middle-income countries, but remained higher among men in upper-middle-income coun-

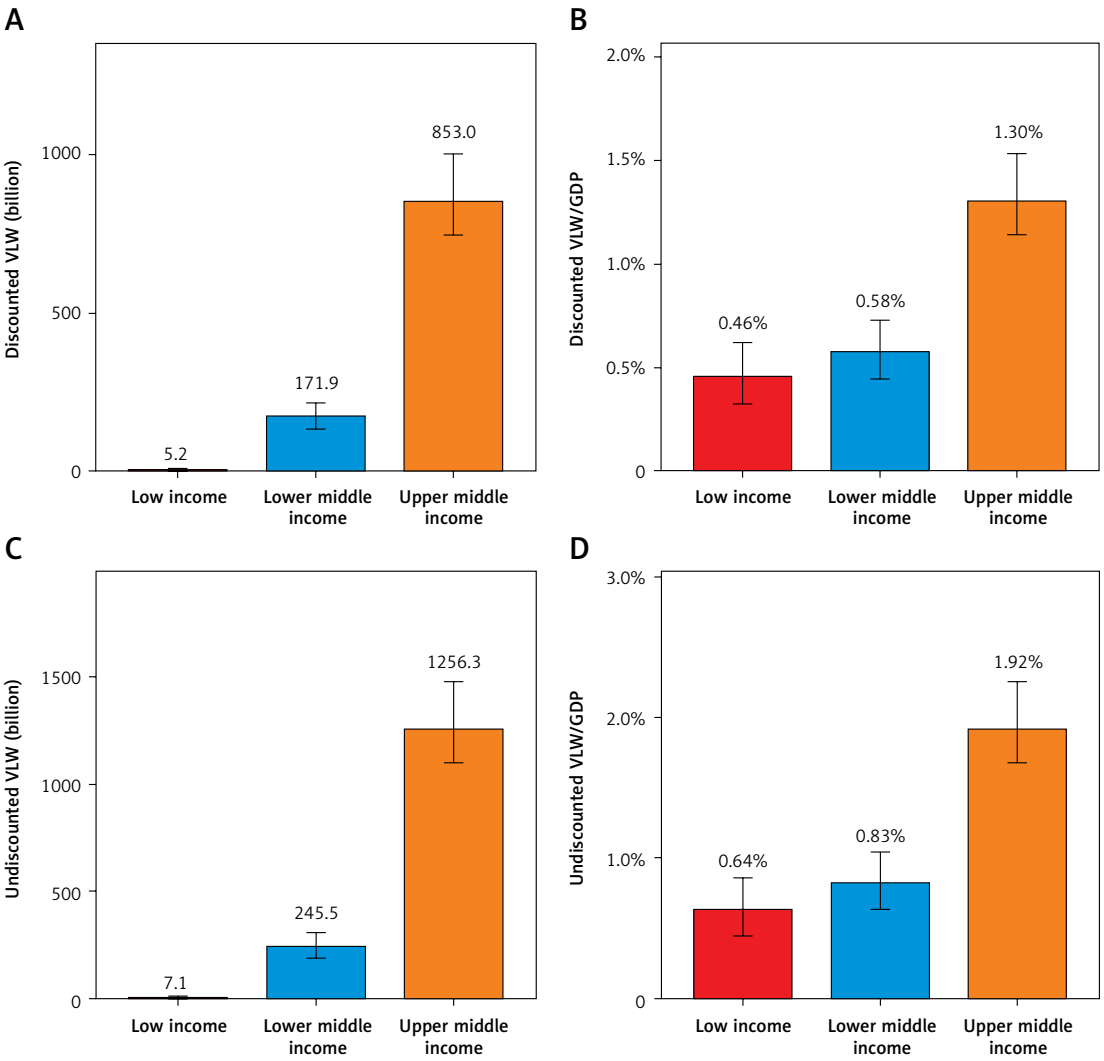


**Figure 2.** Discounted and undiscounted VLW and VLW-to-GDP ratios for CRC by income group across LMICs in 2023 and 2050, IE = 1.0. Data are presented for low-income (red), lower-middle-income (blue), and upper-middle-income (orange) countries. Error bars represent 95% UIs for the 2023 estimates and 95% PIs for the 2050 projections. Panels **A**–**D** present the 2023 estimates: (**A** – discounted VLW; **B** – discounted VLW-to-GDP ratio; **C** – undiscounted VLW; **D** – undiscounted VLW-to-GDP ratio)

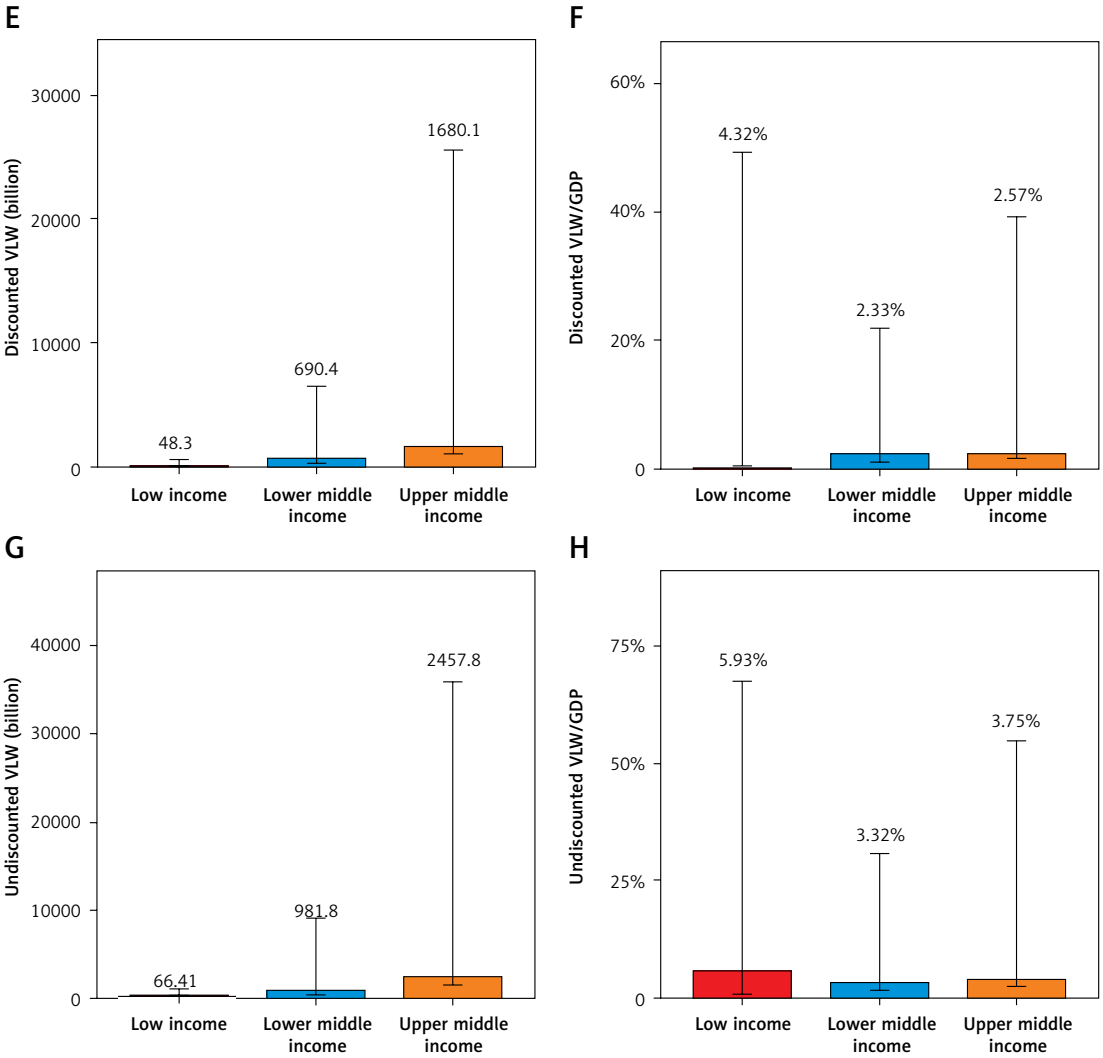


**Figure 2.** Cont. Panels **E**–**H** present the 2050 projections (**E** – discounted VLW; **F** – discounted VLW-to-GDP ratio; **G** – undiscounted VLW; **H** – undiscounted VLW-to-GDP ratio)

tries. These findings indicate substantial heterogeneity in projected sex-specific economic burden across income groups (Figure 3, Table I).

## National welfare-based economic burden of CRC in LMICs

Across the 122 LMICs, CRC-related economic and health burdens were unevenly distributed, with Figure 4 showing the top 10 countries in terms of both absolute VLW and VLW-to-GDP ratios.

The highest absolute losses were concentrated in upper-middle-income countries, which also showed the greatest between-country variation. Absolute VLW was dominated by large economies, including China (Int$489.14 billion), Brazil (Int$58.46 billion), and Indonesia (Int$52.19 billion) under the discounted scenario, with China alone exceeding Int$569 billion under the undiscounted scenario. Several medium-sized economies had disproportionately high VLW-to-GDP ratios, with Serbia, the Republic of Moldova, Ukraine, and Bosnia and Herzegovina exceeding 1.7% under the discounted scenario (0.3–1.0% in most upper-middle-income countries) and surpassing 3% under the undiscounted scenario. Among lower-middle-income countries, absolute VLW was highest in populous economies, particularly India (Int$66.96 billion) and Vietnam (Int$23.04 billion), with undiscounted values exceeding Int$115 billion and Int$44 billion, respectively. Vietnam, in particular, exceeded 1.5% under the discounted scenario and approached 3% under the undiscounted scenario, representing one of the highest relative burdens in this income group. Low-income countries experienced smaller absolute and relative losses, with the highest discounted VLW observed in Uganda (Int$0.89 billion) and the Democratic Republic of the Congo (Int$0.83 billion). VLW-to-GDP ratios were generally below 1%, except for a few smaller economies such as Rwanda (Supplementary Table SI).

By 2050, the disease burden is projected to continue increasing in the largest economies, with China, Brazil, and India remaining the countries with the highest VLW. China is expected to reach 8.99 million DALYs, with an undiscounted VLW of Int$1.04 trillion (2.94% of GDP) and a discounted VLW of Int$701.70 billion (1.98% of GDP). Brazil is projected to reach 2.43 million DALYs, with an undiscounted VLW of Int$255.83 billion (5.72% of GDP) and a discounted VLW of Int$176.44 billion (3.95% of GDP). India's burden is expected to rise to 4.24 billion DALYs, with a discounted VLW of Int$161.45 billion (1.09% of GDP). Notably, projections highlight extremely large relative increases in some smaller economies: DALYs attributable to CRC in Equatorial Guinea and the Congo (The Democratic Republic of the Congo or the Republic of the Congo? Two different countries.!!!!!!!!!!!!) are expected to grow by more than 3000% (Supplementary Figure S5), with corresponding discounted VLW-to-GDP ratios of 23.76% and 13.62%, respectively (Supplementary Table SII).

## Correlation between economic burden and GDP per capita

In 2023, GDP per capita was positively correlated with both discounted VLW-to-GDP ratio (Spearman's ρ = 0.61; 95% bootstrap CI, 0.47–0.72;

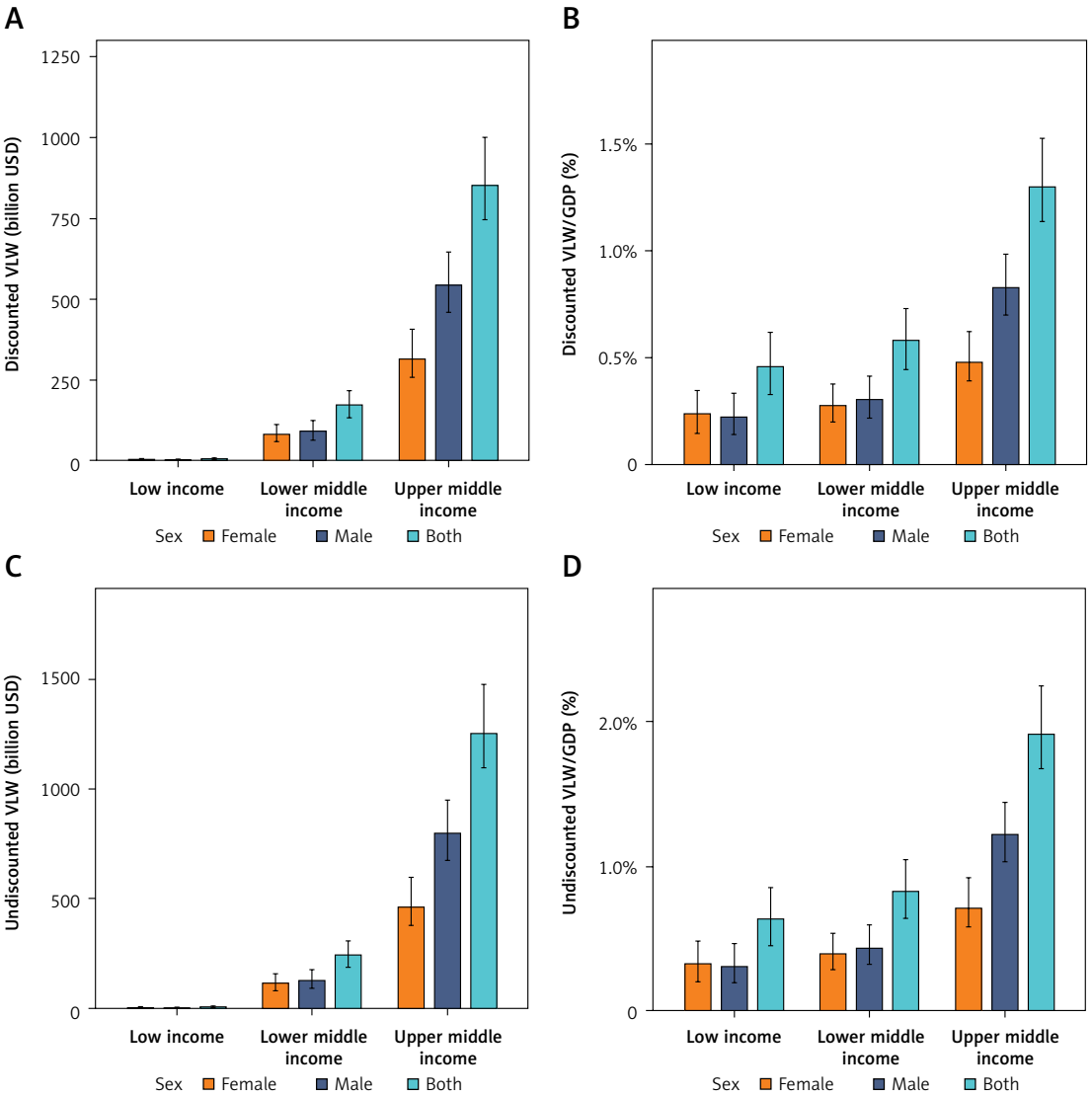


**Figure 3.** Discounted and undiscounted VLW and VLW-to-GDP ratios for CRC across LMICs in 2023 and 2050, stratified by income group and sex, IE = 1.0. The bar chart presents discounted and undiscounted VLW and VLW-to-GDP ratios for CRC across low-income, lower-middle-income, and upper-middle-income countries in 2023 and 2050. Results are stratified by sex, including women (red bars), men (dark blue bars), and both sexes combined (light blue bars). Bar heights represent point estimates, and error bars represent 95% UIs for the 2023 estimates and 95% PIs for the 2050 projections. Panels **A**–**D** present the 2023 estimates (**A** – discounted VLW; **B** – discounted VLW-to-GDP ratio; **C** – undiscounted VLW; **D** – undiscounted VLW-to-GDP ratio)

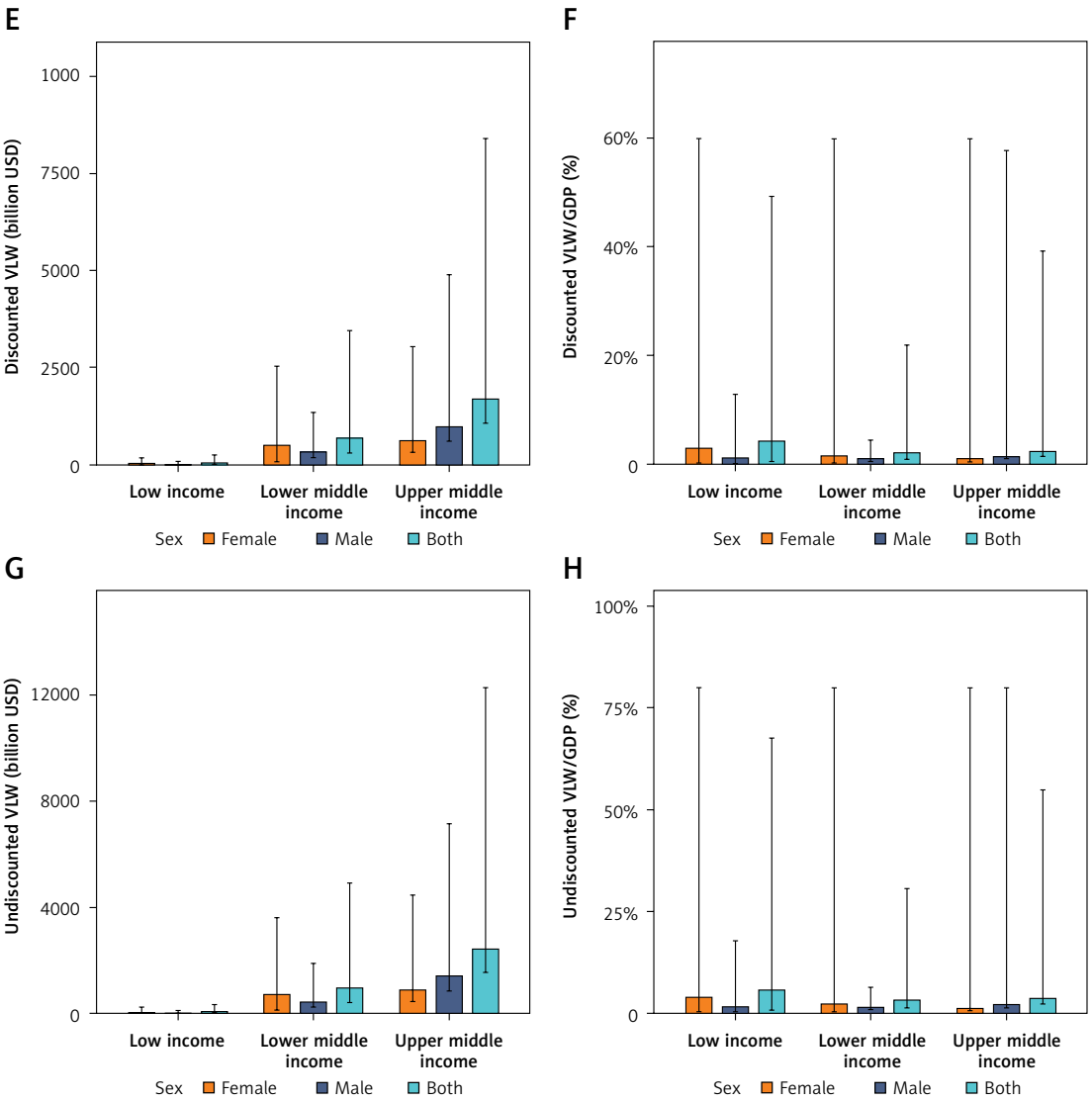


**Figure 3.** Cont. Panels **E**–**H** present the 2050 projections (**E** – discounted VLW; **F** – discounted VLW-to-GDP ratio; **G** – undiscounted VLW; **H** – undiscounted VLW-to-GDP ratio)

BH-adjusted $p < 0.001$) and undiscounted VLW-to-GDP ratio (ρ = 0.62; 95% CI: 0.49–0.73; BH-adjusted $p < 0.001$) across the 122 LMICs. Similar positive trends were observed in both male- and female-specific analyses. Within income groups, the associations were strongest in upper-middle-income countries, whereas no significant association was observed in low-income countries. In contrast, no significant overall association was observed in the 2050 projections for either discounted VLW-to-GDP ratio (ρ = –0.06; 95% CI: –0.23 to 0.13; BH-adjusted $p = 0.655$) or undiscounted VLW-to-GDP ratio (ρ = –0.04; 95% CI: –0.22 to 0.14; BH-adjusted $p = 0.783$). Sex-stratified results also showed less consistent patterns in 2050, and none of the within-income-group associations remained significant. Detailed results are presented in Figure 5 and Supplementary Table SIII.

## Sensitivity analysis

Sensitivity analyses were conducted using IE values of 0.5 and 1.5. Across LMICs, increasing IE from 0.5 to 1.5 resulted in a substantial reduction in estimated economic burden (Supplementary Figure S6). Undiscounted VLW decreased from Int$3.05 trillion to Int$0.78 trillion, while discounted VLW decreased from Int$2.09 trillion to Int$0.53 trillion, with corresponding reductions in VLW-to-GDP ratios (Supplementary Tables SIV, SV). Although discounting reduced the absolute magnitude of VLW, it did not alter the overall patterns or rankings across countries and income groups. Across the 122 countries, clear differences by income level were observed. As IE increased, undiscounted VLW declined from Int$42.17 billion to Int$1.23 billion in low-income countries, from Int$691.39 billion to Int$89.28 billion in lower-middle-income countries, and from Int$2.32

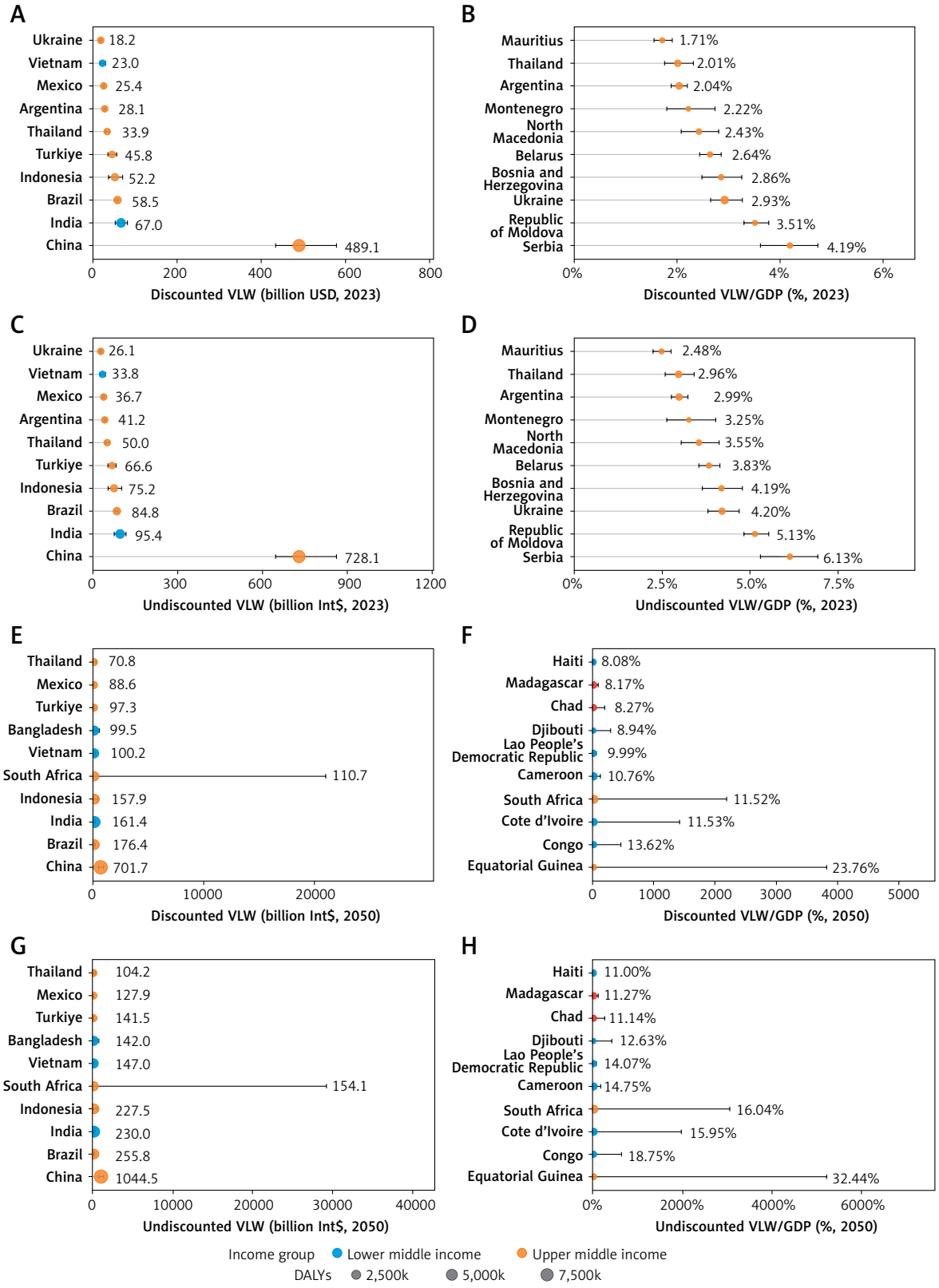


**Figure 4.** Discounted and undiscounted VLW and VLW-to-GDP ratios for CRC across the top 10 countries among the 122 LMICs in 2023 and 2050, IE = 1.0. Each dot represents a country, with colour indicating World Bank income classification, including lower-middle-income (blue) and upper-middle-income (orange) groups. Bubble size corresponds to total DALYs, and horizontal error bars represent 95% UIs for the 2023 estimates and 95% PIs for the 2050 projections. Panels **A**–**D** present the 2023 estimates (**A** – discounted VLW; **B** – discounted VLW-to-GDP ratio; **C** – undiscounted VLW; **D** – undiscounted VLW-to-GDP ratio). Panels **E**–**H** present the 2050 projections (**E** – discounted VLW; **F** – discounted VLW-to-GDP ratio; **G** – undiscounted VLW; **H** – undiscounted VLW-to-GDP ratio)

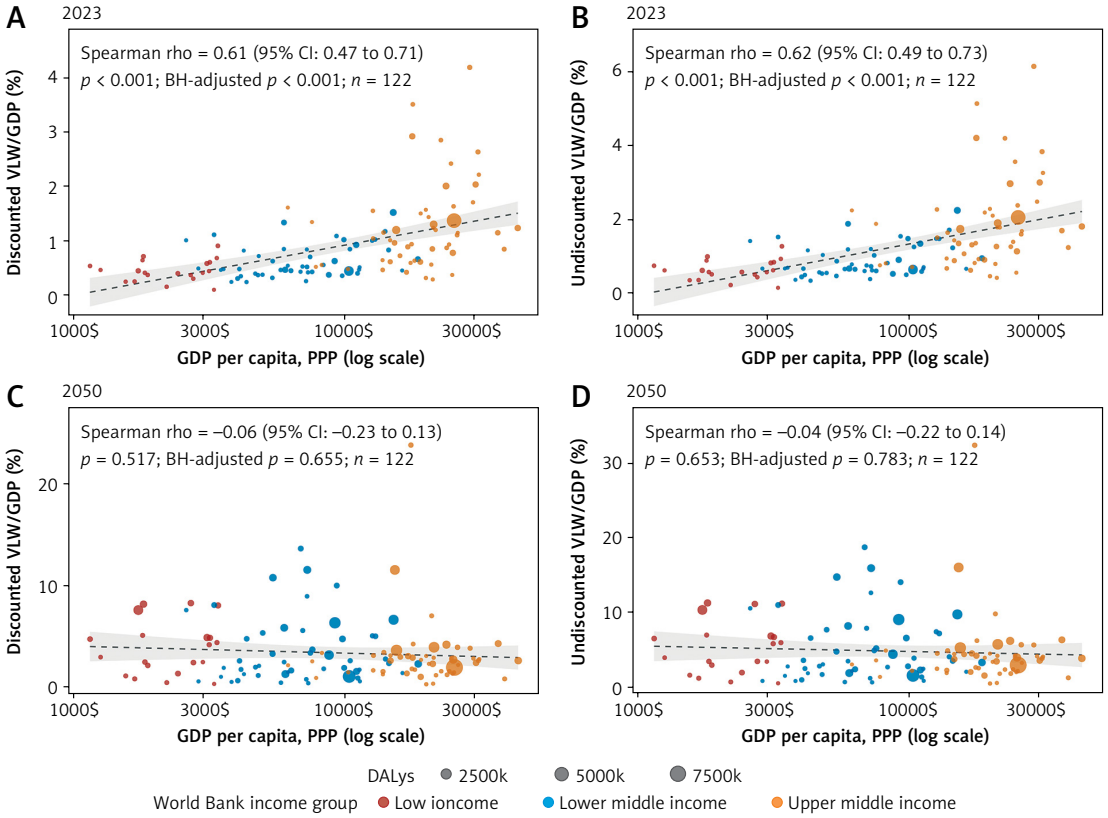


**Figure 5.** Correlation between discounted and undiscounted economic burden of CRC and GDP per capita across LMICs in 2023 and 2050, IE = 1.0. Each bubble represents one of the 122 LMICs. Bubble colour indicates income group, including low-income (red), lower-middle-income (blue), and upper-middle-income (orange) categories. Bubble size corresponds to total DALYs. Spearman rank correlation coefficients, 95% bootstrap CIs, and BH-adjusted *p*-values are shown. Lines represent descriptive linear fits. Panels **A**–**B** present the 2023 estimates (**A** – discounted VLW-to-GDP ratio vs. GDP per capita; **B** – undiscounted VLW-to-GDP ratio vs. GDP per capita). Panels **C**–**D** present the 2050 projections (**C** – discounted VLW-to-GDP ratio vs. GDP per capita; **D** – undiscounted VLW-to-GDP ratio vs. GDP per capita)

billion to Int$0.69 trillion in upper-middle-income countries (Supplementary Figures S7–S9 and Supplementary Tables SIV, SV).

Sex-specific analyses showed consistent patterns across scenarios. As IE increased, VLW estimates decreased for both men and women, but the relative distribution between sexes remained stable, with men consistently accounting for a higher proportion of VLW in most income groups (Supplementary Figure S6 and Supplementary Tables SIV, SV). At the country level, most country–sex combinations showed substantial declines in VLW as IE increased, with the largest absolute reductions observed in upper-middle-income countries (Supplementary Tables SVI, SVII).

Furthermore, the positive association between VLW-to-GDP ratios and GDP per capita became more pronounced as IE increased. Importantly, the overall conclusions remained robust, with no change in the direction of associations across scenarios. These sensitivity results are presented in Supplementary Figures S10, S11.

## Discussion

This study provides a comprehensive, LMIC-focused assessment of the welfare-based economic burden of CRC across 122 countries. By comparing absolute and relative welfare losses and projecting country- and sex-specific burdens to 2050, it extends previous research by highlighting the heterogeneity and long-term economic consequences of CRC within LMICs. Our findings indicate that CRC imposes a substantial and growing health and economic burden in LMICs. In 2023, the total discounted VLW attributable to CRC reached Int$1.03 billion, corresponding to 1.07% of GDP, while the undiscounted VLW was Int$1.51 trillion (1.57% of GDP). By 2050, DALYs are projected to rise to 46.73 million, with discounted and undiscounted VLW increasing to Int$2.42 trillion and Int$3.51 trillion, respectively, representing a 2–3-fold increase driven primarily by projected increases in DALYs. These findings are consistent with broader evidence showing that CRC remains a major con-

tributor to global morbidity and mortality and is rising in populations undergoing demographic and epidemiological transitions [22–25].

A key finding of this study is the divergence between absolute welfare losses and relative economic burden. Total VLW is concentrated in upper-middle-income countries, likely reflecting larger populations, more advanced population ageing, and higher aggregate CRC burden. In contrast, lower-income countries may experience greater proportional economic strain due to limited economic capacity and weaker health-system resilience. Smaller countries such as Equatorial Guinea and the Congo are projected to face extremely large relative increases in both DALYs and VLW-to-GDP ratios, exceeding 3000% in DALYs by 2050. Similar discrepancies between absolute and relative burden have been reported in analyses of other major chronic diseases, suggesting that proportional economic impact may be particularly informative for priority setting in resource-constrained settings [7, 11, 26, 27]. These findings underscore the importance of considering both absolute and relative burdens when planning health and economic interventions.

Importantly, our findings reinforce that LMICs should not be treated as a homogeneous group. Previous studies have shown substantial inequalities in CRC burden across regions, sociodemographic strata, and health-system contexts [28–31]. Our results extend this literature by showing that such heterogeneity is also reflected in macroeconomic outcomes, with wide variation in both VLW and VLW-to-GDP ratios across countries. These differences probably arise from a combination of demographic structure, exposure to modifiable risk factors, screening coverage, diagnostic infrastructure, stage at diagnosis, and access to effective treatment [31–34]. This pattern underscores the need for country-specific cancer control strategies rather than uniform policy responses across LMICs.

We also observed consistent sex differences in the economic burden of CRC, with higher welfare losses among men in most settings. This finding is broadly aligned with previous epidemiological evidence showing higher incidence and mortality among men, partly attributable to differences in smoking, alcohol use, adiposity, diet, and screening uptake [35–38]. While the magnitude of these disparities varied across income groups, the smaller sex differences observed in low-income countries indicate that socio-economic and behavioural factors, rather than biological differences alone, largely determine these patterns. These findings underscore the importance of sex-specific prevention and early detection strategies [39], including targeted risk-reduction interventions for men and enhanced screening outreach [40, 41], to reduce inequalities in colorectal cancer burden.

Methodologically, this study underscores the added value of employing a VSLY framework to quantify the economic burden of disease. Traditional metrics such as DALYs describe health losses but often miss broader welfare and macroeconomic implications. By translating health losses into monetary terms, the VSLY-based VLW framework provides a policy-relevant measure that may facilitate cross-country comparisons and evidence-based resource allocation, which is particularly important for LMICs with constrained budgets [27]. In 2023, GDP per capita was positively associated with both discounted and undiscounted VLW-to-GDP ratios across LMICs, with similar positive patterns observed in both sexes and the strongest evidence found in upper-middle-income countries. Although the overall correlations were attenuated and did not reach statistical significance in the 2050 projections, the differing patterns across sexes and income groups suggest that the relationship between national income and relative welfare burden may evolve over time and warrants further investigation. Given that GDP per capita contributes to the transfer of VSL/VSLY and GDP is included in the denominator of the VLW-to-GDP ratio, these findings should be interpreted as exploratory patterns within the valuation framework. Future studies incorporating age-standardised incidence, prevalence, and mortality rates, together with indicators of screening coverage and health-system capacity, may help clarify how epidemiological transitions and differences in access to care shape the long-term economic burden of CRC.

Several limitations should be acknowledged. First, the estimates rely on GBD-derived DALYs and are therefore subject to uncertainty related to data availability and modelling assumptions [22]. Second, the VSL transfer approach depends on assumptions regarding income elasticity and the use of a reference-country VSL, which may not fully reflect local preferences [42]. Third, the approximation of remaining healthy life expectancy using HALE introduces additional uncertainty. Finally, although discounting was applied, alternative discount rates may affect the magnitude of estimates. Despite these limitations, our findings suggest that CRC imposes a substantial and uneven macroeconomic burden across LMICs and support the integration of macroeconomic evidence into cancer control strategies.

In conclusion, CRC represents a substantial and unevenly distributed health and economic burden across LMICs, with absolute losses concentrated in large economies and relative burdens disproportionately affecting smaller or medium-sized

countries. Sex-specific differences and the amplification of economic loss in wealthier LMICs further highlight the potential value of tailored, evidence-based prevention strategies and equitable resource allocation. These findings may inform national and regional CRC control policies in LMICs.

## Data availability statement

The datasets analysed during the current study are available at https://vizhub.healthdata.org/gbd-results, and the World Bank's World Development Indicators database (https://databank.worldbank.org/databases).

## Funding

This work was supported by the National Key R&D Program of China [2023YFC2605400]; the National Natural Science Foundation of China (NSFC) [32030020, 32288101]; Clinical Research Program of the Shanghai Municipal Health Commission (20254Y0040); the Shanghai Science and Technology Commission [23DZ2290600]; Shanghai Jiao Tong University School of Medicine Project (WK2509); the Office of Global Partnerships (Key Projects Development Fund).

## Ethical approval

This study used publicly available, aggregated data from the GBD 2023 study and the World Bank and did not involve identifiable individual-level data. The GBD study protocol was approved by the University of Washington Institutional Review Board.

## Conflict of interest

The authors declare no conflict of interest.

## References

1. Bray F, Laversanne M, Sung H, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 2024; 74: 229-63.
2. Lopez BAA, Pinto-Colmenarez R, Caliwag FMC, et al. Colorectal cancer screening and management in low- and middle-income countries and high-income countries: a narrative review. Cureus 2024; 16: e70933.
3. Afolaranmi O, Diehl TM, Virani SS, et al. Survival following colorectal cancer surgery in low- and middle-income countries: a systematic review and meta-analysis. J Surg Oncol 2026; 133: 872-80.
4. Hämmerl L, Mezger NCS, Seraphin TP, et al. Treatment and survival among patients with colorectal cancer in Sub-Saharan Africa: a multicentric population-based follow-up study. J Natl Compr Canc Netw 2023; 21: 924-33.e7.
5. Tao M, Zhang P, Yang W, et al. Global, regional, and national burden of disease attributable to a diet low in milk, 1990–2021: an updated analysis of the Global Burden of Disease study 2021. J Dairy Sci 2025; 108: 4558-72.
6. Lv W, Wang S, Duan L, et al. Estimating the global macroeconomic impact of colorectal cancer: evidence from Global Burden of Disease 2021 and Value of a Statistical Life Year framework. Int J Surg 2026; 112: 9577-86.
7. Gerstl JVE, Blitz S, Qu QR, et al. Global, regional, and national economic consequences of stroke. Stroke 2023; 54: 2380-9.
8. Matyja M, Pasternak A, Szura M, et al. How to improve the adenoma detection rate in colorectal cancer screening? Clinical factors and technological advancements. Arch Med Sci 2019; 15: 424-33.
9. Horton S, Gauvreau CL. Cancer in Low- and Middle-Income Countries: An Economic Overview, in Cancer: Disease Control Priorities, Third Edition, H. Gelband, et al., Editors. 2015, The International Bank for Reconstruction and Development/The World Bank: Washington, DC.
10. Chen S, Cao Z, Nandi A, et al. The global macroeconomic burden of Alzheimer's disease and other dementias: estimates and projections for 152 countries or territories. Lancet Glob Health 2024; 12: e1534-43.
11. Ranganathan K, Singh P, Raghavendran K, et al. The global macroeconomic burden of breast cancer: implications for oncologic surgery. Ann Surg 2021; 274: 1067-72.
12. Zheng J, Yao L, Lei K, et al. Economic burden attributable to high BMI-caused cancers: a global level analysis between 2002 and 2021. BMC Med 2025; 23: 297.
13. GBD 2021 Diseases and Injuries Collaborators. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet 2024; 403: 2133-61.
14. GBD 2023 Cancer Collaborators. The global, regional, and national burden of cancer, 1990-2023, with forecasts to 2050: a systematic analysis for the Global Burden of Disease Study 2023. Lancet 2025; 406: 1565-86.
15. The World, B. World Bank Country and Lending Groups. 2024/10/11; Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
16. Zhong H, Yu S, Huang Y, Xuan F. Temporal trends in mortality of female cancers among women and the impact of COVID-19 in low- and middle-income countries, 1990-2023: an age-period-cohort analysis from the Global Burden of Disease Study 2023. Int J Womens Health 2026; 18: 581359.
17. Wang C, Sun Y, Jiang D, Wang C, Liu S. Risk-attributable burden of ischemic heart disease in 137 low- and middle-income countries from 2000 to 2019. J Am Heart Assoc 2021; 10: e021024.
18. Erbas B, Hyndman RJ, Gertig DM. Forecasting age-specific breast cancer mortality using functional data models. Stat Med 2007; 26: 458-70.
19. Hyndman RJ, Khandakar Y. Automatic time series forecasting: the forecast Package for R. J Stat Software 2008; 27: 1-22.
20. Hurvich CM, Tsai CL. Regression and time series model selection in small samples. Biometrika 1989; 76: 297-307.
21. Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. Value Health 2022; 25: 3-9.

22. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet 2020; 396: 1204-22.
23. He Y, Wang X, Zhou M, et al. Global, regional and national burden of colon and rectum cancer: a systematic analysis of prevalence, incidence, deaths and DALYs from 1990 to 2021 using data from the Global Burden of Disease Study 2021 with projections to 2036. BMJ Open 2025; 15: e100042.
24. Arnold M, Sierra MS, Laversanne M, et al. Global patterns and trends in colorectal cancer incidence and mortality. Gut 2017; 66: 683-91.
25. Islami F, Marlow EC, Thomson B, et al. Proportion and number of cancer cases and deaths attributable to potentially modifiable risk factors in the United States, 2019. CA Cancer J Clin 2024; 74: 405-32.
26. Jamison DT, Summers LH, Alleyne G, et al. Global health 2035: a world converging within a generation. Lancet 2013; 382: 1898-955.
27. Kazi DS, Elind MSV, Deutsch A, et al. Forecasting the economic burden of cardiovascular disease and stroke in the United States through 2050: a presidential advisory from the American Heart Association. Circulation 2024; 150: e89-101.
28. Dekker E, Tanis PJ, Vleugels JLA, Kasi PM, Wallace MB. Colorectal cancer. Lancet 2019; 394: 1467-80.
29. Murphy CC, Harlan LC, Lund JL, et al. Patterns of colorectal cancer care in the United States: 1990-2010. J Natl Cancer Inst 2015; 107: djv198.
30. Wong MC, Ding H, Wang J, Chan PSF, Huang J. Prevalence and risk factors of colorectal cancer in Asia. Intest Res 2019; 17: 317-29.
31. Favoriti P, Carbone G, Greco M, Pirozzi F, Pirozzi REM, Corcione F. Worldwide burden of colorectal cancer: a review. Updates Surg 2016; 68: 7-11.
32. Yu KX, Yuan WJ, Huang CH, et al. Socioeconomic deprivation and survival outcomes in patients with colorectal cancer. Am J Cancer Res 2022; 12: 829-38.
33. Carethers JM. Racial and ethnic disparities in colorectal cancer incidence and mortality. Adv Cancer Res 2021; 151: 197-229.
34. Poulson MR, Geary A, Annesi C, Dechert T, Kenzik K, Hall J. The impact of income and social mobility on colorectal cancer outcomes and treatment: a cross-sectional study. Ann Surg 2022; 275: 546-50.
35. Tsokkou S, Konstantinidis I, Papakonstantinou M, et al. Sex differences in colorectal cancer: epidemiology, risk factors, and clinical outcomes. J Clin Med 2025; 14: 5539.
36. González-Flores E, Garcia-Carbonero R, Élez E, et al. Gender and sex differences in colorectal cancer screening, diagnosis and treatment. Clin Transl Oncol 2025; 27: 2825-37.
37. van Erning FN, Greidanus NEM, Verhoeven RHA, et al. Gender differences in tumor characteristics, treatment and survival of colorectal cancer: a population-based study. Cancer Epidemiol 2023; 86: 102441.
38. Kuipers EJ, Grady WM, Lieberman D, et al. Colorectal cancer. Nat Rev Dis Primers 2015; 1: 15065.
39. Rolfo C, Russo A. The next frontier for colorectal cancer screening: blood-based tests. Cancer Res 2024; 84: 3128-9.
40. Waldmann E, Jiricka L, Zessner-Spitzenberg J, et al. Differences between men and women with respect to colorectal cancer mortality despite screening colonoscopy. Gastrointest Endosc 2024; 99: 998-1005.e2.
41. Shao M, Yu J, Dai S, Zhang W. Transcobalamin I: a potential diagnostic biomarker and therapeutic target for deep venous thrombus in colorectal cancer. Arch Med Sci 2025; 21: 2868-71.
42. Robinson LA, Hammitt JK, O'Keeffe L. Valuing mortality risk reductions in global benefit-cost analysis. J Benefit Cost Anal 2019; 10 (Suppl 1): 15-50.