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Economic Burden and Disability-Adjusted Life Years (DALYs) Associated with Cardiac Diseases in Pakistan: A Comprehensive Cross-Sectional Analysis

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ABSTRACT

Background: Cardiac diseases represent a major public health challenge in Pakistan, contributing significantly to mortality, morbidity, and economic burden. Despite the prevalence of cardiovascular conditions in low- and middle-income countries, comprehensive data on economic impact and disability burden remains limited in Pakistan. This study aimed to explore the economic burden and quantify disability-adjusted life years (DALYs) associated with cardiac diseases across healthcare settings in Pakistan.
Methods: A cross-sectional mixed-methods analysis was conducted across major healthcare facilities in Islamabad and Sindh (Hyderabad) from January 2023 to December 2024. Primary data collection involved 1,486 cardiac patients combined with secondary analysis of hospital records. Direct, indirect, and intangible costs were systematically assessed using a societal perspective. DALYs were calculated using WHO methodology, incorporating years of life lost (YLL) and years lived with disability (YLD). Statistical analysis included descriptive statistics, regression modeling, and sensitivity analyses.
Results: Mean annual direct medical costs were PKR 387,450 per patient in Islamabad and PKR 298,750 in Hyderabad. Total societal costs reached PKR 892,340 and PKR 674,890 respectively. Catastrophic health expenditure affected 68.4% of Islamabad families and 74.2% in Hyderabad. The analysis identified 847,620 DALYs lost annually, with ischemic heart disease accounting for 52.3% of burden. Regional disparities showed higher DALY rates in Sindh (1,456 per 100,000) versus Islamabad (1,289 per 100,000).
Conclusions: This comprehensive assessment reveals substantial healthcare and societal costs, with widespread catastrophic health expenditure indicating significant financial vulnerability. The considerable DALY burden underscores urgent needs for enhanced prevention strategies and improved care services, with critical implications for healthcare policy and resource allocation.

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Introduction

Cardiovascular diseases (CVDs) represent one of the most significant public health challenges globally, constituting the leading cause of mortality and morbidity worldwide. According to the Global Burden of Disease (GBD) 2019, CVDs account for approximately 18.6 million deaths annually, representing nearly one-third of all global deaths, with disability-adjusted life years (DALYs) reaching 365.9 million globally (Raheem et al., 2022). The substantial impact of cardiovascular diseases extends beyond immediate health consequences, imposing considerable economic burdens on healthcare systems, families, and national economies across both developed and developing nations (Masebi et al., 2021).

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The global epidemiological landscape of cardiovascular diseases has undergone significant transformation over the past three decades. While high-income countries have experienced remarkable declines in age-standardized cardiovascular death rates—with reductions exceeding 50% from 1990 to 2017—low and middle-income countries (LMICs) continue to bear a disproportionate burden of cardiovascular morbidity and mortality (Li et al., 2021). This disparity is particularly pronounced when examining the relationship between socioeconomic development and cardiovascular disease burden, where countries with higher Human Development Index (HDI) levels demonstrate consistently lower rates of cardiovascular-related DALYs compared to their less developed counterparts (Raheem et al., 2022).

Pakistan, as a lower-middle-income country, faces an exceptionally challenging cardiovascular disease landscape that threatens both individual health outcomes and national economic stability (Xu et al., 2024). With an estimated population of over 230 million people, Pakistan ranks among the top three countries globally for diabetes prevalence and demonstrates alarming cardiovascular disease statistics. Recent data indicates that approximately 33% of all deaths in Pakistan are attributable to cardiovascular diseases, with the prevalence continuing to rise due to rapidly changing demographic patterns, urbanization, and lifestyle modifications (Yan et al., 2023; Raheem et al 2022). The country's cardiovascular disease burden is further exacerbated by limited healthcare infrastructure, inadequate prevention strategies, and substantial disparities in healthcare access across urban and rural populations. The economic implications of cardiovascular diseases in Pakistan extend far beyond direct medical expenditures, encompassing a complex web of costs that include direct medical expenses, indirect productivity losses, and intangible societal impacts (Saeed et al., 2021). Direct costs encompass medical consultations, medications, hospitalizations, diagnostic procedures, and long-term care requirements, while indirect costs include productivity losses due to morbidity, premature mortality, and caregiver burden. International evidence suggests that cardiovascular diseases can consume between 1.5% to 3% of gross domestic product in developing countries, with individual patients facing catastrophic health expenditures that often exceed 40% of household income (Kumar et al., 2022).

The concept of disability-adjusted life years provides a comprehensive metric for quantifying the total burden of cardiovascular diseases by combining years of life lost due to premature mortality and years lived with disability (Ferrari et al., 2024). Global trend analyses demonstrate that while overall cardiovascular DALYs have declined in high-income regions, LMICs continue to experience either stable or increasing DALY rates. This pattern reflects persistent challenges in implementing effective prevention strategies, limited access to quality healthcare services, and inadequate management of cardiovascular risk factors in resource-constrained settings (Daroudi et al., 2021).

Pakistan's unique demographic and epidemiological profile presents distinct challenges for cardiovascular disease management. The country experiences a dual burden of communicable and non-communicable diseases, with cardiovascular conditions emerging as the dominant cause of adult mortality. Risk factors such as hypertension affect approximately 33% of the adult population, diabetes mellitus affects 26.7% of adults, and tobacco use remains prevalent across various demographic groups (Ahmad & Anwar 2023). Additionally, Pakistan's healthcare system is characterized by significant under-

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investment, with total health expenditure representing only 3.2% of GDP, substantially below the World Health Organization's recommended minimum of 5% (Khalid & Qayyum, 2021).

The economic burden assessment of cardiovascular diseases requires sophisticated analytical approaches that capture both the breadth and depth of disease impact across different population segments. Previous studies in similar settings have employed cost-of-illness methodologies, markov modeling, and cross-sectional surveys to quantify economic burden, yet comprehensive data specific to Pakistan's context remains limited (Sharma et al., 2022). Understanding the economic burden and DALY implications of cardiovascular diseases is essential for evidence-based policy formulation, resource allocation decisions, and the development of targeted intervention strategies.

Despite the recognized significance of cardiovascular diseases in Pakistan's health landscape, comprehensive economic burden studies that simultaneously examine direct costs, indirect costs, and DALY implications remain scarce. Existing research has primarily focused on single disease entities or limited geographic regions, failing to capture the full spectrum of cardiovascular disease burden across Pakistan's diverse population. This knowledge gap significantly hampers evidence-based healthcare planning and resource allocation, particularly in a resource-constrained environment where optimal utilization of limited healthcare resources is paramount for achieving maximum population health benefits.

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Literature Review

Global Economic Burden of Cardiovascular Diseases

Cardiovascular diseases impose substantial economic burden globally, representing a critical challenge for healthcare systems and national economies. CVD is a general term for a class of diseases that affect the heart or blood vessels, including coronary artery disease, heart attack, stroke, arrhythmia, heart failure, heart valve problems, congenital heart defects, cardiomyopathy and peripheral artery disease. The global prevalence of CVDs had an increase of 93% (from 271 million in 1990 to 523 million in 2019) and the CVD mortality has risen about 54% (from 12.1 million in 1990 to 18.6 million in 2019) which represents about one-third of the annual deaths across the world (Raheem et al., 2022).

The economic implications are staggering, with CVDs responsible for approximately 60% of disability-adjusted life years (DALY) globally, about one-fourth of this burden is attributable to cardiovascular diseases (Vaduganathan et al 2022). An estimation of the burden of hypertension in Australia in terms of productivity lost over the working lifetime has shown that a 25% reduction in hypertension prevalence, could save 37,000 lives and return AUD$34.3 billion in gross domestic product to the Australian economy, whereas the adequate treatment and control hypertension would save AUD$91.6 billion (Xu Islam et al., 2024).

Regional Economic Burden in South Asia

South Asia faces disproportionate cardiovascular burden with significant economic ramifications. The SA region is experiencing an increasing trend in prevalence, deaths, and DALYs due to CVD, with ischemic heart disease (IHD) and stroke remained the main contributors to the regional

burden of CVD. Pakistan, as part of this region, demonstrates particularly concerning trends with a relative increase of 30.3% in CVD mortality rates from 1990 to 2019 (Shams et al., 2021).

Economic analysis reveals that Pakistan urgently needs to develop and formulate a prevention and control strategy for obesity at the national level, as Pakistan with 50% of obesity is the tenth most obese nation in the world due to intake of a high-fat diet and sedentary lifestyle. The economic implications extend beyond direct healthcare costs to encompass productivity losses, premature mortality, and long-term disability care requirements (Munir et al., 2023).

Disability-Adjusted Life Years (DALYs) Methodology and Applications

DALYs represent a comprehensive metric combining both mortality and morbidity impacts. DALYs are calculated by taking the sum of years of life lost (YLL) and years lived with disability (YLD), allowing an assessment of the total loss of health from different causes. This methodology enables comparison across different disease conditions and geographical regions, providing crucial data for health economic evaluations and policy formulation (Masaebi et al., 2021). Contemporary research demonstrates that all the three indices had a downward trend over the study period globally, with countries experiencing lower burden of CVD in 2019 compared to the starting point of the study.

Pakistan-Specific Cardiovascular Disease Burden

Pakistan presents unique challenges in cardiovascular disease management and economic burden. Pakistan is a country with a low socioeconomic status (SES), with poverty and low SES affecting diet quality and being associated with adverse health outcomes. One-fifth of the population is malnourished and one-third of the population has no access to adequate nutrition, contributing to increased CVD risk profiles (Waghmare et al., 2022).

The healthcare system challenges compound the economic burden. Pakistan urgently needs to develop and formulate a prevention and control strategy for obesity at the national level by implementing the World Health Organization (WHO) policies and recommendations for preventing obesity and diabetes in the Eastern Mediterranean Region. Several factors such as malnutrition, poverty and low diet quality, poor dietary habits and a poor healthcare system may contribute to the increased risk of diet-related premature CVD mortality in Pakistan (Waghmare et al., 2022).

Economic Evaluation Methodologies in Cardiovascular Research

Contemporary economic evaluations employ sophisticated methodologies to capture comprehensive cost structures. These include direct medical costs (hospitalization, medications, procedures), direct non-medical costs (transportation, caregiving), and indirect costs (productivity losses, premature mortality). The integration of DALY calculations with economic analysis provides policymakers with crucial information for resource allocation and intervention prioritization.

The burden of CVD varies widely across different ages, sexes, and countries/regions around the world, particularly in different economic development or social demographic index regions. This variability necessitates country-specific economic burden assessments to inform targeted policy interventions and healthcare system strengthening initiatives.

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Knowledge Gaps and Research Imperatives

Despite growing recognition of CVD's economic impact, comprehensive country-specific economic burden analyses incorporating DALYs remain limited, particularly for South Asian populations. Few studies have systematically quantified the complete economic burden of cardiac diseases in Pakistan, incorporating both direct and indirect costs alongside disability-adjusted life years. Furthermore, cross-sectional analyses providing contemporary snapshots of economic burden are essential for informing immediate policy decisions and resource allocation strategies.

Therefore, this study aims to conduct a comprehensive cross-sectional analysis of the economic burden and disability-adjusted life years associated with cardiac diseases in Pakistan, providing crucial evidence for healthcare policy formulation and resource optimization strategies.

Methodology

Study Design and Setting

A comprehensive cross-sectional mixed-methods analysis was conducted across major healthcare facilities in two strategically selected provinces of Pakistan: Islamabad Capital Territory and Sindh Province (specifically Hyderabad district). The study period extended from January 2023 to December 2024, providing a 24-month observation window to capture seasonal variations and ensure robust data collection.

Study Population and Sampling

The study employed a stratified purposive sampling approach targeting adult patients (≥18 years) diagnosed with cardiac diseases across tertiary care hospitals, specialized cardiac centers, and district-level healthcare facilities. A total of 1,486 cardiac patients were enrolled, with 742 participants from Islamabad and 744 from Hyderabad. Inclusion criteria comprised confirmed cardiac diagnoses including ischemic heart disease, heart failure, arrhythmias, valvular diseases, and congenital heart conditions. Patients with incomplete medical records or those unwilling to provide informed consent were excluded.

Data Collection Framework

Primary Data Collection

Structured interviews were conducted using validated questionnaires to assess direct medical costs, direct non-medical costs, and indirect costs. Patient interviews captured out-of-pocket expenditures, transportation costs, caregiving expenses, and productivity losses. Healthcare provider interviews supplemented cost data with clinical severity assessments and treatment protocols.

Secondary Data Analysis

Hospital records, billing systems, and administrative databases provided comprehensive treatment costs, diagnostic expenses, and healthcare utilization patterns. Regional health information systems contributed population-level epidemiological data for DALY calculations.

Economic Burden Assessment

Cost Categories

1. **Direct Medical Costs:** Hospital charges, physician fees, diagnostic procedures, medications, surgical interventions, and rehabilitation services.
2. **Direct Non-Medical Costs:** Transportation expenses, accommodation costs for patients and caregivers, and food expenses during treatment periods.
3. **Indirect Costs:** Productivity losses due to illness, premature mortality, and caregiving responsibilities calculated using human capital approach.
4. **Intangible Costs:** Quality of life impacts assessed through validated instruments and converted to monetary values using willingness-to-pay estimates.

Economic Analysis Perspective

A societal perspective was adopted to capture comprehensive economic impact, including costs borne by patients, families, healthcare systems, and society. All costs were standardized to 2024 Pakistani Rupees (PKR) and adjusted for purchasing power parity where appropriate.

Disability-Adjusted Life Years (DALYs) Calculation

DALYs were calculated following WHO methodology:

- **DALY = YLL + YLD**

- **Years of Life Lost (YLL)**
  YLL = Σ(deaths × standard life expectancy at age of death)

- **Years Lived with Disability (YLD)**
  YLD = Prevalence × Disability Weight × Duration

Disability weights were obtained from Global Burden of Disease Study 2019, with age-specific life expectancy data from Pakistan demographic surveys. Disease-specific disability weights ranged from 0.031 for mild heart failure to 0.439 for severe ischemic heart disease.

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Statistical Analysis

Descriptive statistics included means, medians, and proportions with 95% confidence intervals. Regional comparisons employed independent t-tests for continuous variables and chi-square tests for categorical variables. Multivariate regression models identified factors associated with cost variations and DALY burden. Sensitivity analyses tested robustness of economic estimates using Monte Carlo simulations. Statistical significance was set at $p<0.05$, with analyses conducted using SPSS version 28.0.

Ethical Considerations

The study received approval from institutional review boards of participating hospitals and the National Bioethics Committee of Pakistan. Written informed consent was obtained from all participants, with special provisions for critically ill patients. Data confidentiality and patient privacy were strictly maintained throughout the study period.

Results

Patient Demographics and Clinical Characteristics

The study enrolled 1,486 cardiac patients across Islamabad (n=742) and Hyderabad (n=744) with mean age of 58.3±14.7years. Male patients comprised 61.2% of the sample, reflecting typical gender distribution in cardiac disease presentation. Ischemic heart disease represented the most prevalent condition (52.3%), followed by heart failure (23.8%), arrhythmias (12.4%), and valvular diseases (11.5%). Educational attainment showed regional disparities, with 34.7% of Islamabad patients having secondary education compared to 19.2% in Hyderabad.

Economic Burden Analysis

Regional Cost Disparities and Healthcare Access

The economic burden analysis reveals profound regional disparities in cardiac disease costs across Pakistan's healthcare landscape. Table-1 demonstrates that while Islamabad patients face substantially higher absolute costs across all categories, this differential reflects complex interactions between healthcare infrastructure, service availability, and treatment intensity rather than simple cost inflation. The 29.8% higher direct medical costs in Islamabad (PKR 387,450 vs PKR 298,750) primarily stem from greater access to specialized cardiac interventions and advanced diagnostic technologies. However, when examined through the lens of relative economic impact, Hyderabad patients experience proportionally greater financial burden due to lower baseline household incomes, highlighting critical healthcare equity concerns across Pakistan's diverse socioeconomic landscape.

Table-1: Regional Economic Burden of Cardiac Diseases in Pakistan

Cost Category	Islamabad (n=742)	Hyderabad (n=744)	Difference	P-value
Direct Medical Costs				
Hospitalization	260,890 (±45,670)	201,230 (±38,920)	59,660	<0.001
Medications	70,880 (±12,340)	54,670 (±9,880)	16,210	<0.001
Diagnostics	55,680 (±8,920)	42,850 (±7,230)	12,830	<0.001
Subtotal Direct	**387,450**	**298,750**	**88,700**	**<0.001**
Indirect Costs				
Productivity Loss	234,890 (±56,780)	198,340 (±48,920)	36,550	<0.001
Caregiver Costs	89,650 (±23,450)	76,890 (±19,670)	12,760	0.002
Transportation	45,230 (±12,890)	38,670 (±11,240)	6,560	0.008
Subtotal Indirect	**369,770**	**313,900**	**55,870**	**<0.001**
Intangible Costs	135,120 (±34,560)	62,240 (±18,890)	72,880	<0.001
Total Societal Cost	**892,340**	**674,890**	**217,450**	**<0.001**

The significant productivity losses observed across both regions (PKR 234,890 in Islamabad vs PKR 198,340 in Hyderabad) underscore the broader economic implications extending beyond direct healthcare expenditures. These indirect costs, representing 41.4% and 46.5% of total societal costs respectively, highlight how cardiac diseases perpetuate economic vulnerability through reduced earning capacity and increased dependency ratios within affected households.

Catastrophic Health Expenditure and Financial Protection Gaps

The catastrophic health expenditure analysis presented in **Table-2** reveals alarming financial vulnerability across Pakistan's cardiac patient population, with implications extending far beyond immediate healthcare costs. The paradoxical finding that Hyderabad demonstrates higher catastrophic expenditure rates (74.2%) despite lower absolute costs reflects the region's substantially lower baseline household incomes and limited financial protection mechanisms. This 5.8 percentage point differential becomes even more concerning when examining severe financial hardship indicators, where 32.8% of Hyderabad families face healthcare costs exceeding 40% of household income compared to 24.1% in Islamabad.

The impoverishment analysis demonstrates how cardiac diseases function as poverty traps, with over one-third of Hyderabad families being pushed below the poverty line due to healthcare expenses. The widespread adoption of negative coping strategies—including asset liquidation (49.1%), borrowing (70.6%), and treatment avoidance (29.6%)—indicates systemic failures in financial protection and suggests that current healthcare financing mechanisms inadequately address the economic realities of cardiac disease management in Pakistan.

ISSN: 3007-2115

Table-2: Catastrophic Health Expenditure and Financial Impact Analysis				
Financial Impact Indicator	**Islamabad**	**Hyderabad**	**Overall**	**95% CI**
Catastrophic Health Expenditure				
>10% of household income	68.4%	74.2%	71.3%	(68.9-73.7)
>25% of household income	42.7%	51.3%	47.0%	(44.4-49.6)
>40% of household income	24.1%	32.8%	28.5%	(26.2-30.8)
Impoverishment Risk				
Pushed below poverty line	28.7%	34.2%	31.5%	(29.1-33.9)
Median income reduction	23.4%	31.7%	27.6%	(25.8-29.4)
Coping Strategies				
Asset liquidation	45.8%	52.3%	49.1%	(46.5-51.7)
Borrowing	67.2%	73.9%	70.6%	(68.1-73.1)
Treatment delay/avoidance	23.4%	35.7%	29.6%	(27.2-32.0)

Disability-Adjusted Life Years (DALYs) Assessment

The primary analysis reveals the comprehensive burden of cardiac diseases across Pakistan, with several critical findings. The total burden of 847,620 DALYs represents a substantial population health impact, with ischemic heart disease emerging as the dominant contributor at 52.3% of total burden. The disproportionate contribution of years of life lost (YLL) versus years lived with disability (YLD) - representing 73.6% versus 26.4% respectively - indicates that cardiac diseases in Pakistan are characterized more by premature mortality than by long-term disability, suggesting either inadequate treatment access or delayed diagnosis leading to fatal outcomes.

The regional disparities are particularly striking, with Hyderabad consistently showing higher burden rates across all cardiac disease categories. The most pronounced difference appears in heart failure (68.5% higher in Hyderabad: 487 vs 289 per 100,000), followed by ischemic heart disease (40.3% higher: 923 vs 658 per 100,000). These disparities likely reflect differences in healthcare infrastructure, specialist availability, and socioeconomic determinants of health between the capital territory and provincial settings. The age-standardized rates (1,456 vs 1,289 per 100,000) confirm that these differences persist even after controlling for demographic variations, indicating genuine disparities in disease burden or healthcare outcomes (Table-3).

Table-3. Disability-Adjusted Life Years (DALYs) by Cardiac Disease Categories						
Disease Category	**Total DALYs**	**YLL**	**YLD**	**DALY Rate per 100,000**	**Islamabad**	**Hyderabad**
Ischemic Heart Disease	443,223	325,670	117,553	719	658	923
Heart Failure	201,786	142,250	59,536	327	289	487
Arrhythmias	105,124	68,920	36,204	171	156	218
Valvular Diseases	97,487	86,610	10,877	158	142	201
Total Cardiac DALYs	**847,620**	**623,450**	**224,170**	**1,374**	**1,245**	**1,829**
Age-Standardized Rates	-	-	-	-	**1,289**	**1,456**

Gender Distribution of DALYs by Region

The gender analysis reveals significant disparities in cardiac disease burden, with males experiencing substantially higher DALY rates than females across both regions. The overall male-to-female ratio of 1.61:1 (1,689 vs 1,051 per 100,000) reflects well-documented epidemiological patterns of cardiovascular disease, where men typically experience earlier onset and more severe manifestations of cardiac conditions. This pattern is consistent across both regions, with Islamabad showing a 55.5% higher male burden and Hyderabad demonstrating a 59.4% differential.

The regional variations within gender categories are equally concerning. Male DALY rates in Hyderabad exceed those in Islamabad by 28.2% (1,967 vs 1,534 per 100,000), while female rates show a 25.0% differential (1,234 vs 987 per 100,000). The higher proportion of YLL relative to YLD in males (74.5% vs 72.1% in females) suggests that men not only experience higher disease incidence but also face greater mortality risk, potentially due to delayed healthcare-seeking behavior, occupational risk factors, or lifestyle-related cardiovascular risk profiles prevalent in Pakistani society (Table-3A).

Table-3A: Gender Distribution of DALYs by Region

Gender	Total DALYs	YLL	YLD	Overall Rate per 100,000	Islamabad	Hyderabad
Male DALYs	523,254	389,670	133,584	1,689	1,534	1,967
Female DALYs	324,366	233,780	90,586	1,051	987	1,234

The age-stratified analysis reveals a concerning epidemiological profile with significant implications for Pakistan's economic development and healthcare planning. The dramatic increase in DALY rates with advancing age - from 287 per 100,000 in young adults to 4,567 per 100,000 in elderly populations - demonstrates the typical age-related progression of cardiovascular disease. However, the substantial burden among productive-age adults (45-64 years), contributing 43.0% of total DALYs despite representing a smaller demographic proportion, highlights the economic implications of premature cardiovascular morbidity and mortality.

The regional disparities are most pronounced in the elderly population (≥65 years), where Hyderabad shows 23.6% higher rates than Islamabad (5,234 vs 4,234 per 100,000). This differential may reflect limited access to specialized geriatric cardiac care in provincial settings or disparities in long-term disease management capabilities. The productive-age group (45-64 years) shows a 27.2% higher burden in Hyderabad, which has particular economic significance given this population's role in household income generation and economic productivity.

Most concerning is the young adult burden (18-44 years), where Hyderabad shows 45.3% higher rates than Islamabad (356 vs 245 per 100,000). This early-onset disease burden suggests potential differences in risk factor exposure, preventive care access, or environmental determinants between regions. The high proportion of YLL in this age group (87.4%) indicates that young adults with cardiac disease face substantial mortality risk, representing significant years of productive life lost and highlighting the urgent need for early detection and intervention programs targeting this vulnerable population (Table-3B).

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Table-3B: Age Group Distribution of DALYs by Region

Age Group	Total DALYs	YLL	YLD	Overall Rate per 100,000	Islamabad	Hyderabad
18-44 years	112,340	98,230	14,110	287	245	356
45-64 years	364,780	267,890	96,890	1,823	1,678	2,134
≥65 years	370,500	257,330	113,170	4,567	4,234	5,234

Discussion

The comprehensive analysis of 1,486 cardiac patients across Islamabad and Hyderabad provides crucial insights into the substantial economic burden and health impact of cardiovascular diseases in Pakistan. Our findings demonstrate that cardiac diseases impose a total societal cost ranging from PKR 674,890 to PKR 892,340 per patient, with significant regional disparities that reflect broader healthcare inequities across the country. The study reveals a total burden of 847,620 DALYs, with age-standardized rates of 1,289 per 100,000 in Islamabad and 1,456 per 100,000 in Hyderabad, indicating substantial population health impact particularly in provincial settings.

The 29.8% higher direct medical costs observed in Islamabad (PKR 387,450 vs PKR 298,750) paradoxically coexist with higher rates of catastrophic health expenditure in Hyderabad (74.2% vs 68.4%), highlighting how absolute costs alone fail to capture the true financial burden experienced by patients and families. This finding underscores the critical importance of considering regional economic contexts when evaluating healthcare costs, as the lower baseline household incomes in Hyderabad render even relatively modest healthcare expenses financially devastating. The predominance of ischemic heart disease (52.3% of total burden) and the substantial contribution of years of life lost (73.6%) versus years lived with disability (26.4%) suggest that cardiac diseases in Pakistan are characterized more by premature mortality than chronic disability, potentially indicating delayed diagnosis or inadequate treatment access.

These findings align with the most recent global cardiovascular disease burden studies from 2023-2024. The Global Burden of Disease Study 2023 reported ischemic heart disease as having the highest global age-standardized DALYs of all diseases at 2,275.9 per 100,000, with global CVD mortality increasing from 12.4 million in 1990 to 19.8 million in 2022 (Mensah et al., 2023). Our observed age-standardized DALY rates substantially exceed the global averages reported in this latest data, with Pakistan's rates being particularly elevated compared to other South Asian countries. Recent forecasting

studies for Asia from 2024 project that between 2025 and 2050, crude cardiovascular mortality is expected to rise 91.2% despite a 23.0% decrease in age-standardized cardiovascular mortality rates, with ischemic heart disease and stroke remaining leading drivers (Goh et al., 2024).

The catastrophic health expenditure rates observed in our study (71.3% overall) are considerably higher than recent findings from other South Asian countries. A 2024 study examining catastrophic health expenditure in India found that 28% of households experienced catastrophic expenditure, substantially lower than our Pakistani findings (Saeed et al., 2024). Recent 2023 research from Sub-Saharan Africa demonstrated that cardiovascular diseases significantly increase the risk of catastrophic health expenditure, with CVD patients being 2.3 times more likely to experience such financial hardship (Adeniji & Obembe, 2023). This comparison suggests that Pakistan's healthcare financing mechanisms provide particularly inadequate financial protection compared to regional counterparts, potentially reflecting more limited health insurance coverage and weaker social safety nets. The widespread adoption of negative coping strategies observed in our study, particularly asset liquidation (49.1%) and borrowing (70.6%), aligns with recent studies examining economic burden in low- and middle-income countries. A 2024 analysis of South Asian populations noted that "the prohibitive cost of CVD care exacerbates poverty, leading to catastrophic healthcare spending and lower employment rates" (Nammi et al., 2024), which directly corresponds with our findings regarding treatment avoidance and delay patterns.

The regional disparities in DALY rates between Hyderabad and Islamabad (1,456 vs 1,289 per 100,000) reflect patterns documented in recent global burden studies. The 2023 Global Burden of Disease special report found that more than 75% of the global CVD burden is concentrated in low- and middle-income countries in regions including South Asia, with significant variations between urban and provincial areas (Mensah et al., 2023). Recent literature emphasizes that LMICs contribute 80% of all cardiovascular deaths worldwide, with limited healthcare infrastructure and specialist availability contributing to regional disparities.

The substantial productivity losses identified in our analysis (PKR 234,890 in Islamabad vs PKR 198,340 in Hyderabad) correspond with recent economic projections for the global CVD burden. The American Heart Association's 2024 forecasting study projects that cardiovascular healthcare costs will triple between 2020 and 2050, from $400 billion to $1,344 billion in the United States alone, highlighting the enormous economic implications of CVD burden globally (Kazi et al., 2024). The 2024

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World Heart Report estimates that air pollution-related health damages cost $8.1 trillion globally, equivalent to 6.1% of global GDP, with 1.2 billion annual workdays lost (Rwebembara et al., 2024).

Our finding that cardiac diseases function as poverty traps, pushing 31.5% of families below the poverty line, corresponds with recent theoretical and empirical work on health shocks in low-income settings. A 2023 analysis specific to Pakistan noted that with health spending at only $43 per person and government health expenditure representing just 1.2% of GDP, the country falls in the lowest decile globally for Universal Health Coverage effectiveness (Jafar & Quadri et al., 2023). The treatment delay and avoidance rates observed (29.6% overall, 35.7% in Hyderabad) exceed those reported in recent comparable studies from other South Asian countries, indicating particular challenges in healthcare access and affordability within the Pakistani context.

The age-stratified analysis revealing substantial burden among productive-age adults (43.0% of total DALYs in 45-64 year group) reflects recent demographic and epidemiological analyses of cardiovascular disease patterns in South Asia. A 2024 European Journal of Preventive Cardiology study projecting global cardiovascular trends to 2050 found that while age-standardized mortality is expected to decrease by 30.5%, the absolute burden will increase substantially due to population aging and growth (Chong et al., 2024). Our observed early-onset burden (18-44 years showing 45.3% higher rates in Hyderabad versus Islamabad) aligns with recent reports documenting accelerated cardiovascular disease progression in South Asian populations, potentially reflecting increasing prevalence of diabetes, hypertension, and metabolic syndrome (Nammi et al., 2024).

Conclusion

Our study provides compelling evidence that cardiac diseases impose an enormous economic and health burden on Pakistani society, with regional disparities that reflect broader healthcare inequities and socioeconomic differences. The catastrophic health expenditure rates approaching three-quarters of affected families, combined with substantial DALY burden concentrated among productive-age populations, demonstrate that cardiovascular diseases represent both a significant public health challenge and a barrier to economic development. The findings suggest urgent need for comprehensive healthcare financing reforms, including expanded insurance coverage and strengthened financial protection mechanisms, particularly for provincial populations who face disproportionate economic hardship despite lower absolute healthcare costs. Furthermore, the predominance of premature mortality over disability in the DALY calculations indicates critical gaps in early detection, prevention, and timely

intervention that require immediate policy attention. Investment in cardiovascular disease prevention programs, particularly targeting younger adult populations and addressing regional healthcare infrastructure disparities, represents both a public health imperative and an economic necessity for Pakistan's sustainable development trajectory.

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