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CLINICAL RESEARCH
Heart failure and cardiomyopathies

Heart failure in China: a macroeconomic modelling study of intervention strategies

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See the editorial comment for this article 'Heart failure and economic resilience: why China's decade-long projection matters', by C.S.P. Lam *et al*., https://doi.org/10.1093/eurheartj/ehaf901.

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Abstract

Background and Aims Heart failure (HF) imposes a growing public health and macroeconomic burden in low- and middle-income countries (LMICs), yet its long-term economic impact remains unquantified. China, characterized by rapid ageing and escalating cardiovascular risks, provides a critical setting to model HF economic implications.

Methods Using data from the Global Burden of Disease Study 2021, China Cardiovascular Association Registry, and national insurance databases, HF macroeconomic burden (2025–35) was projected via a health-augmented macroeconomic model. Three interventions were evaluated: B-type natriuretic peptide (BNP) screening (adults ≥40 years), intensive blood pressure (BP) control (hypertensive patients), and guideline-directed medical therapy (GDMT) optimization for HF with reduced ejection fraction. Costs are reported in 2017 international dollars (INT$).

Results By 2035, HF cases in China will reach 22.7 million [95% uncertainty interval (UI): 9.5–36.9 million], with an age-standardized prevalence of 760.65/100 000 (95% UI: 283.2–1340.8/100 000). The cumulative economic burden (2025–35) is INT$1001.1 billion (95% UI: 733.4–1365.6 billion), representing 0.26% of gross domestic product (95% UI: 0.19%–0.34%), driven by labour force attrition (72.1%; 95% UI: 64.4%–74.8%). Interventions reduced the total burden by 12.5% (95% UI: 10.4%–14.5%): BNP screening (25% coverage) saved INT$78.5 billion (95% UI: 62.8–94.1 billion; 8.10% reduction; cost-benefit ratio 0.49), Intensive BP control saved INT$27.5 billion (95% UI: 25.1–29.9 billion; 2.74% reduction; ratio 0.22), GDMT optimization saved INT$17.0 billion (95% UI: 12.8–22.4 billion; 1.70% reduction; ratio 0.48).

Conclusions HF imposes a substantial and increasing macroeconomic burden in China, largely through workforce productivity losses. Scalable, cost-effective strategies, including primary care-based BNP screening, subsidized hypertension control, and enhanced GDMT adherence, are essential to curb economic losses. These findings inform policy priorities for China and other LMICs confronting demographic transitions.

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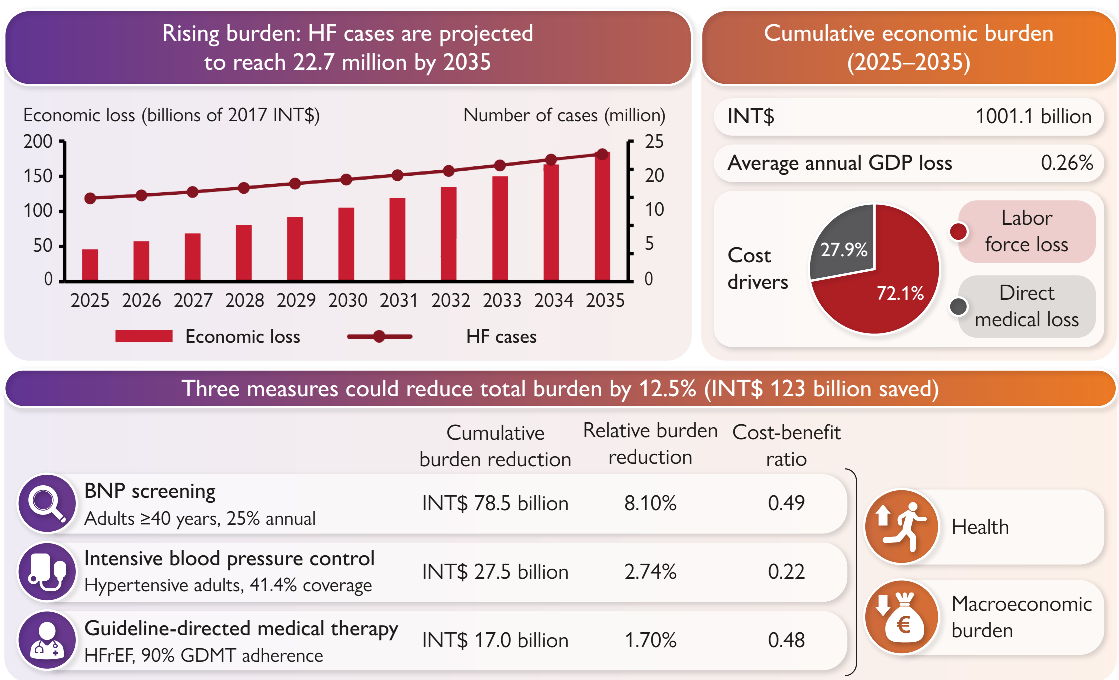
Structured Graphical Abstract

Key Question
What is the projected macroeconomic burden of heart failure (HF) in China (2025–2035)? Which scalable interventions can effectively mitigate it?

Key Finding
The projected 22.7 million HF cases by 2035 and international dollars (INT$) 1,001 billion in economic losses was found to be mitigated by 12.5% via brain natriuretic peptide (BNP) screening, intensive blood pressure (BP) control, and global guideline-directed medical therapy (GDMT) for heart failure with reduced ejection fraction.

Take Home Message
Cost-effective mitigation of China's HF burden requires integrating BNP screening into primary care, scaling GDMT optimization, and subsidizing intensive BP control. This comprehensive strategy safeguards economic growth and aligns with national health goals.



BNP, B-type natriuretic peptide; **GDP**, gross domestic product; **GDMT**, guideline-directed medical therapy; **HF**, heart failure; **HFrEF**, heart failure with reduced ejection fraction; **INT$**, international dollars

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The macroeconomic modelling study projecting that heart failure in China will accumulate an economic burden of INT$1001.1 billion (2025–2035), and three evidence–based interventions (BNP screening, intensive BP control, and GDMT optimization) could mitigate 12.5% of this burden.

Keywords Heart failure • Macroeconomic burden • Cost-benefit interventions • B-type natriuretic peptide • Guideline-directed medical therapy

Introduction

Heart failure (HF), the final stage of cardiovascular diseases (CVDs), affects over 64 million people globally, a number projected to rise with population ageing and improved survival after acute cardiac events.[1,2] In China, an estimated 12.1 million adults have HF, against a backdrop of 245 million with hypertension and 140 million with diabetes.[3,4] The rapidly ageing population and increasing CVD risk factors pose a severe challenge to public health and socioeconomic stability, underscoring the urgent need for effective HF management strategies.[5,6]

The economic impact of HF is two-fold. First, premature mortality and chronic disability in the working-age population reduce labour supply and productivity. Second, financial burdens on households, health systems, and insurers divert resources from productive investments in education, infrastructure, and business. These dynamics risk perpetuating poverty cycles and jeopardizing long-term development.

Existing literature on HF economic burden focuses predominantly on direct medical costs in high-income countries.[2] Such frameworks are less applicable to low- and middle-income countries (LMICs) like China, where labour-intensive economies mean health threats like HF affect a larger segment of the workforce, albeit with lower per-capita productivity loss. The rising incidence of HF among Chinese adults raises concerns about its impact on economic productivity during peak working years.[3] Both European and Chinese guidelines recommend B-type natriuretic peptide (BNP) screening, intensive blood pressure (BP) control, and guideline-directed medical therapy (GDMT) for HF with reduced ejection fraction (HFrEF).[7–10] However, implementation gaps persist in China's fragmented primary care system, and no studies have modelled the macroeconomic burden of HF or assessed scalable interventions, creating a significant policy vacuum.

This study integrates HF epidemiology with a health-augmented macroeconomic model to quantify the burden of HF in China from 2025 to 2035. Using data from the Global Burden of Disease (GBD) study, national registries, and insurance claims, we project prevalence trends and economic impacts, and evaluate three targeted interventions: (i) BNP screening for early detection, (ii) intensive BP control, and (iii) GDMT optimization for HFrEF. Our aim is to provide policymakers with actionable strategies to mitigate economic losses, strengthen health system resilience, and align HF management with China's demographic challenges.

Methods

Projection of HF prevalence in China from 2025 to 2035

The projected prevalence of HF in China from 2025 to 2035 was modelled by incorporating epidemiological data from the 2021 GBD study and the demographic projections derived from the United Nations World Population Prospects 2024.[5,6] Age- and sex-specific HF prevalence estimates for 2021 and their 95% uncertainty intervals (UIs) were extracted from the 2021 GBD study, which used Bayesian meta-regression for their quantification. This projection leveraged nationally representative population-level data encompassing the entire demographic structure of China, thereby providing a comprehensive and robust basis for our analysis without the constraints of sample-based estimations.

The Bayesian age-period-cohort (BAPC) model was implemented with the R package BAPC, which uses integrated nested Laplace approximations for inference. Age, period, and cohort effects were modelled with second-order random walk (RW2) priors and the precision parameters were assigned gamma hyperpriors.[11] For projections, the 95% UIs were derived as the 2.5th and 97.5th percentiles of the posterior predictive distribution generated by the BAPC model. The BAPC model uses a Poisson regression structure with a logarithmic link function, and the expected prevalence is a multiplicative function of age, period, and cohort effects. In the BAPC framework, these effects are modelled as stochastic processes using RW2 priors, which allow flexible nonlinear trajectories over time. The prevalence of HF in 2021 [both case numbers and age-standardized prevalence rates (ASPRs)] was used as the baseline and sensitivity analyses evaluated annual prevalence fluctuations (±1% as reference scenarios).

The selected decade (2025–35) coincides with key epidemiological and policy considerations, including alignment with China's national health planning cycles, correspondence with forecasting windows of primary data sources, and optimization of model robustness by avoiding projections that extend beyond data-supported horizons while capturing peak burdens driven by ageing.

Macroeconomic burden model

We adapted a health-augmented macroeconomic model, which was previously used to estimate the global burden of chronic obstructive pulmonary disease, cancers and Alzheimer's disease, to quantify the direct and indirect economic impacts of HF in China from 2025 to 2035 (see Supplementary data online, *Text S1* and *S2*).[12–14] This model was initially proposed by Bloom *et al*. and expands upon the traditional Solow growth framework to assess economic implications by incorporating mortality, morbidity (as represented by years lived with disease), and treatment costs.[15,16] By assessing the economic costs of diseases on labour supply, capital accumulation, and gross domestic product (GDP), this model evaluates the economic benefits of interventions aimed at reducing disease prevalence and also provides policymakers with valuable insights into cost-effective strategies.

This model integrates epidemiological data with macroeconomic variables via two primary pathways: (i) effects on the labour force: HF-related mortality and morbidity reduce the working-age population and diminishes labour productivity and (ii) effects on capital accumulation: the costs associated with HF treatment divert financial resources from savings and investment, thereby hindering capital accumulation (see Supplementary data online, *Text S3*).

To ascertain the economic burden attributable to HF, we calculated the cumulative difference in GDP between the following two scenarios: (i) status quo scenario: projected GDP under current HF prevalence trends and (ii) counterfactual scenario: hypothetical GDP assuming complete elimination of HF at no cost from 2025 onwards. We made the following key modelling assumptions: (i) HF mortality rates remain fixed at 2021 levels [according to the China Cardiovascular Association (CCA)-Heart Failure Centre Registry];[17] (ii) per capita treatment costs remain constant at 2017 values (see Supplementary data online, *Table S1*);[3] (iii) individuals with HF are excluded from the labour force until either recovery or death; and (iv) retirement ages are established at 60 years for men and 55 years for women, with no adjustments made for potential postponements in retirement policies. UIs for economic burden estimates were derived from the sensitivity analysis by propagating the lower and upper bounds of the 95% UI for projected HF prevalence through the macroeconomic model. For intervention analyses, UIs were derived from a range of key intervention parameters (coverage for BNP and BP control; case number uncertainty for GDMT). Additional details regarding model assumptions are provided in the Supplementary data online, *Table S2* and Supplementary data online, *Text S4*. While causal inference methods such as the parametric g-formula are well-suited to estimate intervention effects on disease incidence, our health-augmented macroeconomic model translates such epidemiological changes into long-term economic outcomes.[18] We used relative risk reductions from established trials to project impacts on labour supply, capital accumulation, and GDP.

Data sources

Prevalence and mortality rates were obtained from the 2021 GBD study and the CCA Database-Heart Failure Centre Registry.[5,17] The economic data were obtained from the World Bank's World Development Indicators database, the International Monetary Fund's World Economic Outlook database and the United Nations' World Population Prospects (2024 revision) (see Supplementary data online, *Text S4*). Healthcare costs data were obtained from the National Urban Employee Basic Medical Insurance programme, which spans six provinces in China (2017).[3] All economic data were converted to 2017 international dollars (INT$) to ensure consistency and comparability.

Intervention impact assessment

To address the increasing burden of HF in China, we assessed three evidence-based interventions using a health-augmented macroeconomic model: BNP screening, intensive BP control and optimization of GDMT for HFrEF. These interventions were prioritized based on their Class I recommendation in both ESC and Chinese guidelines.[7–10] These interventions have demonstrated cost-benefit efficiency in landmark trials (STOP-HF for BNP; SPRINT/STEP for BP; BIOSTAT-CHF for GDMT) and assess the principal modifiable risk factors in China, wherein hypertension is reported in 245 million adults and HFrEF comprises 35.6% of incident HF cases.[17,19–23] *Table 1* shows details of the adaptations specific to each intervention for implementation within China's primary care framework.

Table 1 Key input parameters for intervention scenarios

Parameter	BNP screening[a]	Intensive BP control[b]	GDMT for HFrEF[c]
Target population	Adults ≥40 years	245 million patients with hypertension	HFrEF patients
Intervention coverage	25% (20%–30%)	41.4% (37.8%–45.1%)[d]	GDMT From 30% to 90%
Annual cost per person, (RMB/$/€)	400/59.2/52.4	600/88.8/78.6	5000/740.0/655.0
Annual cost per person, (2017INT$)	85.74	128.61	1071.81
HF incidence reduction or LVEF recovery	HF Incidence Reduction 0.62% to 0.27% annually[a]	HF Incidence Reduction 0.67% to 0.41% annually[b]	20% recover normal LVEF[c]

BNP, B-type natriuretic peptide; BP, blood pressure; GDMT, guideline-directed medical treatment; HF, heart failure; HFrEF, heart failure with reduced ejection fraction; LVEF, left ventricular ejection fraction.
In 2025, 1 INT$2017 ≈ 1.31 USD ≈ 1.12 EUR.
[a]Modelled after the STOP-HF trial, targeting high-risk populations (e.g. hypertensive and diabetic patients).[19]
[b]Based on the SPRINT trial, targeting systolic blood pressure <120 mmHg.[21]
[c]Based on BIOSTAT-CHF and ASIAN-HF registries, assuming 22% of HFrEF patients recover normal ejection fraction within 1 year.[23]
[d]Based on a cost-effectiveness modelling study of the SPRINT trial in the Chinese population.[20]

BNP screening for early detection

This intervention targets adults aged 40 years and older, especially those with hypertension, diabetes, or a history of CVD. The annual screening coverage was 25%, with a sensitivity ranging from 20% to 30%. The total cost per person was RMB 400 (INT$85.74/$59.20/€52.40) and included costs towards general practitioner consultation (RMB 50), BNP testing (RMB 100), and a cardiology specialist review (RMB 250). Consistent with the findings from the STOP-HF trial, BNP-based screening combined with collaborative care significantly reduced the annual incidence of new-onset HF from 0.62% to 0.27%.[19] This reduction was primarily attributed to the early identification and management of at-risk individuals, which effectively prevented progression to left ventricular dysfunction.

Intensive blood pressure control

This strategy aimed to achieve a target systolic BP <120 mmHg among the 245 million hypertensive adults in China, as indicated by the China Hypertension Survey 2023. Among these individuals, 41.4% (37.8%–45.1%) met the inclusion criteria established by the SPRINT trial.[20] The estimated annual cost per patient was RMB 600 (INT$128.61/$88.80/€78.60), which included the cost of antihypertensive medications (RMB 350) and monitoring (RMB 250). The reduction in annual HF incidence from 0.67% to 0.41% was driven by attenuated left ventricular remodelling.[21] Furthermore, the China STEP trial validated this approach in older adults by targeting those with a systolic BP <130 mmHg and demonstrated a 26% reduction in acute decompensated HF [hazard ratio (HR) 0.27; 95% confidence interval 0.08–0.98].[22]

GDMT for HFrEF

This intervention in China aimed to improve adherence to GDMT from 30% to 90% in HF patients, especially those diagnosed with HFrEF, which accounts for approximately 35.6% of the 3 million new cases diagnosed annually.[3,17] The annual per-patient cost for GDMT is estimated at RMB 5000 (2017 INT$1071.81/$740.00/€655.00), including 60% to 70% of the cost for pharmacotherapy. The costs for the three key medications are as follows: sacubitril/valsartan, RMB 1200–1800; metoprolol, RMB 240–360; and dapagliflozin, RMB 360–600. The remaining 30% to 40% of costs are attributed towards monitoring, which includes BNP tests administered three times per year and echocardiographic assessments conducted one to two times annually. Clinically, GDMT facilitates left ventricular functional recovery (left ventricular ejection fraction >40%) in 20% to 30% of patients with HFrEF within a 12-month period, thereby enhancing their physical capacity.[23]

We calculated the economic burden reduction linked to each intervention using the previously described health-augmented macroeconomic model (see Supplementary data online, *Text S2*). We then conducted a comparative analysis of the annual aggregate output (GDP) across two scenarios from 2025 to 2035. The key modelling assumptions were as follows: (i) GDP projections were derived from current estimates and projections of disease prevalence in the status quo scenario. (ii) Conversely, in the counterfactual scenario, the prevalence of HF decreases due to the intervention, thereby reducing additional incurred costs. The average duration of HF was assumed to be 4 years, with an estimated three million new HF cases reported each year.[3,17] For each intervention, we estimated the following: (i) reduction in HF prevalence; (ii) healthcare expenditure savings; (iii) productivity gains resulting from decreased disability and premature mortality; and (iv) cumulative economic benefits projected over a 10-year horizon (2025–35).

Sensitivity analysis

We conducted sensitivity analyses to evaluate the robustness of our estimates. The baseline estimates were according to the mean prevalence rates, and the UIs were calculated based on the lower and upper bounds of the 95% UI derived from GBD data. The discount rates of 0%, 2%, 3%, 4%, and 5% were applied, and the 3% discount rate was used as the baseline in the main analysis. The regional cost heterogeneity was estimated by calculating the treatment costs stratified by province, sex and age from six economically diverse provinces using the minimum and maximum cost values across provinces for each subgroup. The predictive accuracy of the model was validated against historical data on HF epidemiology and economic burden.

Results

Projected prevalence and burden of heart failure in China (2025–35)

Based on data from the 2021 GBD study, the prevalence of HF in China is projected to increase significantly between 2021 and 2035 (*Figure 1A and B*; Supplementary data online, *Table S3*). In 2021, there were an estimated 13.1 million HF cases (95% UI: 12.8–13.4 million) with an age-standardized prevalence rate (ASPR) of 693.5 (95% UI: 675.2–711.8) per 100 000 persons. By 2025, the number of HF cases are projected to rise to 14.9 million (95% UI: 12.1–17.6 million), corresponding to an ASPR of 696.3 (95% UI: 552.6–840.1) per 100 000 persons.

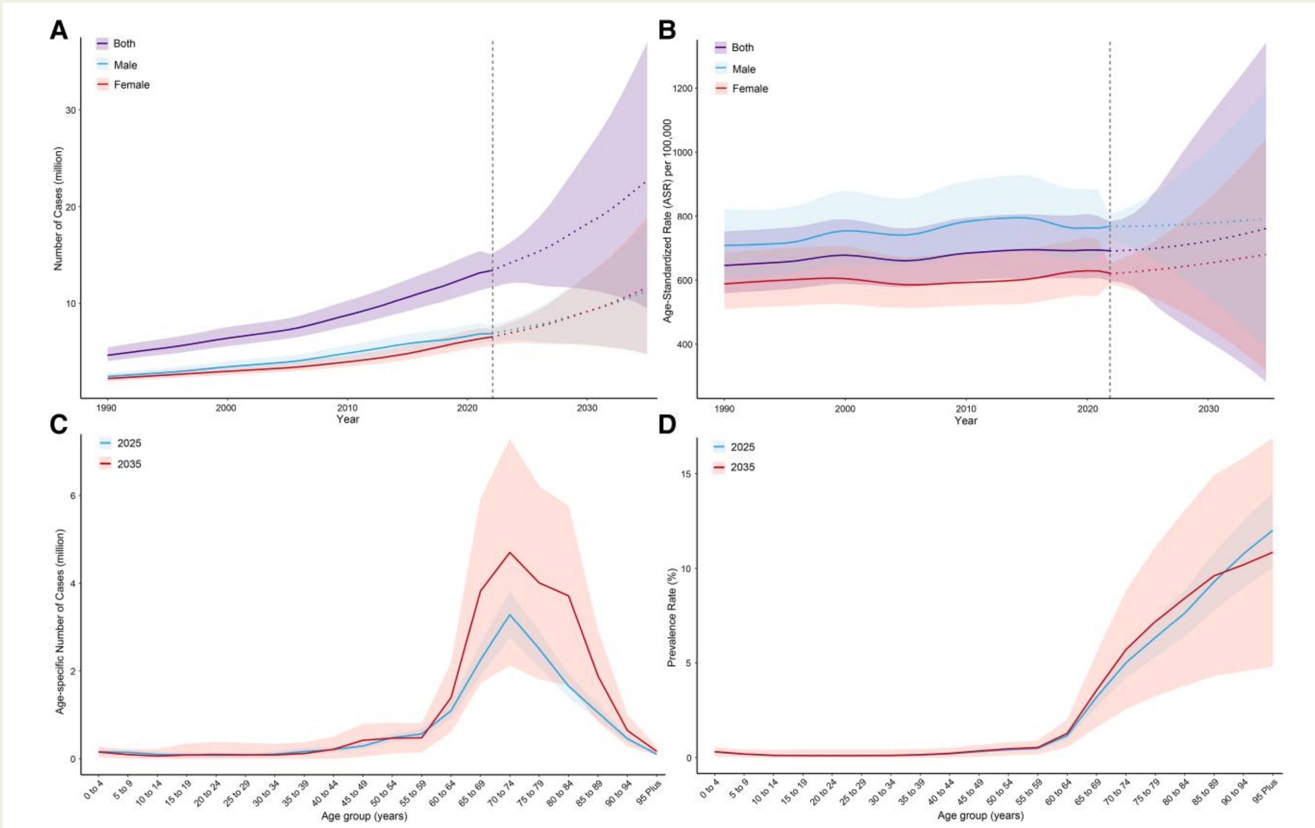

Figure 1 Projected Growth of Heart Failure Burden in China (2021–35), Including total cases, age-standardized prevalence and age-specific trends. (*A*) Projected total HF cases (millions) with 95% uncertainty intervals (UIs) between 2021 and 2035. (*B*) Age-standardized prevalence per 100 000 individuals with 95% UI between 2021 and 2035. (*C*) Age-stratified HF cases (millions) highlighting accelerated burden in adults ≥60 in 2025 and 2035. (*D*) Age-stratified HF prevalence (%) in 2025 and 2035. Note: HF prevalence and the 95% UIs quantified by GBD 2021 via Bayesian meta-regression were extracted from the 2021 GBD study (1990–2021); for projections (2021–35), the 95% UIs were derived as the 2.5th and 97.5th percentiles of the posterior predictive distribution generated by the Bayesian age-period-cohort model

This upwards trend is expected to reach an estimated 22.7 million HF cases (95% UI: 9.5–36.9 million) by 2035, representing a 73% increase from 2021. The ASPR is projected to be 760.7 (95% UI: 283.2–1340.8) per 100 000 persons by 2035. This reflects compounding effects of demographic ageing and persistent cardiovascular risk factors.

Age-specific trends indicate a consistent upwards trajectory in HF prevalence across all age groups within China, with the most significant increases in the older populations (*Figure 1C* and *D*; Supplementary data online, *Table S4*). HF prevalence remains relatively low among younger adults aged 15–49 years but has demonstrated a gradual increase over time. For example, the prevalence in the 35–39 years age group is projected to increase from 0.127% in 2021% to 0.146% by 2035, a relative increase of 14.9%. HF prevalence is also expected to increase significantly among the middle-aged populations (50–64 years). In the 60–64 years age group cohort, HF prevalence is expected to rise from 0.974% to 1.269% (a relative increase of 30.3%), with an expected increase in cases from 711 347 to 1.39 million (a relative increase of 95.5%). However, the highest increase in HF prevalence is expected to be among older adults. HF prevalence in the 65–69 years age group is projected to increase from 2.728% to 3.549% (a relative increase of 30.1%), with an expected increase in cases from 2.09 million in 2021 to 3.82 million by 2035 (a relative increase of 82.7%). In the 70–74 years cohort, HF prevalence is expected to increase from 4.679% to 5.692% (a relative increase of 21.6%), with the number of cases rising from 2.49 million to 4.70 million (a relative increase of 88.8%). The prevalence rates for males and females across different age groups are shown in the Supplementary data online, *Tables S5* and *S6*.

Projected macroeconomic burden of heart failure in China (2025–35)

Our macroeconomic model forecasted a significant increase in the economic burden of HF in China from 2025 to 2035 (*Table 2*).

The burden is expected to rise from INT$46.6 billion (UI: INT$39.6–54.4 billion) in 2025 to INT$183.5 billion (UI: INT$119.0–273.8 billion) by 2035. Concurrently, HF-related economic loss in GDP is projected to increase from 0.14% (UI: 0.12%–0.16%) in 2025% to 0.37% (UI: 0.24%–0.54%) by 2035. Cumulatively, the discounted total burden over the 2025–35 period is estimated to reach INT$1001.1 billion (UI: INT$733.4–1365.6 billion), representing an average annual GDP loss of 0.26% (UI: 0.19%–0.34%) in China. The economic burden of HF is expected to be driven predominantly by the direct medical costs (27.9%; UI: 25.2%–35.6%) and indirect costs (72.1%; UI: 64.4%–74.8%). Direct costs include hospitalizations, medications, and outpatient care, whereas indirect costs result from reduction in labour force participation and productivity losses.

Table 2 Projected macroeconomic burden of heart failure in China (2025–35)

Year	Economic loss[a], Billions of 2017 INT$	Proportion of GDP[a], %	Proportion due to physical capital decline[b], %	Proportion due to labor force decline[b], %
2025	46.552 (39.534–54.418)	0.137 (0.116–0.160)	—	—
2026	57.595 (47.911–68.601)	0.162 (0.135–0.193)	9.7 (8.5–13.5)	90.3 (86.5–91.6)
2027	68.780 (55.959–83.590)	0.187 (0.152–0.227)	16.4 (14.5–22.2)	83.6 (77.8–85.5)
2028	80.092 (63.639–99.445)	0.211 (0.168–0.262)	21.4 (19.1–28.2)	78.6 (71.8–80.9)
2029	91.643 (71.017–116.392)	0.234 (0.181–0.297)	25.3 (22.7–32.7)	74.7 (67.3–77.3)
2030	104.662 (78.992–136.140)	0.256 (0.193–0.333)	28.3 (25..5–36.2)	71.7 (63.8–74.5)
2031	118.542 (87.022–158.109)	0.278 (0.204–0.371)	30.7 (27.8–38.8)	69.3 (61.2–72.2)
2032	133.329 (95.073–182.565)	0.300 (0.214–0.411)	32.7 (29.7–40.9)	67.3 (59.1–70.3)
2033	149.021 (103.083–209.724)	0.322 (0.222–0.453)	34.3 (31.3–42.6)	65.7 (57.4–68.8)
2034	165.660 (111.019–239.889)	0.343 (0.230–0.497)	35.6 (32.6–44.0)	64.4 (56.0–67.4)
2035	183.512 (118.975–273.759)	0.365 (0.236–0.544)	36.8 (33.7–45.1)	63.2 (54.9–66.3)
Total[c] (Discounted)	1001.140 (733.444–1345.639)	0.256 (0.188–0.344)	27.9 (25.2–35.6)	72.1 (64.4–74.8)

GDP, gross domestic product.
Economic loss is expressed in billions of 2017 international dollars (2017INT$).
In 2025, 1 INT$2017 ≈ 1.31 USD ≈ 1.12 EUR.
[a]The total economic burden includes direct healthcare costs (e.g. hospitalizations, medications) and indirect costs (e.g. lost productivity, disability). The uncertainty intervals for the 'Economic Loss, Billions of 2017 INT$' and 'Proportion of GDP, %' are calculated based on the lower and upper bounds of 95% uncertainty intervals for Projected Heart Failure Prevalence by Age Group derived from the GBD Study 2021, adjusted for China-specific demographic and risk factor trends.
[b]The uncertainty intervals for the 'Proportion Due to Physical Capital Decline, %' and 'Proportion Due to Labor Force Decline, %' are derived from sensitivity analyses conducted on per capita treatment costs, which were calculated by gender and age group at the provincial level using National Urban Employee Basic Medical Insurance data. A dash (—) indicates that the proportion is not applicable for the year 2025, as the model assumes no decline in physical capital occurs in the first year of the projection; therefore, the entire economic burden is attributed to the decline in the labour force.
[c]The cumulative economic burden is adjusted for discounting at 3% per year.

Impact of intervention strategies on the HF macroeconomic burden

The impact of the three interventions on reducing the economic burden of HF over a 10-year period is shown in *Table 3*. BNP-based screening demonstrates the highest macroeconomic efficiency, with a cumulative 10-year cost of INT$160.5 billion (UI: INT$128.4–192.6 billion), leading to a reduction in economic burden by INT$78.5 billion (UI: INT$62.8–94.1 billion), which is equivalent to 8.1% (UI: 6.3%–9.7%) of the total HF burden. The impact of BNP-based screening on GDP is marginal at 0.02% (UI: 0.016%–0.024%), but its cost-benefit ratio is 0.49 (95% UI: 0.39–0.59), which highlights significant returns. This is primarily driven by labour force retention, which accounts for 96.9% of the total benefits through early detection of at-risk individuals.

Intensive BP control will target 245 million hypertensive adults and require a total investment of INT$124.3 billion (UI: INT$113.5–135.4 billion) to reduce HF burden by INT$27.5 billion (UI: INT$25.1–29.9 billion). The total burden reduction is expected to be 2.7% (UI: 2.5%–3.0%) with a cost-benefit ratio of 0.22 (UI: 0.20–0.24). Although this strategy offers broader cardiovascular benefits beyond HF prevention, its scalability is constrained by significant upfront financial requirements, thereby limiting its feasibility in resource-constrained settings.

The GDMT for HFrEF emerged as a cost-effective and balanced strategy that would require an investment of INT$35.3 billion (UI: INT$26.1–47.1 billion) and reduce the economic burden by INT $17.0 billion (UI: INT$12.8–22.4 billion). The total burden reduction is expected to be 1.7% (UI: 1.66%–1.74%) with a cost-benefit ratio of 0.48 (UI: 0.36–0.63). Furthermore, more than 96.5% (UI: 96.1%–96.8%) of the economic benefits were attributed to productivity restoration in younger patients through improved cardiac function and the remaining 3.5% (UI: 3.2%–3.9%) were due to reduced long-term care costs. Based on its efficiency and targeted impact on the working-age population, GDMT represents a sustainable and scalable intervention, especially in resource-limited settings.

Figure 2 shows the annual proportion of economic burden reduction and patient reductions from 2025 to 2035 to illustrate the impact of the three interventions. The interventions exhibited distinct patterns of reduction in economic burden over time. BNP-based screening showed the most sustained and pronounced decline, thereby highlighting its long-term effectiveness. Conversely, GDMT for HFrEF was effective but contributed only a smaller proportion to the decline because of its narrower target population and higher per-person costs. Collectively, these three interventions are projected to reduce the economic burden by 12.5% (UI: 10.4%–14.5%) from 2025 to 2035, which would be worth saving INT$123.0 billion (UI: INT$100.7–146.4 billion).

Sensitivity analysis

The robustness of projected macroeconomic burden estimates was assessed for various discount rates (0%–5%) and regional cost heterogeneity, and the results are shown in Supplementary data online, *Tables S7* and *S8*, respectively.

Table 3 Cost-benefit of heart failure interventions (2025–35)

Parameter	BNP screening	Intensive BP control	GDMT for HFrEF
Total cost (10-year cumulative), billions of 2017 INT$	160.469 (128.375–192.563)	124.328 (113.517–135.439)	35.327 (26.047–47.101)
Reduction in patients (10-year cumulative)	7 589 641 (6 071 715–9 107 573)	2 900 898 (2 648 646–3 160 157)	1 851 445 (1 328 668–2 526 094)
Economic burden reduction (10-year cumulative)[a], billions of 2017 INT$	78.49 (62.79–94.09)	27.48 (25.09–29.94)	17.03 (12.77–22.36)
Relative economic burden reduction rate, %	8.10 (6.27–9.74)	2.74 (2.51–2.99)	1.70 (1.66–1.74)
GDP reduction, %	0.020 (0.016–0.024)	0.007(0.006–0.008)	0.004 (0.003–0.006)
Contribution to burden reduction			
Physical capital improvement[b], %	3.1	−35.0[b]	3.5 (3.2–3.9)
Labour force improvement[c], %	96.9	135.0	96.5 (96.1–96.8)
Cost-benefit ratio[d] (burden reduction per unit cost)	0.489 (0.391–0.586)	0.221 (0.202–0.241)	0.482 (0.361–0.633)

BNP, B-type natriuretic peptide; BP, blood pressure; GDMT, guideline-directed medical therapy; GDP, gross domestic product; HF, heart failure; HFrEF, heart failure with reduced ejection fraction; LVEF, left ventricular ejection fraction.
In 2025, 1 INT$2017 ≈ 1.31 USD ≈ 1.12 EUR.
For BNP screening and intensive BP control, uncertainty intervals in parentheses are calculated based on the range of intervention coverage (see *Table 1*). Regarding GDMT for HFrEF, uncertainty intervals in parentheses are calculated based on the lower and upper bounds of the 95% uncertainty intervals for projected heart failure prevalence by age group, which are derived from the GBD Study 2021 and adjusted for China-specific demographic and risk factor trends.
[a]Economic burden reductions are adjusted for discounting at 3% per year.
[b]Physical capital improvement captures savings from reduced healthcare expenditures redirected to investments; negative values indicate net capital depletion due to intervention costs.
[c]Labour force improvement exceeding 100% reflects indirect productivity gains from reduced caregiver burden and avoided premature mortality, which amplifies direct workforce retention effects.
[d]Cost-benefit ratio = Economic burden reduction/total cost.

Discussion

This study presents the first macroeconomic projection on HF in China and forecasts that the number of HF cases will reach 22.7 million (95% UI: 9.5–36.9 million) by the year 2035 with an age-standardized prevalence rate of 760.7 (95% UI: 283.2–1340.8) per 100 000 individuals. Furthermore, we project a cumulative economic burden of INT$1001.1 billion (0.26% of GDP) from 2025 to 2035, with indirect costs arising from labour force attrition (72.1%) being the main source for the financial losses. The three critical insights of this study are as follows: (i) the dual burden of HF among ageing and younger populations signals a major crisis for China's labour-driven economy; (ii) scalable interventions—including BNP screening, intensive BP control, and GDMT—could mitigate 12.5% of this burden and save INT$123.0 billion; and (iii) the predominance of indirect costs associated with HF in China starkly contrasts with trends observed in high-income countries, where direct medical costs prevail (*Structured Graphical Abstract*). These results highlight the urgent need to integrate HF management into national health agendas and align with the Healthy China 2030 initiative and the United Nations Sustainable Development Goals (SDGs).

Globally, HF costs rise with ageing populations, but China's economic vulnerability is exacerbated by its reliance on workforce productivity. In high-income countries, direct medical costs account for 65%–80% of HF expenditures, whereas in China, indirect costs dominate (72.1%).[2,24,25] This pattern is also observed with other chronic diseases in LMICs such as chronic obstructive pulmonary disease (COPD) and cancer, where the indirect costs constitute the major expenditure.[13,14] However, the projected GDP loss from HF (0.26%) surpasses that of other conditions (e.g. global COPD: 0.111% GDP/year), establishing HF as a macroeconomic priority requiring systemic interventions.[13]

Age-specific analysis shows steep rises in HF prevalence across all age groups, particularly older adults (e.g. 60–64 years: prevalence increase of 30.3%, case increase of 95.5% from 2021 to 2035). Younger populations (35–39 years) also show a 14.9% relative prevalence increase. This trend underscores the need for life-course prevention strategies. While global age-standardized CVD prevalence is stable, China's growing HF burden demands urgent action.[26] Hypertension, a leading modifiable risk factor, is projected to cause 18.9 million cardiovascular deaths globally by 2050.[26] Although absolute HF risk is lower in younger populations, the strong association of modifiable risk factors like hypertension and diabetes in adults aged 35–55 necessitates targeted prevention to mitigate productivity losses during peak working years.[27,28] Hypertension and obesity are predominant modifiable risk factors for both HF with reduced and preserved ejection fraction globally, highlighting the need for a comprehensive life-course strategy for China.[29]

BNP-based screening emerged as the most cost-effective intervention with a potential to reduce 8.1% (INT$78.5 billion) of the total HF burden and a favourable cost-benefit ratio of 0.49. This finding is consistent with the evidence from the STOP-HF trial, which demonstrated that BNP-guided care led to a 41% reduction in the incidence of left ventricular dysfunction (odds ratio [OR]: 0.55; 95% CI: 0.37–0.82).[19] Cost-effectiveness analysis further supports its scalability.[30] Patients suspected of *de novo* HF with elevated NT-proBNP levels are associated with higher mortality and morbidity rates within weeks of presentation, thereby accruing significant healthcare costs.[31] This highlights the clinical urgency for early identification of HF. However, successful implementation of this intervention depends on the integration of BNP screening

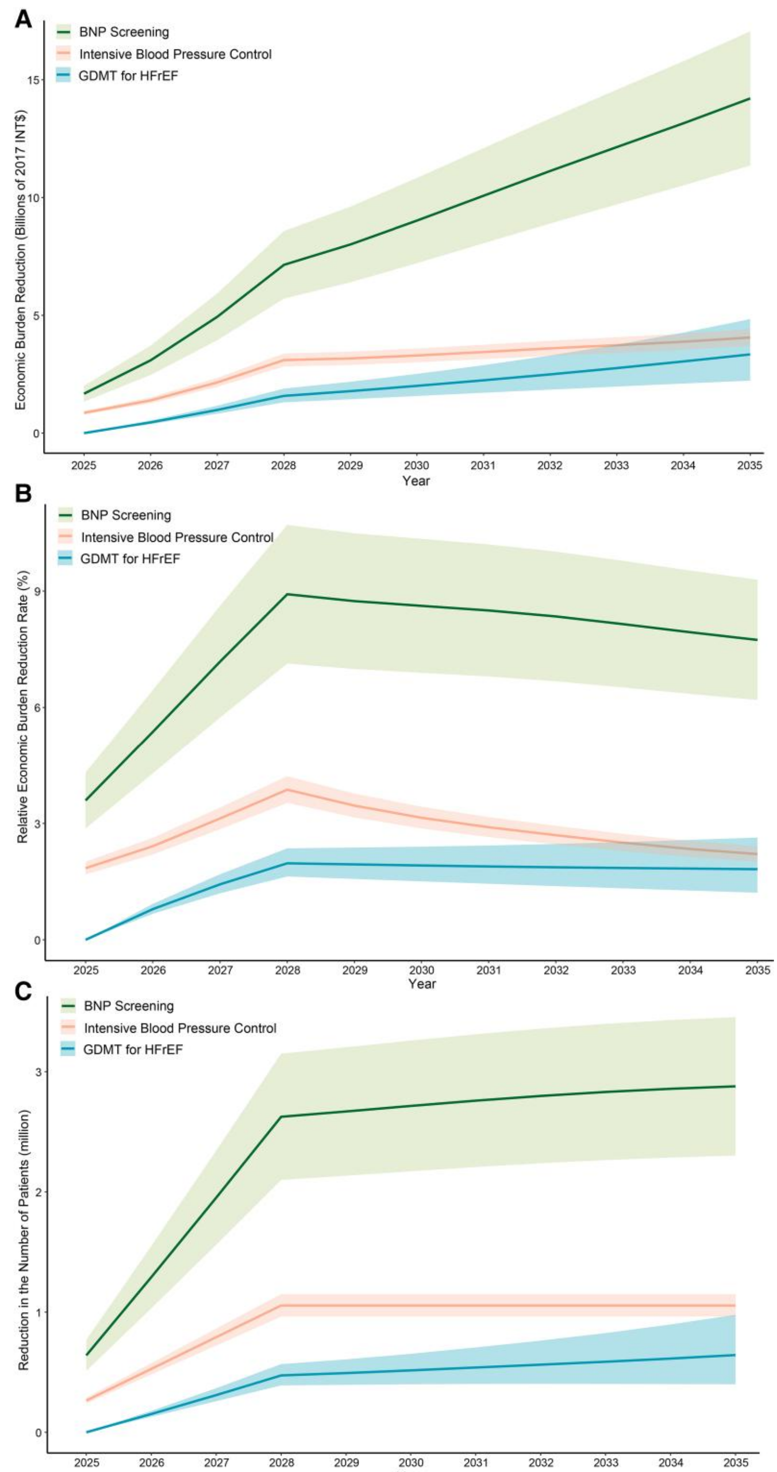

Figure 2 Impact of BNP Screening, Intensive Blood Pressure Control and GDMT for HFrEF on Economic Burden and Patient Reduction (2025–35) (*A*) Absolute reduction in economic burden (billions of 2017 international dollars, INT$) attributable to BNP screening (25% annual coverage in high-risk adults ≥40 years), Intensive BP control (systolic BP <120 mmHg; target: hypertensive adults) and GDMT for HFrEF (adherence improvement: 30%–90%). (*B*) Relative reduction in economic burden (%) demonstrating intervention efficiency. (*C*) Reduction in incident HF cases (millions) reflecting epidemiological impact. BNP screening yields highest cumulative economic savings (INT$78.5 billion); GDMT shows progressive case reduction through functional recovery; Intensive BP control provides consistent burden mitigation. Note: BNP, B-type natriuretic peptide; GDMT, guideline-directed medical therapy; HF, heart failure; HFrEF, heart failure with reduced ejection fraction. In 2025, 1 INT$2017 ≈ 1.31 USD ≈ 1.12 EUR. The shaded areas represent the 95% uncertainty intervals around the central estimates. For BNP screening and intensive BP control, uncertainty reflects the range of intervention coverage (see *Table 1*). For GDMT, uncertainty reflects the uncertainty in the projected prevalence of HF cases

into primary care, especially in rural China, where access to diagnostic tools and specialist care remains limited.[32] Besides, this would require integrating BNP screening into China's Essential Public Health Services framework and prioritizing adults aged 40 years and older in the high-risk populations for HF. Based on data from the STOP-HF trial, our model incorporated costs associated with false positives, including downstream echocardiography and specialist referrals. Despite these expenditures, BNP screening retains a net macroeconomic benefit (cost-benefit ratio: 0.49) according to our model. Initiatives that employ portable BNP devices in conjunction with telemedicine platforms could bridge existing diagnostic gaps, whereas training primary care providers on risk stratification would enhance early detection.

Intensive systolic BP control could potentially reduce HF-related economic costs by 2.7% (INT$27.5 billion). This finding aligns with the SPRINT trial, which reported a 25% reduction in HF risk (HR: 0.75; 95% CI: 0.64–0.89).[21] The China STEP trial further validated this approach in older adults (target BP <130 mmHg) and reported significant reductions in the incidence of cardiovascular events (HR: 0.74; 95% CI: 0.60–0.92) and a 73% decline in acute HF episodes (HR: 0.27; 95% CI: 0.08–0.98).[22] However, to address a physical capital depletion rate of 35.0% attributed to medication costs, subsidization of antihypertensive therapies through national insurance is imperative. Systemic barriers, including fragmented medication access and limited BP monitoring infrastructure, further hinder the scalability of intensive BP control measures. Scalable solutions such as village doctor-led rural programmes, workplace-based BP monitoring and digital adherence tools, aligned with China's Essential Public Health Services framework, could bridge implementation barriers and translate clinical effectiveness into equitable health and economic outcomes.[33,34] Our emphasis on intensive BP control stems from its significant epidemiological contribution to the HF burden in China. According to the CCA Database–Heart Failure Centre Registry, the prevalence of hypertension (56%) is significantly higher than diabetes (27.1%) and smoking (32.3%) in the HF cases.[17] Although multi-risk factor strategies such as integrated glycaemic and lipid screening or smoking cessation programmes hold considerable potential for future preventive models, they were excluded from this analysis because of insufficient data on their cost-effectiveness, synergistic interactions, and implementation feasibility. Addressing these gaps remains a priority for future research.

Optimizing GDMT for HFrEF demonstrated balanced efficiency. Despite robust evidence for angiotensin-converting enzyme inhibitors, beta-blockers, and sodium-glucose co-transporter 2 inhibitors, adherence remains suboptimal.[35–38] US data (2016–20) show only 6.2% of new HFrEF patients achieved optimal GDMT within 12 months, driven by systematic prescription barriers (fragmented care transitions, therapeutic inertia) rather than patient non-adherence.[37] Sex disparities exist, with women receiving GDMT less frequently, attributed to older age, higher comorbidity, referral deficits, and sex-specific behaviours.[37] Despite higher overall HF prevalence in men, this highlights the need for targeted interventions to improve diagnosis and treatment in women. HFrEF patients in LMICs are less likely to receive guideline-recommended medications at target doses, and post-discharge mortality is higher in low-income regions, correlating with inadequate GDMT prescription.[39,40] The Chinese Heart Failure Centre model successfully achieved 80% GDMT adherence through standardized protocols and multidisciplinary care, demonstrating actionable success.[17] A randomized trial showed digital consultations improved GDMT adherence, offering a scalable solution for fragmented healthcare access.[41] Prioritizing equity-focused policies, multidisciplinary collaboration, artificial intelligence (AI)-driven decision support, and telehealth is critical to bridging implementation gaps.

Our findings support three specific policy measures: (i) integration of BNP screening into China's Essential Public Health Services, with phased implementation through primary care facilities, task-shifting to community health workers, and targeting rural populations with high CVD risk profiles; (ii) reform national insurance policies to expand coverage for evidence-based antihypertensive fixed-dose combination therapies and prioritizing high-risk groups; and (iii) scaling of the 'Heart Failure Centre' model via telemedicine networks to standardize guideline-directed therapy in county-level hospitals and utilizing AI decision support tools. These strategies are transferable to other LMICs facing similar demographic and resource challenges.

HF is a significant clinical and macroeconomic challenge in China, necessitating integrated policies focusing on prevention, workforce protection, and health system strengthening. The proposed scalable interventions align with Healthy China 2030 and the Lancet Global Health 2035 Commission's '50 by 50' goal.[42] Despite progress, universal health coverage lags in preventive care, requiring investments in primary healthcare infrastructure to address the dual burden of non-communicable diseases and ageing.[32,43] Prioritizing BNP screening and GDMT for labour force protection is critical due to their high cost-effectiveness. Implementing hypertension management subsidies and leveraging AI and telemedicine for treatment standardization can reduce rural–urban disparities.[44] An AI model can effectively predict the risk of future HF from a single ECG image.[45] Combining BNP screening and hypertension management can reduce expenditures while improving productivity. Joint interventions may yield greater burden reduction than BNP screening alone. Scaling up BNP screening nationally, especially in rural regions, is necessary for maximal impact.

The increasing HF burden in China reflects challenges faced by LMICs navigating demographic ageing and epidemiological transitions. Integrating HF prevention into national health agendas aligns with Healthy China 2030, UN SDGs, and Global Health 2050, advocating for policies that prioritize prevention, early detection (e.g. BNP screening), and optimized chronic disease management (e.g. GDMT) to enhance workforce sustainability. Cost-effective interventions like BNP screening and GDMT optimization are inherently scalable across LMICs, offering pathways to mitigate HF's long-term societal and economic impacts. The COVID-19 pandemic exposed vulnerabilities in low-income and rural health systems, underscoring the need for investments in digital health technologies and infrastructure to address care disparities. Policymakers must prioritize data-driven strategies to address rural–urban gaps, strengthen primary care, and leverage innovation to ensure equitable and sustainable HF management for ageing populations globally.

Strengths and limitations of the study

The findings of this study highlight the urgent need for targeted national policies to address the growing burden of HF in China. Failure to implement effective prevention and management strategies will increase strain on the healthcare resources, reduce workforce productivity, and exacerbate economic losses. However, several limitations warrant cautious interpretation of our findings.

First, while leveraging nationally representative data, this study may not fully account for the variations in HF prevalence, healthcare access, and economic conditions. This limitation risks overgeneralizing the findings by overlooking significant local heterogeneity, especially disparities in diagnostic capacity between rural and urban settings. To mitigate potential projection biases, we conducted province-level sensitivity analyses, which highlighted regional variations in economic burden.

Second, the structure of our model may be susceptible to misspecification bias. Key assumptions of the model—that treatment costs directly reduce physical capital investment and that mortality rates and costs remain constant—simplify the complex economic and epidemiological relationships.[12–14] Besides, health spending may affect savings and investment in nonlinear ways, and future medical advances or cost fluctuations could alter disease trajectories and expenditures. While these assumptions ensure tractability and align with standard macroeconomic models, they may lead to over- or underestimation of the true economic burden. Furthermore, the BAPC model's projections depend on prior specifications and smooth trend assumptions, which may not capture abrupt future shifts in epidemiology.

Third, the scalability of interventions—especially BNP screening and intensive BP control—faces significant operational constraints because of China's fragmented primary care system. Our assumption of uniform adoption rates may overestimate real-world effectiveness in the context of resource limitations and persistent structural barriers.

Fourth, the wide UIs associated with our projections reflect inherent methodological challenges in long-term modelling, including limitations of the age–period–cohort framework and smoothing of prior sensitivities. These uncertainties necessitate cautious interpretation of projection precision, especially concerning distributional extremes.

Fifth, the analysis primarily focused on HF-specific burdens and did not incorporate broader health economic gains, such as potential stroke reduction from intensive BP control. Quantifying these synergistic effects could significantly enhance societal value assessments of the proposed interventions.

Finally, the cost estimates derived from this study are context-specific and reflective of China's current healthcare delivery. There are significant differences in the HF management models from different countries. For example, the prevalence of nurse-led clinics in the United Kingdom. These disparities significantly affect unit costs and care pathways. Therefore, our projections may not be generalizable to countries with structurally different health systems and may require local cost inputs to ensure accuracy.

Conclusion

HF in China represents a critical public health challenge and a significant long-term macroeconomic burden. By prioritizing BNP screening, intensive BP control and optimized GDMT adherence, policymakers can reduce 12.5% of the projected burden and save INT$123.0 billion, thereby safeguarding GDP growth and aligning with global sustainability agendas. For China and other LMICs, prioritizing HF management must be viewed as an investment in both health and economic resilience.

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Supplementary data

Supplementary data are available at *European Heart Journal* online.

Declarations

Disclosure of Interest

All authors declare no disclosure of interest for this contribution.

Data Availability

No individual-level data were used in this modelling study. Data from this modelling study are available to anyone who requests them for any non-commercial purposes and can be accessed by contacting HW (wanghua2764@bjhmoh.cn), who will provide guidance on how to use and interpret the data.

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Ethical Approval

This study utilized de-identified data from three sources: the Global Burden of Disease Study 2021 (publicly available aggregate data), the China Cardiovascular Association Registry, and national insurance databases. Ethical approval for the use of the China Cardiovascular Association Registry data was obtained from the Central Ethics Committee of Beijing Hospital (Approval No.: 2022BJYYEC-346-01). Access to the national insurance databases was approved by the Ethical Review Committee of Beijing Hospital (IRB No.: 2019BJYYEC-219-01), with waived informed consent due to the retrospective, anonymized nature of the data. The Global Burden of Disease Study 2021 adheres to ethical standards for global health data aggregation, ensuring no individual-level identifiers. All analyses complied with institutional and national guidelines for secondary data use, and no additional ethics review was required for this modelling study.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT and DeepSeek to improve language clarity and correct grammatical errors. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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