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SPECIAL ARTICLE
Epidemiology, prevention, and health care policies

European Society of Cardiology: the 2023 Atlas of Cardiovascular Disease Statistics

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Abstract

This report from the European Society of Cardiology (ESC) Atlas Project updates and expands upon the 2021 report in presenting cardiovascular disease (CVD) statistics for the ESC member countries. This paper examines inequalities in cardiovascular healthcare and outcomes in ESC member countries utilizing mortality and risk factor data from the World Health Organization and the Global Burden of Disease study with additional economic data from the World Bank. Cardiovascular healthcare data were collected by questionnaire circulated to the national cardiac societies of ESC member countries. Statistics pertaining to 2022, or latest available year, are presented. New material in this report includes contemporary estimates of the economic burden of CVD and mortality statistics for a range of CVD phenotypes. CVD accounts for 11% of the EU's total healthcare expenditure. It remains the most common cause of death in ESC member countries with over 3 million deaths per year. Proportionately more deaths from CVD occur in middle-income compared with high-income countries in both females (53% vs. 34%) and males (46% vs. 30%). Between 1990 and 2021, median age-standardized mortality rates (ASMRs) for CVD decreased by median >50% in high-income ESC member countries but in middle-income countries the median decrease was <12%. These inequalities between middle- and high-income ESC member countries likely reflect heterogeneous exposures to a range of environmental, socioeconomic, and clinical risk factors. The 2023 survey suggests that treatment factors may also contribute with middle-income countries reporting lower rates per million of percutaneous coronary intervention (1355 vs. 2330), transcatheter aortic valve implantation (4.0 vs. 153.4) and pacemaker implantation (147.0 vs. 831.9) compared with high-income countries. The ESC Atlas 2023 report shows continuing inequalities in the epidemiology and management of CVD between middle-income and high-income ESC member countries. These inequalities are exemplified by the changes in CVD ASMRs during the last 30 years. In the high-income ESC member countries, ASMRs have been in steep decline during this period but in the middle-income countries declines have been very small. There is now an important need for targeted action to reduce the burden of CVD, particularly in those countries where the burden is greatest.

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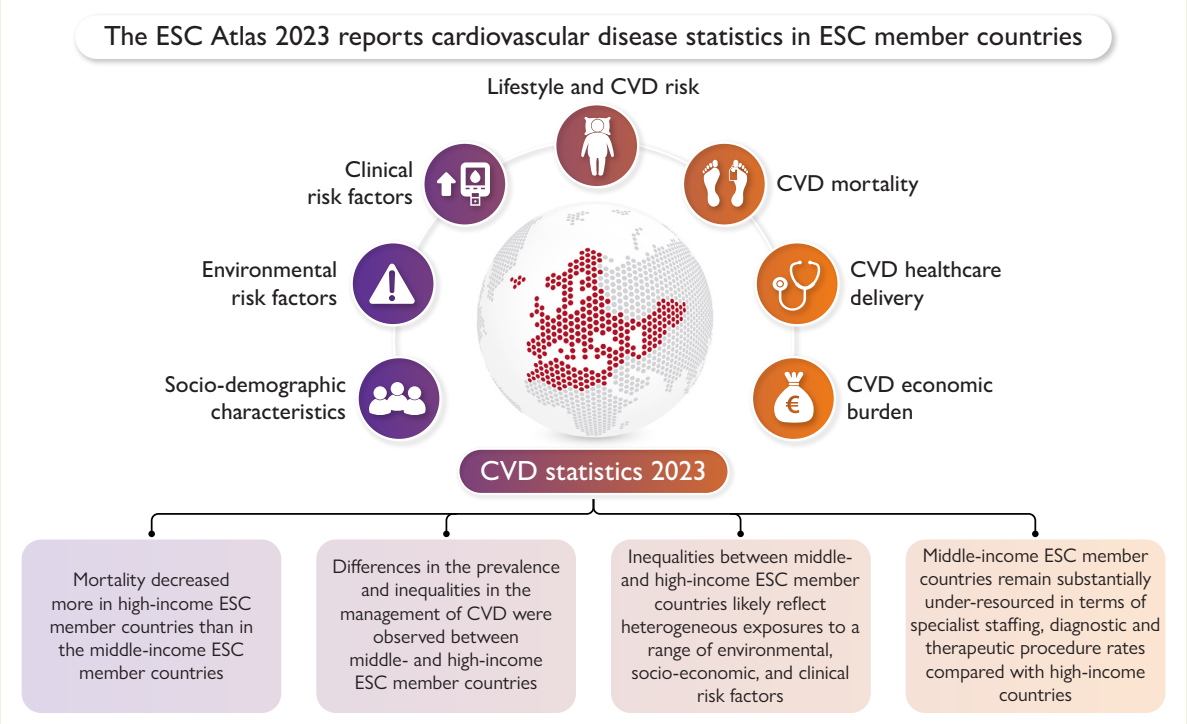
Graphical Abstract



2023 Cardiovascular Disease Statistics. The 2023 ESC Atlas Project report provides contemporary cardiovascular disease (CVD) statistics for the European Society of Cardiology (ESC) member countries. The updated CVD statistics are presented in a consistent and assertive approach with the aim of advancing knowledge and reducing the burden of CVD.

Keywords Cardiovascular disease • Statistics • European Society of Cardiology • Health infrastructure • Service provision • Risk factors • Mortality

Abbreviations

AMI	Acute myocardial infarction
ASMR	Age-standardized mortality rate
AF	Atrial fibrillation
AVD	Aortic valve disease
BMI	Body mass index
BoD	Burden of disease
CABG	Coronary artery bypass graft
CHD	Coronary heart disease
CHE	Current healthcare expenditure
CRT	Cardiac resynchronization therapy
CTCA	Computed tomography coronary angiography
CVD	Cardiovascular disease
DALY	Disability-adjusted life year
Db[A]	A-weighted decibels
€	Euro
ESC	European Society of Cardiology
EU	European Union
EuReCa	European Registry of Cardiac Arrest
GBD	Global burden of disease
GDP	Gross domestic product
ICD	Implantable cardioverter–defibrillator
IHD	Ischaemic heart disease
IHME	Institute for Health Metrics and Evaluation
IQR	Interquartile range
LEAD	Lower extremity artery disease
LVAD	Left ventricular assist device
MVD	Mitral valve disease
NHS	National Health Service
OECD	Organisation for Economic Co-Operation and Development
OHCA	Out-of-hospital cardiac arrest
PCI	Percutaneous coronary intervention
$PM_{2.5}$	Particulate matter ≤2.5 μm in diameter
PYLL	Potential years of life lost
SAVR	Surgical aortic valve replacement
SES	Socioeconomic status
TAVI	Transcatheter aortic valve implantation
UK	United Kingdom
USA	United States of America
USD	US dollars
WB	World Bank
WHO	World Health Organization

Executive summary

This 2023 report from the European Society of Cardiology (ESC) Atlas Project updates and expands upon the previous 2021 report in

presenting cardiovascular disease (CVD) statistics for 55 out of 57 ESC member countries, with Belarus and Russia currently not included.

Statistics pertaining to 2022, or latest available year, are presented. Alongside an update of previously presented epidemiological data, new material on the economic burden of CVD and mortality statistics for a range of CVD phenotypes are included. Sections such as air pollution and hypercholesterolaemia, for which there are no new data available, have been omitted from the report, and readers are directed to the previous report from the ESC Atlas Project.

European Society of Cardiology atlas of cardiology

The CVD statistics that constitute this report are drawn from the ESC Atlas of Cardiology (henceforth called the ESC Atlas) that is compiled and regularly updated by the European Heart Agency in Brussels. Its key objectives are to:

- assess and compare CVD burden across ESC member countries;
- drive policy initiatives to help reduce inequalities in CVD burden;
- map European CVD healthcare delivery; and
- provide a one-stop source of CVD statistics for academics, clinicians, and other stakeholders.

Data sources and presentation

The ESC Atlas is a repository of CVD data collected by organizations such as the World Health Organization (WHO), the Institute for Health Metrics and Evaluation (IHME), and the World Bank (WB). It also includes novel ESC sponsored data on human and capital infrastructure and cardiovascular healthcare delivery obtained from the 2023 survey distributed among the national cardiovascular societies of ESC member countries.

Throughout the 2023 report, ESC member countries are categorized according to 2021 WB definitions as high-income and middle-income (a composite of upper-middle-income and lower-middle-income ESC member countries, yet also including Syria, which continues to be classified as a low-income country). This is to permit stratified presentations of CVD statistics by national income status.

The data sources come with important limitations that include:

- adjustments performed by the different data providers to account for missing data;
- differences in reporting practices causing variable imprecision of national data estimates;
- misclassification bias due to miscoding of diagnostic groups and death certificates; and
- hidden within-country inequalities in disease burden and healthcare delivery.

These limitations as they apply to the quality, precision, and availability of the data emphasize the need for cautious interpretation of the CVD statistics presented in this report.

Economic burden of cardiovascular disease

Cardiovascular disease imposes a substantial economic burden on societies worldwide. A study across European Union (EU) countries found that health and social care costs alone amounted to €155 billion in 2021, constituting 11% of the EU's total healthcare expenditure. To these direct healthcare costs should be added the indirect costs to society of the working or leisure time that patients forgo as well as carers looking after relatives or friends with CVD. These costs are estimated at €79 billion across the EU with a further €61.6 billion in productivity losses caused by reduced work capacity, absenteeism, and early retirement of population affected by CVD. The wide-ranging socioeconomic consequences of CVD place huge strains on healthcare systems, productivity levels, and national budgets.

National sociodemographic and environmental risk factors

Across ESC member countries a continuing high prevalence of CVD is driven by ageing populations and a sustained shift towards urbanization with its associated exposures to air and noise pollution. In 2019, air pollution with particulate matter ≤2.5 μm in diameter ($PM_{2.5}$) exceeded the EU air quality standard in 14 middle-income countries, while noise exposure was estimated to exceed recommended residential limits in up to 40% of people living in the EU. Immigrant groups tend to concentrate in urban areas and are subject to health inequalities that further contribute to disease prevalence, particularly in middle-income countries where socioeconomic deprivation evidenced by low household incomes, unemployment, and educational under-attainment are common. These sociodemographic and environmental risk factors are not readily amenable to change and are likely to remain important drivers of poor cardiovascular health in many ESC member countries.

Lifestyle and cardiovascular disease risk

Lifestyle factors, including diet, alcohol consumption, tobacco use, and physical activity are major determinants of cardiovascular risk. Smoking increases the risk of death from CVD by up to three times. In 2020, 25.4% of persons aged ≥15 years in ESC member countries were current users of tobacco products, with lower rates in females than in males [19.7%, interquartile range (IQR) 11.6%–24.6% vs. 33.4% (IQR 24.4%–40.5%)]. Use of tobacco products was particularly high among males in middle-income ESC member countries where 40.9% (IQR 37.6%–42.1%) were smokers. Policy measures to reduce tobacco use have been effective in reducing smoking rates across ESC member countries over the last 20 years from 34.3% (IQR 29.7%–37.6%) to its current level. The harmful use of alcohol, however, has remained stable during this period and in 2019 alcohol consumption was nearly twice as high in high-income compared with middle-income ESC member countries. Young adults are most susceptible to the harmful effects of alcohol and current recommendations are for them to be prioritized in strategies aimed at minimizing consumption. Regarding diet, sugar consumption, as well as dietary fats and oils, is higher in high-income compared with middle-income countries [345 (IQR 290–432) vs. 289 (IQR 227–333) kcal/capita/day]. A sugar reduction initiative is now being launched across Europe in a drive to reduce rates of diabetes and CVD. Physical activity is also protective against CVD. Insufficient physical activity levels—<150 min of moderate-intensity physical activity per week or <75 min of vigorous-intensity physical activity per week—caused more disability-adjusted life years (DALYs) per 100 000 in middle-income compared with high-income ESC member countries [275 (IQR 224–607) vs. 160 (IQR 141–202)].

Clinical risk factors

Raised blood pressure is a leading risk factor for CVD and in 2019 affected 36% (IQR 26%–41%) of females and 41% (IQR 35%–48%) of males, in ESC member countries. Rates were higher in middle-income countries where >40% of females and males had high blood pressure compared to <30% of females and <40% of males in the high-income countries. Non-high-density lipoprotein (non-HDL) cholesterol is also

a major determinant of CVD risk with median concentrations across ESC member countries in 2019 of 3.36 (IQR 3.20–3.49) mmol/L in females and 3.53 (IQR 3.28–3.68) mmol/L in males. Concentrations in high-income countries tended to be higher than in middle-income countries in both females and males. Population measures to reduce blood pressure and non-HDL cholesterol have shown variable success particularly in high-income countries but prevalence rates for overweight and obesity have increased relentlessly. In 2019, 54.8% (IQR 49.6%–56.7%) of people in ESC member countries were overweight and 17.0% (IQR 15%–20%) obese, with rates similar for middle-income and high-income countries. Population solutions should lie in lifestyle modification and policy initiatives to encourage exercise and healthy living but to date public health programmes have been largely ineffective and the obesity epidemic has continued unabated. The association of overweight and obesity with dysfunctional glucose metabolism largely accounts for the parallel epidemic of type 2 diabetes which in 2021 had an estimated prevalence of 6.5% (IQR 5.6%–8.4%) across ESC member countries, higher in middle-income compared with high-income countries [7.7% (IQR 6.2%–9.1%) vs. 6.0% (IQR 5.2%–6.9%)].

Cardiovascular disease mortality

Mortality rates for CVD have declined across ESC member countries by >50% over the last 29 years. However, it remained the most common cause of death responsible for >1.6 million deaths in females and >1.5 million in males. With age-standardization, however, mortality rates per 100 000 were higher in males [395.1 (IQR 287.1–873.5)] than females [322.0 (IQR 228.8–673.0)] and in both sexes mortality rates were ≥2.5 times higher in middle-income compared with high-income countries. Ischaemic heart disease (IHD) was the largest contributor to CVD mortality with age-standardized mortality rates (ASMRs) per 100 000 nearly twice as high for males than females [171.4 (IQR 88.7–287.8) vs. 90.8 (IQR 47.8–171.9)]. Similarly, ASMRs per 100 000 were higher in middle-income than high-income countries both for females [159.9 (IQR 48.3–178.1) vs. 67.2 (IQR 46.2–142.6)] and for males [218.0 (IQR 87.3–296.8) vs. 142.9 (IQR 93.1–227.6)]. Stroke and heart failure mortality exhibited a similar pattern with ASMRs higher in males than females and higher in middle-income compared with high-income countries. The epidemiology of lower extremity artery disease, however, showed important differences with ASMRs per 100 000 only 1.3 times higher in males than females while stratification by national income status revealed lower rates in middle-income compared with high-income countries in both sexes, perhaps reflecting underdiagnosis or premature death from other causes. In other manifestations of CVD, ASMRs are less predictable in analyses stratified by sex and national income status. Thus, for both atrial fibrillation and degenerative mitral valve disease ASMRs were similar by sex and higher in high-income compared with middle-income ESC member countries.

Cardiovascular disease healthcare delivery

In the 2023 survey, ESC member countries reported a median of 95.0 (IQR 50.9–123.4) cardiologists per million people of whom 38.6% were female. There were almost twice as many cardiologists in high-income compared with middle-income countries. Despite higher mortality from ischaemic heart disease, middle-income countries reported lower use of diagnostic coronary angiography [3086/million (IQR 1361–4439) vs. 3773/million (IQR 3164–5706)] and percutaneous coronary intervention (PCI) [1355/million (IQR 708.4–2316) vs. 2330/million (IQR 1790–2499)], compared with high-income countries, although the use of coronary artery bypass surgery were similar [278.0/million (IQR 120.0–407.0) vs. 260.4/million (IQR 213.5–376.9)]. Interventional heart valve procedures were performed almost exclusively in high-income countries where rates of transcatheter aortic valve implantation (TAVI) and transcatheter mitral valve interventions have each increased by ∼300% since the 2019 survey of ESC member countries. Ablation procedures and cardiac electronic device implants were also performed more commonly in high-income countries. The relative underuse of diagnostic and therapeutic technology in middle-income ESC member countries does not necessarily imply undertreatment, even though this seems likely given how consistent were the differences in procedure rates. Caution is also necessary in ascribing the inequalities in ASMRs between middle- and high-income countries to differences in procedure rates, bearing in mind that, apart from primary PCI and aortic valve replacement, there is little evidence that the symptomatic benefits of these cardiovascular procedures are associated with reductions in mortality.

Introduction

The healthcare systems across Europe, as well as globally, must adapt to evolving financial demands to address the shifting landscape resulting from an ageing population, the escalating prevalence of non-communicable diseases, and the imminent threat posed by new pandemics, as underscored by recent global spread of COVID-19.

Faced with these challenges, a redesign of healthcare delivery, proper stratification of competing healthcare priorities and evidence-based planning are required, the ultimate goal being to optimize value generated through cost-effective healthcare investments.

Use of evidence to inform these decisions is crucial. Metrics and specific indicators are increasingly recognized as essential for the depiction of the actual status of health and healthcare systems, contributing among other things to performance measurement, quality improvement, resource allocation, policy- and decision-making, accountability and transparency, and of course to healthcare equity.[1]

The European Society of Cardiology (ESC), and the ESC Atlas project in particular, periodically provides a comprehensive set of indicators focused on the cardiovascular health of the population, together with an overview of data from health systems across the ESC member countries. These statistics are drawn from the ESC Atlas of Cardiology, published and regularly updated by the European Heart Agency in Brussels.[2] The ESC Atlas presents cardiovascular disease (CVD)-related statistics collected by international organizations including the World Health Organization (WHO), the Organisation for Economic Cooperation and Development (OECD), the Institute for Health Metrics and Evaluation (IHME), and the World Bank (WB). It also collects novel data on human and capital infrastructure provided by the national cardiovascular societies of ESC member countries, obtained through biennial surveys sponsored by the ESC.

The data presented in this edition are based on metrics from 2022 or the latest available year and have been enriched with economic data from the ESC's Burden of CVD project developed in collaboration with Nuffield Department of Population Health, Oxford University. These initiatives were introduced and developed by the ESC based on a central strategic plan to improve cardiovascular care in its 55 out of 57 member countries and reduce inequalities in healthcare delivery, with the aim of reducing the CVD burden.

We trust that the data presented in this year's edition will receive the attention of all those involved in the design and implementation of cardiovascular care in ESC member countries, in order to reduce gaps in healthcare provision at national and regional levels, so that all patients

can benefit equally from what modern science prioritizes as the essential requirements for effective treatment of CVD.

Data sources and presentation

The CVD statistics provided in this report were compiled as part of the ESC Atlas project by the European Heart Health Institute embedded in the European Heart Agency in Brussels. All analyses, interpretations, and conclusions are those of the authors. A detailed account of the data, particularly its sources, analytic methodology, presentation, and limitations, has been provided elsewhere.[2]

The purpose of ESC CVD statistics is to map those factors that contribute to the development of CVD, and to characterize disease epidemiology and quality of care in the ESC member countries. Key objectives are to assess and compare CVD burden across member countries, drive policy initiatives to help reduce inequalities in CVD burden, map European CVD healthcare delivery, and provide a one-stop source of CVD statistics for academics, clinicians, and other stakeholders.

Each topic throughout the manuscript is introduced with a summary of present knowledge followed by a bulleted presentation of national CVD statistics. Data presentation is descriptive and stratified by 2022 WB definitions of national income status.[3] Time series and sex-stratified data are also presented when available. Throughout the manuscript, the terms 'high-income countries' and 'middle-income countries' are used, with the latter representing a composite of upper-middle-income and lower-middle-income ESC member countries, yet, also including Syria which is now classified as a low-income country. National CVD statistics for the most recently available year are illustrated using bar charts, while time series data are illustrated using locally weighted scatterplot smoothing.[4] Box plots are used for comparison of CVD statistics between high-income and middle-income ESC member countries. The plots display a box representing the median value and first and third quartile values, with whiskers positioned at the furthest data points within 1.5 times the interquartile range (IQR). Any countries outside this range are defined as outliers and are plotted individually.

In summary, this report focuses on adults (age >16 years) from 55 of the 57 member countries of the ESC (Belarus and Russia are not included). The report leverages both primary and secondary data sources. Cardiovascular healthcare delivery data are drawn from 2023 ESC General Atlas survey—collected by questionnaire from the national cardiac societies of ESC member countries and subjected to a range of quality control procedures before final approval. The questionnaire has received minor modification since the previous 2021 report to clarify as necessary the responses we are seeking. Secondary data are for 2022 or latest available year and refer to risk factors, economic, and epidemiological disease burden, and mortality data from the WB, WHO, and the Global Burden of Disease (GBD) study.[5–7] All these data are tabulated in the online supplementary material (see Supplementary data online, *Table S1*) which tabulates the dates, sources, and completeness of the statistics presented in this manuscript.

No attempt is made to determine the statistical significance of differences observed in stratified analyses. When associations are identified there is no assumption of causation. For consistency, measures of central tendency across groups of countries are presented as medians with IQR ranges in parentheses. Values >1000 are not decimalized. Changes in risk factor exposures and mortality rates are represented by relative (%) differences between median estimates. The survey and the data from WHO yield absolute numbers. Rates per million people are computed from WB population estimates with age standardization using the direct method with the 2013 European Standard Population.[8,9]

The WB, WHO, and GBD study together constitute the most credible sources of national estimates of CVD and its associated risk factors. The validity of the statistics these sources provide is a function of the procedures applied in their collection that can be reviewed in the source addresses provided in the data provenance table. General limitations of the data include the adjustment applied by all the main providers to account for missing data, and differences in reporting practices such that precision of the estimates they provide often varies by country. Misclassification bias due to miscoding of diagnostic groups and death certificates is another potential limitation. Data completeness also varies by country and is defined in the data provenance table (see Supplementary data online, *Table S1*). The ESC Atlas does not provide information about within-country inequalities.[10] Moreover, inequalities between high- and middle-income countries are determined by comparing national medians averaged across the groups, which obscures within-category differences. These limitations in the quality, precision, and availability of the data are well recognized and are the subject of continuous review by the data providers in seeking to improve the data quality. Meanwhile, we emphasize the need for cautious interpretation of the CVD statistics presented in this report.

Economic burden of cardiovascular disease

Cardiovascular disease imposes a substantial economic burden on societies worldwide based on the combined costs of health and social care, informal care, and productivity losses. These costs are substantial[11,12] and likely fall most heavily on those middle-income European countries where CVD is most prevalent and financial resource most limited.

Health and social care costs

The treatment of CVD involves a wide array of medical services, including hospitalization, surgeries, medications, and long-term care. These services are expensive and can be overwhelming, particularly in countries with limited access to affordable healthcare. The ESC Atlas Project has partnered with the University of Oxford, Nuffield Department of Population Health in estimating European Union (EU) country-level costs of CVD associated with primary care, accident and emergency, hospital and outpatient services, and medications.[13] The analysis also included costs linked to residential and home-based care to understand the economic impact of Europe's ageing populations. Based on data from 27 EU-member countries, CVD cost estimates for 2021 amounted to €155 billion, constituting 11% of the EU's total healthcare expenditure. There was, however, considerable heterogeneity, with the proportional contribution of CVD care to total healthcare expenditure ranging from 6% in Denmark to 19% in Hungary. Hospital care was a major component of the overall CVD spending totalling €79 billion, of which €30 billion (38%) was allocated to cover the costs associated with CVD procedures. These expensive procedures are increasingly technological and are predicted to become a more significant factor than population ageing in driving up healthcare costs during the next 50 years.[14] The costs of CVD procedures were matched by the €31 billion cost of CVD medications with care home costs coming in at €15 billion, representing 20% and 9%, respectively, of overall CVD-related expenditure.

The ESC Atlas and Oxford investigators estimated the annual health and social care costs of CVD to average €347 per EU citizen, but there was significant threefold variation across the 27 EU-member countries,

ranging from €154 in Croatia to €505 in Austria.[13] CVD-related health and social care costs correlated significantly ($P < .001$) with national income and health expenditure emphasizing the economic implications of CVD on health and social care systems throughout the EU. The substantial international variations in CVD-related care expenditure underscore the need for tailored interventions and strategies to address the multifaceted challenges posed by CVD.

Informal care costs and productivity losses

The direct healthcare costs of CVD are substantial but indirect costs, defined as the opportunity cost of unpaid care as well as productivity losses due to disease, also require consideration. The unpaid care represents a cost to society through the working or leisure time that carers forgo in looking after relatives and friends. This amounted to an estimated 7.5 billion hours of unpaid care to friends or family that could be directly attributable to CVD, representing a total cost of €79 billion across the EU, almost exactly equivalent to the hospital costs of CVD and accounting for 28% of total societal costs.[13,14] Productivity losses attributable to CVD caused by reduced work capacity, absenteeism, and early retirement not only affect household income but also lead to decreased productivity in the economy. In a 2018 study involving 54 ESC member countries, working years and earnings lost due to premature death from CVD were calculated.[15] CVD caused losses of 7.1 million working years with a productivity loss of €61.6 billion. Median lost earnings *per capita* amounted to €56 (IQR €38–€85) ranging from just €6 in Algeria to €133 in Switzerland.

The study by the ESC Atlas and the University of Oxford investigators reminds us that the immediate health consequence of CVD in terms of mortality and morbidity are not its only legacy and that assessment of the disease burden needs to take proper account of its wide-ranging socioeconomic consequences. It not only affects individuals and families directly but also places huge strains on healthcare systems, productivity levels, and national budgets. Addressing this burden requires a comprehensive approach involving preventive measures, improved access to healthcare, and research to develop more effective treatments. By investing in the prevention and management of CVD, societies can mitigate the economic impact and promote healthier, more prosperous communities both nationally and globally.

Risk factors for cardiovascular disease

The INTERHEART case-control study in 52 countries attributed 90% of the risk of myocardial infarction to nine modifiable risk factors including abnormal lipids, smoking, hypertension, diabetes, abdominal obesity, psychosocial factors, consumption of fruits, vegetables, and alcohol, and regular physical activity.[16] This may have been an overestimate, however, the more recent Prospective Urban Rural Epidemiology (PURE) study suggests that 71% of CVD cases are attributable to 14 modifiable risk factors.[17] Consistent with the PURE findings are those from the Global Cardiovascular Risk Consortium, which suggest that strict control of just five modifiable risk factors could potentially prevent 57.2% of all cases of CVD in women and 52.6% in men worldwide, with blood pressure control offering the greatest potential for CVD prevention.[18] Important as clinical risk factors are, the European Environment Agency[19] reminds us that an estimated 18% of all CVD deaths in Europe come from key environmental factors, including air pollution and noise.[20,21] CVD prevention, therefore, needs to target not only the clinical and behavioural risk factors listed above, but also environmental risks and their socioeconomic determinants.

National sociodemographic characteristics

Population ageing, urbanization, ethnic migration and poverty have all impacted on the changing epidemiology of CVD in ways that are rarely amenable to modification by policy makers, still less by clinicians. These sociodemographic characteristics are likely to increase, ensuring that CVD will remain a continuing threat to populations in the upcoming decades.

Population ageing

In 2020, life expectancy at birth in the EU was 83.2 years for females and 77.5 years for males.[22] In both sexes, it has increased by over 3 years compared with 2002. This has had important consequences for CVD which becomes progressively more common with increasing age. Nevertheless, age-standardized mortality due to CVD has declined in high-income ESC member countries during the same period but continues to increase in many of the middle-income countries where a substantial proportion of the disease burden now resides.[2] These epidemiological shifts have been influenced not only by the ageing of populations but also by their urbanization and globalization.[23] As ageing increases in the middle-income countries of the ESC, it will accelerate the growing burden of CVD. It will also combine with the ageing populations of high-income countries to drive up the proportion of inhabitants aged >65 years which is predicted to exceed 30% by the end of the century.[24] This will have important consequences for healthcare and national economies.

Population age

- **National statistics, stratified by sex**. In 2021, the median population age across all ESC member countries was 39.6 (IQR 33.1–42.7) years, ranging from <30 years in Algeria, Egypt, Israel, Kazakhstan, Kyrgyzstan, Lebanon, Libya, Morocco, Syria, and Uzbekistan to >45 years in Italy and Republic of San Marino.
- **Time series data (1970–2021)**. During this period, median population age for all ESC member countries increased from 27.7 (IQR 20.6–31.7) years to 39.6 (IQR 33.1–42.7) years. The increase was slightly greater in middle-income compared with high-income countries (13.4 vs. 10.6 years) (see Supplementary data online, *Figure S1*).
- **Stratification by national income status.** The median population age in 2021 was lower in middle-income countries [31.4 (IQR 28.0–37.7) years] compared with high-income countries [41.8 (IQR 39.6–43.6) years]. Among middle-income countries, median age exceeded 40 years only in Bosnia and Herzegovina, Bulgaria, Serbia, and Ukraine. Among high-income countries, the median population age fell below 40 years only in Cyprus, Iceland, Ireland, Israel, Luxembourg, Malta, Norway, Sweden, and UK.

Proportion of population aged ≥65 years

- **National statistics, stratified by sex**. In 2021, 18.1% (IQR 12.3%–20.4%) of the population across all ESC member countries was aged ≥65 years, including 20.3% (IQR 14.2%–23.4%) of females and 15.5% (IQR 10.0%–17.6%) of males (*Figure 1*). There was considerable heterogeneity with <5% of people in Egypt, Kyrgyzstan, Libya, Syria, and Uzbekistan aged >65 years increasing to >22% in Bulgaria, Finland, Germany, Greece, Italy, and Portugal.

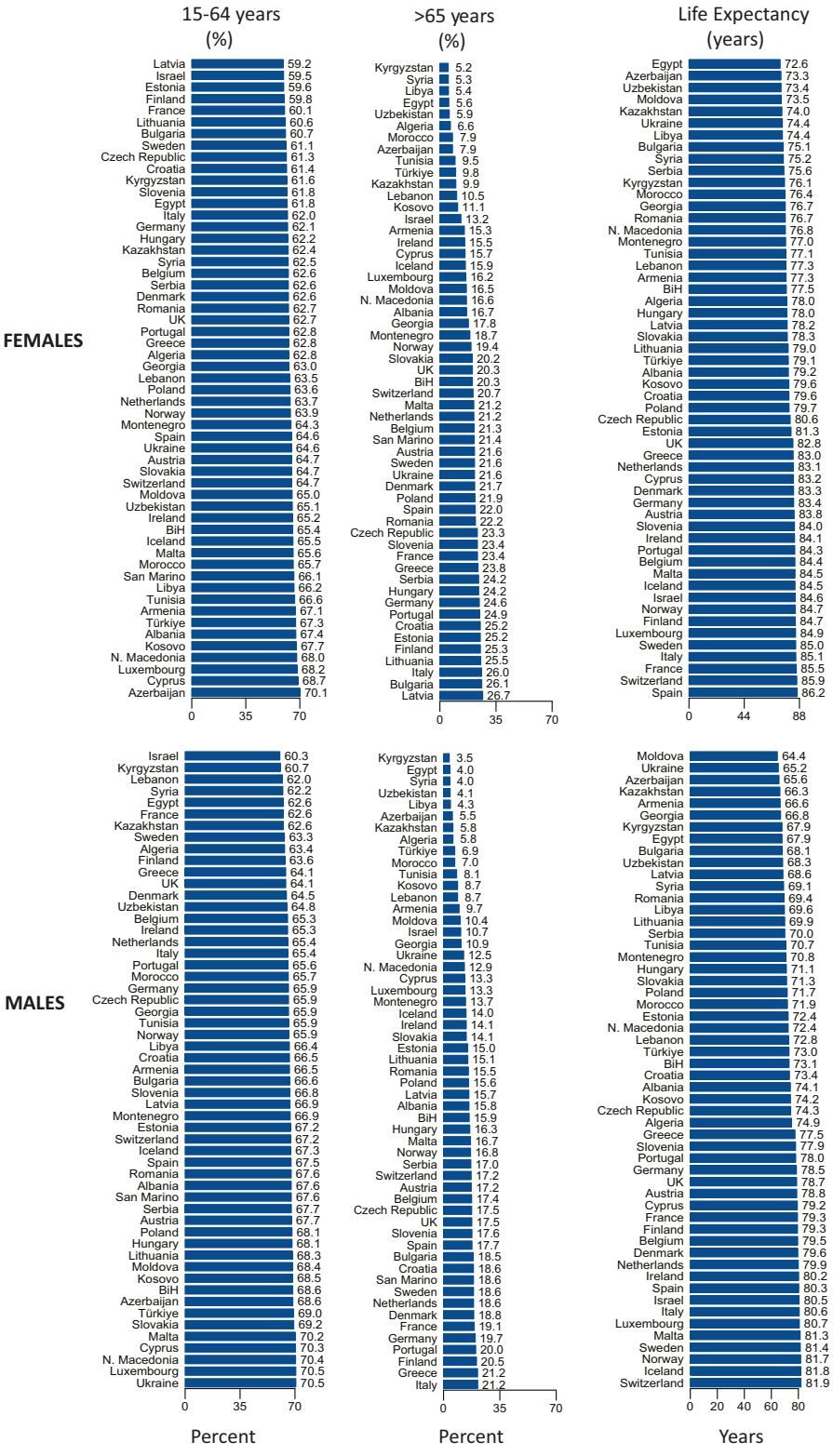


Figure 1 Age distribution and life expectancy in European Society of Cardiology member countries, stratified by sex. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

- **Time series data (1970–2021).** During this period, the proportion of population aged >65 years increased from 9.1% (IQR 5.2%–11.3%) to 18.1% (IQR 12.3%–20.4%). Increases were similar in females [10.3% (IQR 6.0%–12.8%) to 20.3% (IQR 14.2%–23.4%)] and in males [7.9% (IQR 4.5%–9.5%) to 15.5% (IQR 10.0%–17.6%)] (see Supplementary data online, *Figure S2*).

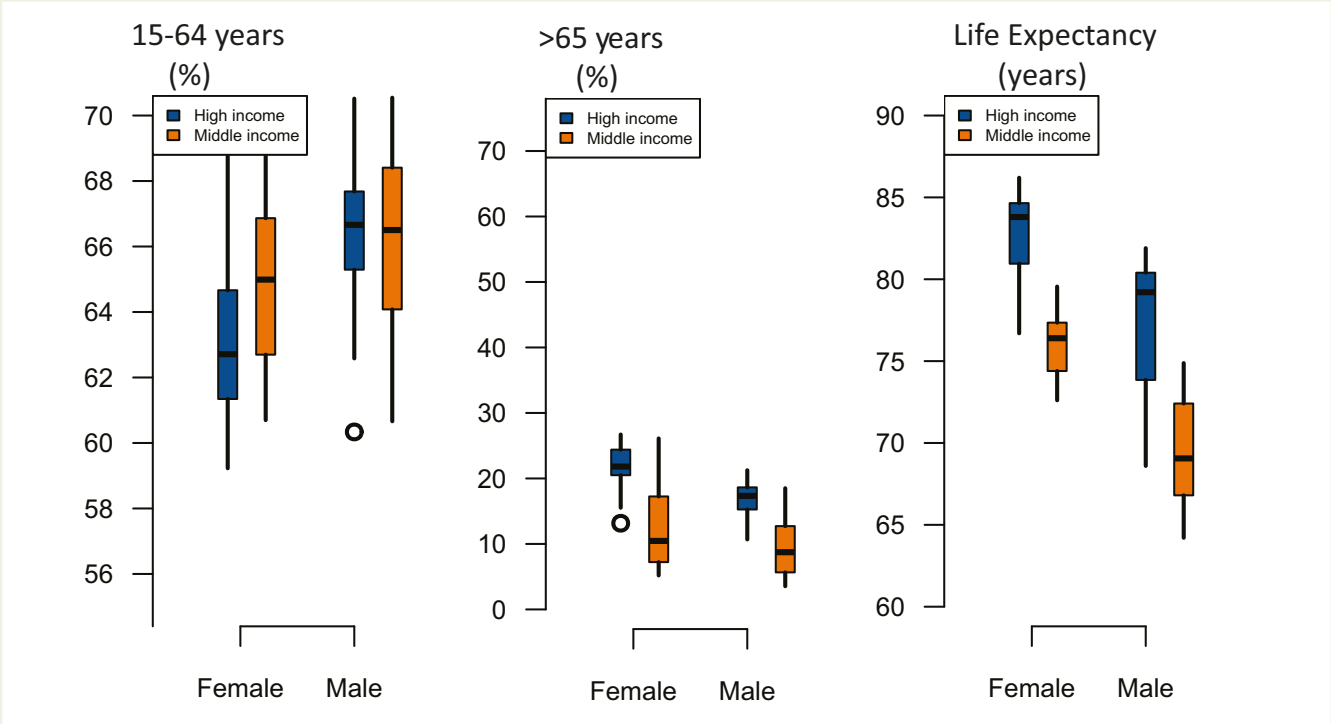


Figure 2 Age distribution and life expectancy in European Society of Cardiology member countries, stratified by national income status

- **Stratification by national income status.** The proportion of population aged >65 in middle-income ESC member countries was 9.6% (IQR 6.5%–15.5%), exceeding 20% only in Bulgaria and Serbia. In high-income countries the proportion of population aged >65 was twice as high at 20.0% (IQR 18.9%–20.8%) (*Figure 2*), dropping below 15% only in Cyprus, Iceland, Ireland, Israel, and Luxembourg. Between 1970 and 2021, the proportion of the population aged >65 almost doubled in both middle-income countries [5.0% (IQR 4.2%–6.4%) to 9.6% (IQR 6.5%–15.5%)] and high-income countries [11.1% (IQR 9.4%–12.4%) to 20.0% (IQR 18.9%–20.8%)].

Life expectancy

- **National statistics, stratified by sex**. In 2021, the median life expectancy at birth across all ESC member countries was 76.4 (IQR 73.0–81.5) years, ranging from <70 years in Azerbaijan, Moldova, and Ukraine to >83 years in Iceland, Norway, Spain, Sweden, and Switzerland (*Figure 1*). Median life expectancy at birth was higher in females [79.4 (IQR 76.7–84.1) years] compared with males [73.3 (IQR 69.7–79.3) years].
- **Time series data (1970–2021).** Median life expectancy at birth increased from 69.1 (IQR 64.2–71.0) years to 76.4 (IQR 73.0–81.5) years between 1970 and 2021 (see Supplementary data online, *Figure S3*). The increase in life expectancy during this period was comparable for females and males (6.8 vs. 7.4 years) but was greater in high-income compared with middle-income countries (8.3 vs. 10.8 years). The increase in life expectancy for females was similar for middle- and high-income countries (10.7 vs. 9.8 years, respectively). In contrast, the increase in life expectancy for males was higher in the high-income countries (12.4 years) than in middle-income countries (9.7 years).
- **Stratification by national income status.** In 2021, median life expectancy at birth was 72.1 (IQR 71.2–74.8) years for middle-income ESC member countries, exceeding 75 years only in Albania, Algeria, Bosnia and Herzegovina, Republic of Kosovo, Lebanon, and Türkiye. In high-income countries, median life expectancy at birth was 81.2 (IQR 77.1–82.6) years, dropping below 75 years in Hungary, Latvia, Lithuania, Romania, and Slovakia (*Figure 2*).

Ethnicity

In 2020, 1.9 million immigrants entered the EU from non-EU countries.[25] Net inward migration was highest for Germany which received >300 000 people while net outward migration was highest in Türkiye which saw net departure of nearly 70 000 people.[26] Migrants are typically young and of working age and may help reverse the ongoing trend of population ageing in ESC member countries. However, health inequalities are almost universal among ethnic minority immigrant groups, with South Asians living in the UK and North America, for example, particularly prone to coronary heart disease (CHD) compared with indigenous white populations.[27] Black people are similarly affected in the USA but not the UK where people of African and Afro-Caribbean origin appear relatively protected against CHD while exhibiting high rates of hypertension and stroke compared with the white population.[28] These health inequalities have many causes but are underpinned by racism and discrimination that are fundamental determinants of ill-health globally.[29]

- **National statistics.** Ethnicity statistics are missing for France, Italy, Malta, and Republic of San Marino but in the other 51 ESC member countries indigenous people constituted 83% (IQR 75%–92%) of the population, ranging from <60% in Bosnia and Herzegovina, Czech Republic, Luxembourg, Montenegro, Republic of North Macedonia,

and Syria, to >95% in Algeria, Armenia, Cyprus, Egypt, Libya, Morocco, Poland, and Tunisia.
- **Stratification by national income status.** Median proportions of indigenous people were similar in middle-income [83% (IQR 74%–96%)] and high-income ESC member countries [83% (IQR 75%–88%)].

Urbanization

Urbanization is increasing worldwide[30] and has been associated with upward trends in all CVD risks after adjustment for socioeconomic and demographic confounders.[31,32] Across Europe 55% of the population lived in urban environments in 1955, increasing to 74% in 2020 as transition continued from agricultural to manufacturing and service economies. Urbanization is often associated with economic growth and poverty reduction, but it also threatens cardiovascular health due to over-crowding, air pollution, social deprivation, and stress. Urban living can also remove the autonomy of individuals to make healthy choices, with foods high in salt, sugar, and fats often more cheaply and readily available than fresh fruit and vegetables.[33] The World Heart Federation (WHF) has called for city planners to develop infrastructures to facilitate heart-healthy behaviour, stating that policies and strategies that allow individuals to adopt healthy behaviours and avoid unhealthy ones are crucial to successful urbanization.[34]

- **National statistics.** A median of 69.6% (IQR 58.8%–81.2%) of people across all ESC member countries lived in urban areas in 2021, exceeding 90% in Belgium, Iceland, Israel, Luxembourg, Malta, The Netherlands, and Republic of San Marino and falling below 50% in Bosnia and Herzegovina, Egypt, Kyrgyzstan, and Moldova (see Supplementary data online, *Figure S4*).
- **Time series data (1970–2021).** During this period, the median proportion of people in ESC member countries who lived in urban environments increased from 52.2% (IQR 40.4%–65.2%) to 69.6% (IQR 58.8%–81.2%). (see Supplementary data online, *Figure S5*).
- **Stratification by national income status.** In 2021, a smaller proportion of people lived in urban environments in middle-income compared with high-income countries [61.4% (IQR 56.3%–69.9%) vs. 75.9% (IQR 66.9%–88.2%)] (see Supplementary data online, *Figure S6*). Among middle-income countries, proportions living in urban environments exceeded 80% only in Lebanon and Libya while in high-income ESC countries proportions ranged from <60% in Austria, Croatia, Romania, Slovakia, and Slovenia, to >95% in Belgium and Republic of San Marino.

Socioeconomic status

Socioeconomic status (SES) is an umbrella term for a range of metrics that include income level, educational attainment, employment status, and environmental socioeconomic factors.[35] SES has a measurable and significant impact on cardiovascular health that is equivalent to the impact of traditional risk factors.[36] Although low SES shows association with nearly all traditional risk factors, it confers independent risk of CVD in adjusted analyses.[37,38] Most of the evidence associating low SES with CVD comes from studies in high-income countries where in middle-income and low-income countries evidence is sparser. Nevertheless, SES is by definition lower in middle-income compared with high-income ESC member countries as reflected in differences in gross domestic product (GDP) *per capita*, educational attainment and employment all of which combine to reduce access to healthy life choices and high-quality healthcare. It is likely that many of the inequalities in CVD between middle-income and high-income ESC member countries, including prevalence of smoking, hypertension and diabetes, can be attributed indirectly to differences in SES. While short-term policies to reduce these inequalities must continue to focus on primary prevention, long-term solutions will depend on economic growth and resolution of socioeconomic differences.

Income level

Low-income groups are at increased risk of CVD. The 2017 Health Survey for England reported CVD was more prevalent in 22% of adults from households with the lowest incomes compared with 16% of adults from households with the highest incomes.[39] In The Netherlands, patients admitted with acute myocardial infarction who were in the lower income quintiles had significantly higher rates of 28-day and 1-year mortality compared with patients in the higher income quintiles.[40]

- **National statistics.** In 2021, the median (GDP) *per capita* converted to international dollars using purchasing power parity rates was $36 457 (IQR $17 243–$51 036) across all ESC member countries, ranging from <$15 000 in Algeria, Egypt, Republic of Kosovo, Kyrgyzstan, Lebanon, Morocco, Tunisia, Ukraine, and Uzbekistan to >$100 000 in Ireland and Luxembourg (*Figure 3*).
- **Time series data (2000–21).** During this period, the GDP *per capita* across ESC countries has increased threefold, from $11 378 (IQR $6019–$26 789) to $36 457 (IQR $17 243–$51 036). The increase has been less marked in middle-income compared with high-income countries ($10 016 vs. $22 450) (see Supplementary data online, *Figure S7*).
- **Stratification by national income status.** In 2021, the median GDP *per capita* was about threefold lower in middle-income compared with high-income ESC member countries [$15 597 (IQR $13 195–$20 821) vs. $48 340 (IQR $40 030–$60 004)] (see Supplementary data online, *Figure S8*).

Educational attainment

A registry analysis of 10 European countries reported that in males aged 30–59 years with higher educational level, there was a 55% lower risk of ischaemic heart disease (IHD) mortality compared with males with lower educational level.[41] Among females the excess risk was yet greater. The importance of educational attainment is not restricted to high-income countries and the PURE investigators in their 2019 study showed that people with a lower level of education in low-income and middle-income countries have a higher incidence of and mortality from CVD compared with better educated compatriots.[42]

- **National statistics.** Data for 2020 or latest available year showed that a median of 74.1% (IQR 65.3%–82.9%) of people aged ≥25 years living in ESC member countries completed at least upper-secondary education, ranging from <30% in Algeria, Libya, Syria, and Tunisia to >90% in Czech Republic, Georgia, Kazakhstan, Latvia, and Uzbekistan (see Supplementary data online, *Figure S9*).
- **Stratification by sex.** The median proportion of females aged ≥25 years who completed at least upper-secondary education was 71.1% (IQR 59.4%–80.7%) across all ESC member countries and was lower in middle-income countries compared with high-income countries [64.5% (IQR 36.0%–76.9%) vs. 75.9% (IQR 66.1%–80.9%)]. The median proportion of males aged ≥25 years who completed at least upper-secondary education was 76.4% (IQR 66.3%–86.3%) across all ESC member countries with little difference between middle-income and high-income countries [75.0% (IQR 48.5%–79.5%) vs. 77.9% (IQR 71.8%–86.4%)] (see Supplementary data online, *Figure S10*).

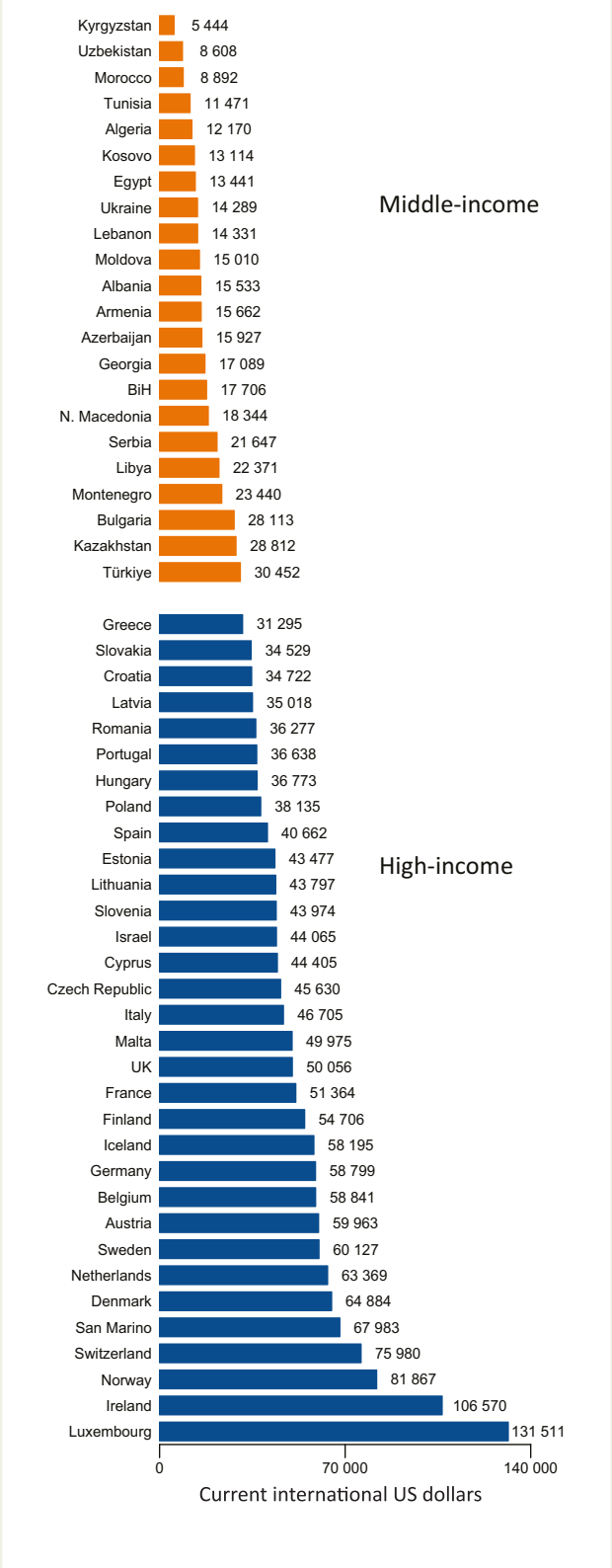


Figure 3 GDP *per capita* in European Society of Cardiology member countries, converted to international dollars. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

- **Stratification by national income status.** In middle-income ESC member countries, a median of 68.3% (IQR 42.2%–77.8%) of people completed at least upper-secondary education compared with 77.4% (IQR 69.2%–83.1%) of people living in high-income countries (see Supplementary data online, *Figure S10*).

Employment

A report from the European Commission concluded that the unemployment rate in European countries shows strong positive associations with mortality from IHD that were robust across middle-aged and elderly age groups.[43] In a French study, unemployment was associated with a 20% increase in risk of CHD with more than half explained by dietary and lifestyle mediators, most notably alcohol consumption and smoking.[44]

- **National statistics by sex.** In 2021, an estimated 6.8% (IQR 5.1%–10.5%) of the labour force across all ESC countries was unemployed, ranging from <4% in Czech Republic, Germany, Malta, Moldova, and Poland, to >14% in Bosnia and Herzegovina, Greece, Libya, Republic of North Macedonia, Montenegro, Spain, and Tunisia (see Supplementary data online, *Figure S11*). Estimated unemployment rates were somewhat higher for females compared with males in middle-income countries [12.5% (IQR 7.8%–17.2%) vs. 9.8% (IQR 5.5%–13.11%)] but in high-income countries rates for females and males were similar [5.9% (IQR 4.6%–7.0%) vs. 6.2% (IQR 4.4%–7.4%)].
- **Time series data (2000–21)**. During this period, unemployment rates across all ESC countries have declined from 10.8% (IQR 6.3%–13.8%) to 6.8% (IQR 5.1%–10.5%).
- **Stratification by national income status.** In 2021, estimated unemployment rates were higher in middle-income compared with high-income countries [11.1% (IQR 6.4%–12.7%) vs. 6.2% (IQR 4.6%–7.5%)] (see Supplementary data online, *Figure S12*), although there was considerable heterogeneity, with rates ranging from <5% in some middle-income countries, including Kyrgyzstan and Moldova, to >10% in Greece and Spain.

Environmental risk factors

Clinical and behavioural risk factors for CVD are potentially reversible and ever since the early Framingham reports[45] have been a major target for clinicians in the drive to prevent CVD. Environmental risk factors including air pollution, noise, and residence in deprived neighbourhoods are also potentially reversible and offer a further means of reducing CVD risks.

Air pollution

There have been no further particulate matter ($PM_{2.5}$) air pollution updates since those provided in 2019 by IHME.[46] These showed declining $PM_{2.5}$ concentrations in high-income ESC member countries during the last 30 years where levels are less than half those in middle-income countries.[8]

Air pollution is the world's largest environmental problem and caused an estimated 4.2 million premature deaths in 2019[47] rivalling the impact of smoking, hypertension and physical inactivity on population health.[48] Increased $PM_{2.5}$ and ozone levels are associated with heart disease and stroke.[49–51] $PM_{2.5}$ may also be a risk factor for dementia.[52] Since 1990, death rates from air pollution have declined by nearly 50%, driven primarily by reductions in indoor air pollution.[53]

Low- and middle-income countries share the greatest burden of air pollution because of reliance on solid fuels for cooking and transition to industrial economies.

Air pollution reduces the mean life expectancy in Europe by an estimated 2.2 years with an annual, attributable *per capita* mortality rate of 133/100 000 people per year.[54] Preventing or limiting exposure is the mainstay of risk modification, for example avoiding busy streets and travel during peak transit hours.[55] In developing its air pollution policy, the EU has set an annual $PM_{2.5}$ exposure limit of 25 μg/m^3 Only three EU-member states failed to register concentrations below this rather conservative target in 2020,[56] in contrast to the more challenging WHO target of ≤5 μg/m^3 [57] which only Estonia managed to achieve.

Environmental noise

There have been no further updates on population noise exposure since those provided in 2019 by the European Environment Agency.[58] *These showed that noise exposure is higher in urban compared with non-urban environments and is driven largely by the effects of road traffic.*[34]

Industrialization and globalization have contributed to increased levels of noise, particularly road, aircraft, and railway noise.[59] Associations between noise exposure and CVD have been widely reported[60,61] with noise pollution responsible for an estimated 48 000 new cases of CHD per year as well as 12 000 premature deaths across Europe.[62] A 2015 meta-analysis found a 6% increase in CHD risk for every 10 dB(A) increase in traffic noise, starting as low as 50 dB(A).[63] The EU has set permissible noise levels in residential areas of 55 and 50 dB during daytime and night-time, respectively.[64] These limits are often exceeded and noise exposure above 55 dB(A) might affect up to 40% of the population of the EU.[65]

Neighbourhood characteristics

Neighbourhood characteristics associate significantly with CVD risk, independently of conventional risk factors. A UK study reported graded associations between quintiles of small area deprivation and risk of myocardial infarction and heart failure.[66] In Denmark, placement of a relatively young population of refugees in socioeconomically deprived neighbourhoods was associated with increased cardiovascular risk[67] while a UK study of men aged 60–79 years confirmed that older people too experience increased cardiovascular risk in deprived neighbourhoods.[68] Residents of deprived neighbourhoods appear to have benefited less from recent improvements in CVD prevention and treatment, as evidenced by declines in CVD mortality in a Swedish study, which have been greater in people living in more affluent neighbourhoods.[69]

- **National statistics.** In 32 ESC member countries with 2020 data available, disadvantaged neighbourhoods characterized by crime, violence, or vandalism were home for 7.8% (IQR 5.5%–11.1%) of people, ranging from <5% in Croatia, Lithuania, Norway, Montenegro, and Slovakia to >15% in Bulgaria, France, Greece, and The Netherlands.
- **Stratification by national income status.** Among the 32 ESC member countries with data available, only five were middle-income where 9.5% (IQR 5.5%–9.8%) of people lived in disadvantaged neighbourhoods compared with 7.3% (IQR 5.6%–11.2%) in high-income countries.

Lifestyle and cardiovascular risk

Lifestyle factors, including diet, alcohol consumption, smoking, physical activity, and body weight, are major determinants of cardiovascular risk. A recent meta-analysis of 20 cohort studies involving 1 090 261 participants found that healthy lifestyle habits in all age groups were associated with a decreased incidence of CVD, with benefits greater in adults aged <50 years compared with older adults.[70] The study emphasizes the importance of correcting unhealthy lifestyle habits, particularly among young and middle-aged adults, in order to improve cardiovascular health at a population level.

Smoking

Tobacco use is a leading behavioural risk factor for CVD, including CHD, ischaemic stroke, peripheral artery disease, and abdominal aortic aneurysm.[71] Risk is greater with increasing smoking duration and number of cigarettes smoked per day.[72,73] Smoking increases the risk of death from CVD by up to three times.[72] Reports published at the beginning of the century indicated that passive exposure to tobacco smoke in non-smokers increased their risk of CVD[74] leading to the introduction of smoking legislation across Europe with salutary effects on the incidence of ST-elevation myocardial infarction.[75]

Tobacco use has been described as 'the single largest avoidable health risk in the EU' by the European Commission's Directorate-General for Health and Food safety.[76] Policy measures related to reducing tobacco use and tobacco derivative commercialization have been promoted by the EU in the last 15 years. During this period, there has been continuous decline in the prevalence of smoking across Europe.[77]

E-cigarettes have emerged as an alternative to cigarettes in providing a nicotine delivery system. A nationally representative cohort study of 32 320 US adults found e-cigarettes to be associated with little additional risk compared with their non-use in non-smokers.[78] However, dual use of cigarettes and e-cigarettes was associated with a significantly increased risk of CVD. Add to this the evidence that e-cigarette use among adolescents and young adults is associated with greater risk for subsequent cigarette smoking,[79] and it remains best advice for protecting against CVD that e-cigarette use should be avoided. However, in established smokers the National Institute for Health and Care Excellence in the UK is now permissive of e-cigarettes to support smoking cessation based on evidence that they are similarly effective to other types of nicotine replacement therapy.[80]

- **National statistics**. In 2020, 25.4% (IQR 21.1%–31.3%) of persons aged ≥15 years in ESC member countries were estimated to be current users of tobacco products, ranging from <15% in Iceland, Morocco, and Uzbekistan, to >35% in, Bulgaria, Croatia, Cyprus, and Serbia (*Figure 4*). Data for 2022/2019 across 28 high-income ESC member countries showed that, a median of 1.9% (IQR 1.6%–3.5%) of persons aged ≥15 years were regular vapers, ranging from <1% in Austria and Croatia to >5% in Czech Republic, Estonia, and Ireland.
- **Stratification by sex.** In 2020, age-standardized estimates of current users of tobacco products across ESC member countries in female were lower [19.7% (IQR 11.6%–24.6%)] compared with males [33.4% (IQR 24.4%–40.5%)]. However, there was considerable heterogeneity with rates in females ranging from <2% in Algeria, Armenia, Azerbaijan, Egypt, Morocco, Tunisia, and Uzbekistan to >30% in Bulgaria, Croatia, France, Greece, Montenegro, and Serbia while in males, rates ranged from <15% in Iceland to >45% in Armenia, Cyprus, Georgia, Kyrgyzstan, and Latvia. Vaping too was less prevalent in females compared with males in high-income ESC member countries [1.6% (IQR 1.2%–2.5%) vs. 2.5% (IQR 2.1%–4.6%)].
- **Time series data (2000–20).** Across all ESC member countries, the proportion of persons aged ≥15 years who were current users of

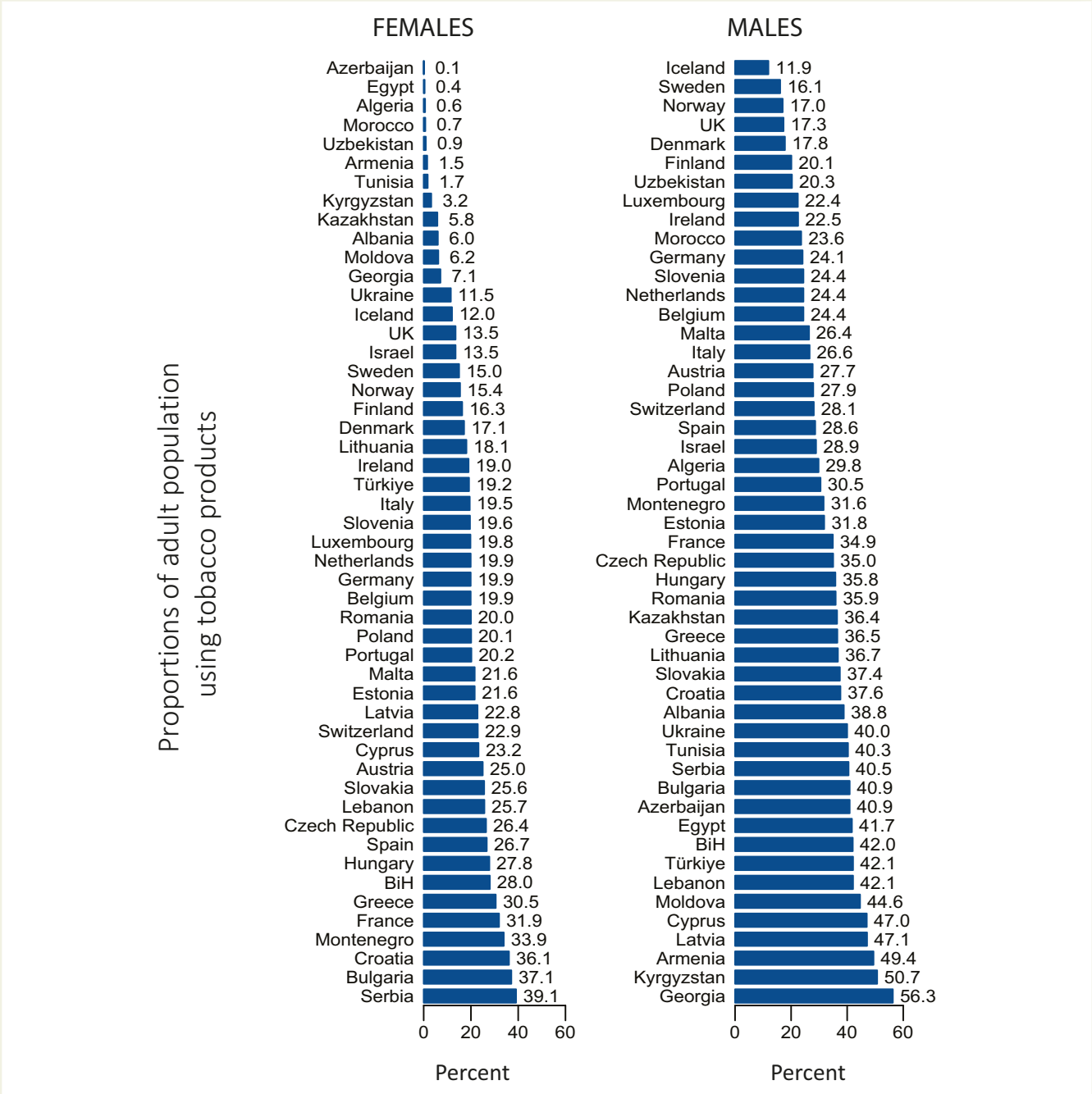


Figure 4 Proportions of adult population using tobacco products in European Society of Cardiology member countries, stratified by sex. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

tobacco products has decreased from 34.3% (IQR 29.7%–37.6%) in 2000 to 25.4% (IQR 21.1%–31.3%) in 2020 (*Figure 5*).

- **Stratification by national income status.** Median age-standardized estimates of current users of any tobacco product were similar in middle-income [25.4% (IQR 21.1%–31.3%)] and high-income [24.0% (IQR 21.2%–29.4%)] ESC member countries (*Figure 6*). However, in high-income countries more women used tobacco compared with women in middle-income countries [20.0% (IQR 18.6%–24.1%) vs. 6.0% (IQR 1.2%–22.4%)] while in men the pattern was reversed with more men in middle-income countries using tobacco compared with men in high-income countries [40.9% (IQR 37.6%–42.1%) vs. 27.9% (IQR 23.3%–35.4%)].

Alcohol consumption

Safe levels of alcohol consumption vary across populations but for young adults in most parts of the world complete abstinence is the safest option.[81] In older adults, particularly those facing a high burden of CVD, moderate compared with high consumption is associated with improved health outcomes. Therefore, the recommendation is that

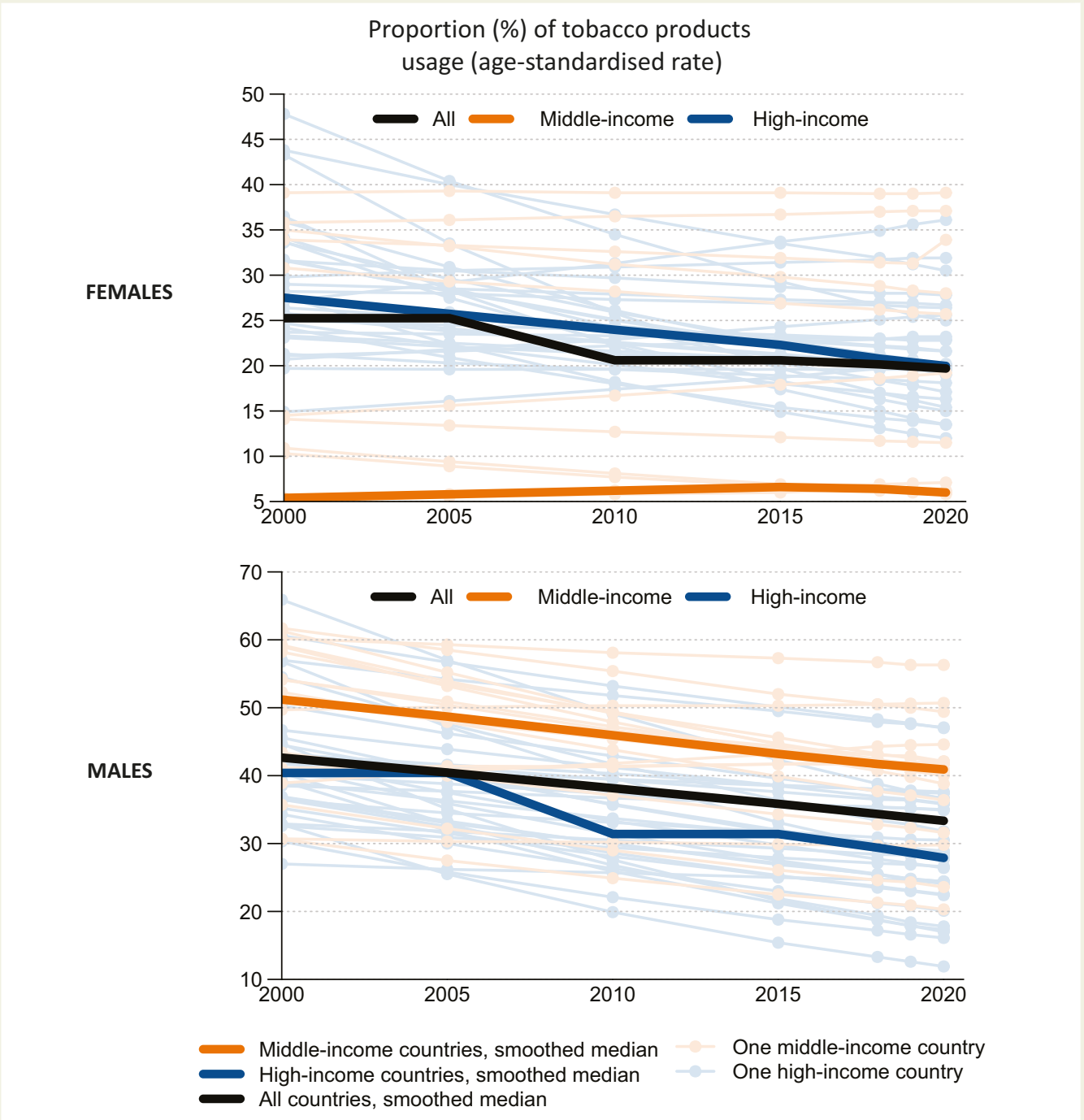


Figure 5 Time series for estimates of current tobacco smoking prevalence (%) among adults (age-standardized rate) in European Society of Cardiology member countries, in females and males (2000–20)

young adults should be prioritized in strategies aimed at minimizing alcohol consumption.

The harmful use of alcohol is particularly common in Europe where alcohol use is responsible for some 255 000–290 000 deaths each year.[82] In most European countries, consumption has decreased over the last decade with the largest reductions in Estonia, Greece, and Lithuania. Many European countries have implemented policies to limit alcohol consumption, including taxation, restrictions on its availability, advertising bans, and public health campaigns.[83] Recent innovative measures include minimum unit pricing, regulation of digital alcohol marketing, and alcohol labelling. Minimum pricing of alcohol units, introduced in Scotland in 2018, has been associated with a reduction in alcohol purchases, especially among households that bought the most alcohol.[84] It has further been associated with significant reductions in deaths attributable to alcohol consumption with greatest benefit experienced by those most socioeconomically deprived.[85]

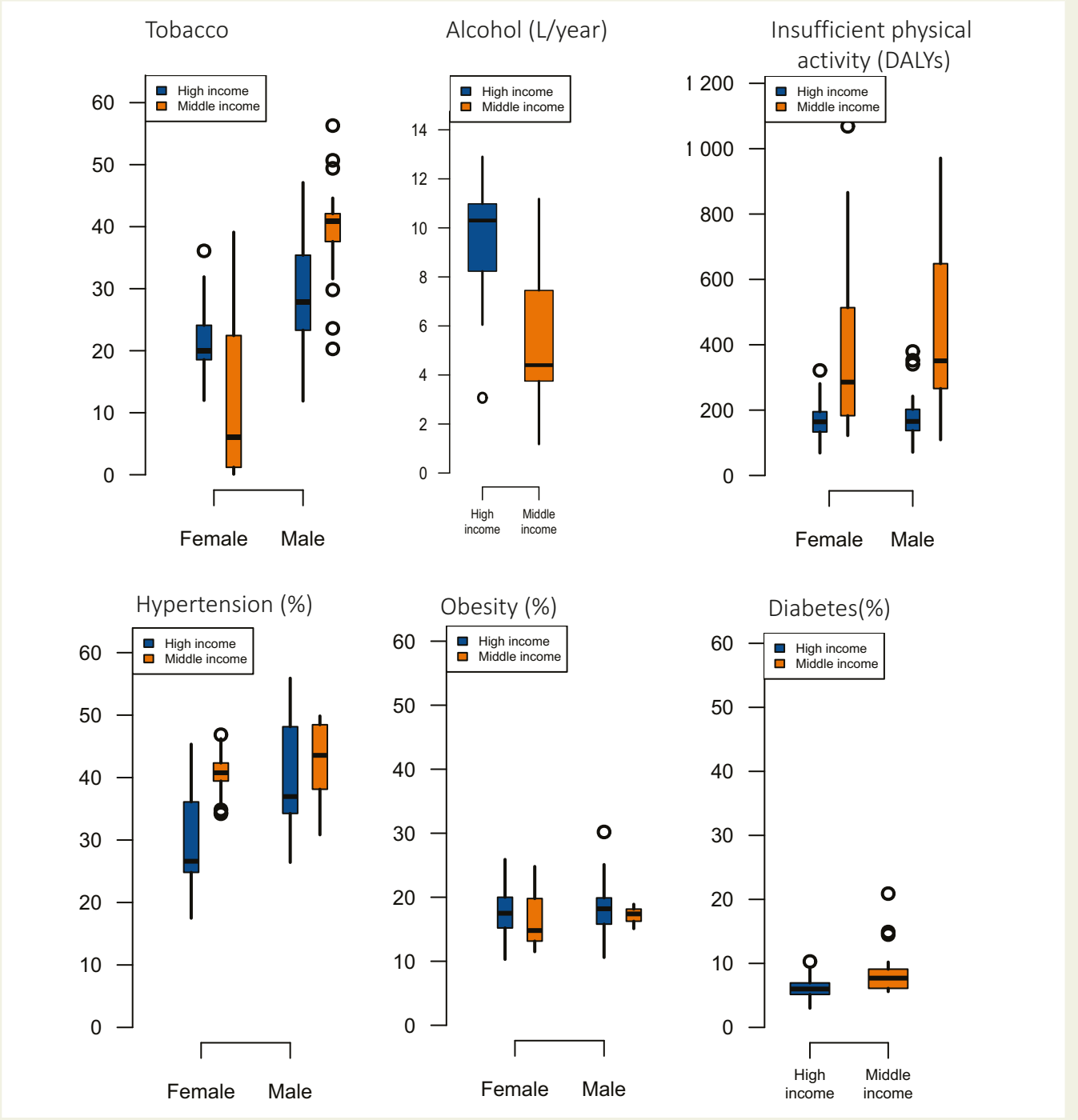


Figure 6 Risk factors in European Society of Cardiology member countries, stratified by sex and national income status

- **National statistics**. In 2019, median pure alcohol consumption *per capita* across ESC member countries was 9.2 (IQR 6.1–10.9) L/year *per capita* ranging from <2 L/year in Azerbaijan and Türkiye to >11 L/year in Austria, Bulgaria, Czech Republic, Estonia, France, Latvia, Lithuania, and Slovenia (see Supplementary data online, *Figure S13*).
- **Time series (1999–2019).** During this period, alcohol consumption *per capita* across ESC members countries has remained stable at 8.9 (IQR 5.4–12.1) L/year in 1999 and 9.2 (IQR 6.1–10.9) L/year in 2019.
- **Stratification by national income status.** In 2019, median pure alcohol consumption *per capita* was nearly twice as high in high-income compared with middle-income ESC member countries [10.3 (IQR 8.2–11.0) vs. 4.4 (IQR 3.8–7.5) L/year] (*Figure 6*). There was considerable heterogeneity in consumption among high-income countries ranging from < 8 L/year in Greece, Iceland, Israel, Italy, Norway, and Sweden to >12 L/year in Czech Republic and Latvia and among middle-income countries from <4 L/year in Armenia, Azerbaijan, Kazakhstan, Republic of North Macedonia, Türkiye, and Uzbekistan to > 9 L/year in Bulgaria and Montenegro. These statistics

can hide important disparities by sex as average consumption is often three to four times higher in males.

Exercise

Insufficient physical activity is defined by the WHO as the proportion of the population attaining <150 min of moderate-intensity physical activity per week or <75 min of vigorous-intensity physical activity per week.[86] It has become more prevalent internationally in recent years, perhaps as the result of increasing adoption of Western lifestyle, characterized by greater sedentary time and less time spent in leisure or purposeful physical activity. Yet leisure time exercise has consistently been shown to improve cardiovascular health[87,88] and the benefits have now been confirmed in large studies in which physical activity has been measured objectively using activity monitors.[89,90] The data are consistent in showing that the outcome benefits of physical activity are largely dose-related with light intensity physical activity inferior to more vigorous physical activity in reducing the incidence of CVD as well as mortality in males and females.

Measures to increase physical activity represent a simple, widely applicable, low cost global strategy for reducing deaths from CVD in middle age.[88] Many national governments have already developed physical activity policies and local governments have a crucial role to play in creating environments and opportunities for physical activity and active living.[91] Meanwhile evidence suggests that the use of wearable devices for personal activity monitoring is associated with increased activity and healthy behaviours with the potential to improve patient outcomes.[91]

- **National statistics**. In 2019, a median estimate of 206.92 (IQR 156–282) age-standardized DALYs were caused by insufficient physical activity across ESC member countries, ranging from <100 in The Netherlands and Slovenia to >500 in Algeria, Egypt, Lebanon, Libya, Morocco, and Syria (see Supplementary data online, *Figure S14*).
- **Stratification by national income status.** Insufficient physical activity caused more DALYs per 100 000 in middle-income compared with high-income ESC member countries [275 (IQR 224–607) vs. 160 (IQR 141–202)] (*Figure 6*). In high-income countries, DALYs ranged from <100 in The Netherlands and Slovenia to >200 in Czech Republic, Ireland, Latvia, Lithuania, Malta, Portugal, Romania, Slovakia, and UK. In middle-income countries, the range was from <200 in Albania and Montenegro to >700 in Egypt, Lebanon, Morocco, and Syria. In a sex-based analysis, DALYs per 100 000 associated with insufficient physical activity were comparable for males and females in high-income ESC countries [165 (IQR 138–202) vs. 164 (IQR 133–195)], but in middle-income ESC countries DALYs were higher for males [351 (IQR 266–642) vs. 286 (IQR 184–488)].
- **Time series data (1990–2019).** During this period, age-standardized DALYs per 100 000 across ESC member countries that were attributable to insufficient physical activity declined from 276 (IQR 224–355) to 207 (IQR 156–282). The results were mainly driven by reductions in insufficient physical activity in high-income countries where DALYs per 100 000 declined from 276 (IQR 239–328) to 160 (IQR 141–202). In middle-income countries age-standardized DALYs per 100 000 showed little change during the same period [273 (IQR 215–554) to 275 (IQR 224–607)].

Dietary factors

A recent study suggests that dietary risks are a primary contributor to IHD mortality worldwide.[92] It is estimated that across the European region one in every five premature deaths could be prevented by an optimized diet.[93] Policy initiatives to encourage healthy eating include taxation and restrictive advertising of food products such as sugar and alcohol, education in the classroom, school lunch programmes, and traffic light labelling on food and drink.[94]

Dietary fats

In a systematic review of studies reporting associations between fat intake and CVD, trans-fats were associated with all-cause and CHD mortality.[95] The same review found no association between saturated fat intake and all-cause mortality although there was a trend for association with CHD mortality and replacement of saturated fat with polyunsaturated fat reduced the risk.[95] The benefits of a diet low in polyunsaturated fat but rich in vegetables, fruits, herbs, nuts, beans, and whole grains—the Mediterranean diet—has been confirmed in the PREDIMED trial in which the incidence of major CV events was reduced by 31% compared with a control diet.[96] A recent randomized trial confirms that in addition to primary prevention the Mediterranean diet is also effective for secondary prevention of cardiovascular events with a 26% reduction of the hazard ratio compared to a low-fat diet in patients with CHD.[97]

- **National statistics.**
  Animal fats: In 2020, animal fat consumption delivered a median stimate of 130 (IQR 68–217) kcal/capita/day across ESC member countries, ranging from <40 kcal/capita/day in Algeria, Bosnia and Herzegovina, Egypt, Kyrgyzstan, Lebanon, Libya, and Tunisia to >400 kcal/capita/day in Belgium, Denmark, and Slovakia (see Supplementary data online, *Figure S15*).
  Vegetables oils: In 2020, vegetable oil consumption delivered a median estimate of 385 (IQR 250–500) kcal/capita/day across ESC member countries, ranging from <200 kcal/capita/day in Denmark, Georgia, Kyrgyzstan, and Serbia to >600 kcal/capita/day in Austria, Greece, Italy, and Spain (see Supplementary data online, *Figure S15*).
- **Time series (2010–20).** During this period, energy delivery from consumption of oil and fat showed a small increase across ESC member countries from 513 (IQR 359–608) kcal/capita/day to 536 (IQR 377–652) kcal/capita/day. During the same period, there was a similar trend for animal fat consumption [from 97 (IQR 52–182) kcal/capita/day to 130 (IQR 68–217) kcal/capita/day] and vegetable oil consumption [from 326 (IQR 234–471) kcal/capita/day to 385 (IQR 250–500) kcal/capita/day].
- **Stratification by national income status.** High-income ESC member countries consumed more oils and fats [603 (IQR 498–770) vs. 358 (IQR 291–513) kcal/capita/day], animal fats [210 (IQR 145–281) vs. 67 (IQR 38–86) kcal/capita/day], and vegetable oils [435 (IQR 269–521) vs. 269 (IQR 213–435) kcal/capita/day] compared with middle-income countries (see Supplementary data online, *Figure S16*).

Sugar and sugar-sweetened beverages

Associations between added sugar consumption and obesity and type 2 diabetes have long been recognized.[98] However, added sugar also shows independent association with CVD mortality with risk increasing with the amount of sugar consumed.[99,100] The WHO guideline recommends that adults and children reduce their daily intake of free sugars to <10% of their total energy intake.[101] A further reduction to below 5% or roughly 25 g (six teaspoons) per day would provide additional health benefits. A new sugar and calorie reduction initiative is now being launched across Europe to promote healthier diets and to challenge the food industry to reduce sugar and calories in its products.[102]

- **National statistics by income status.** In 2020, consumption of sugar and sweeteners delivered an estimated 332 (IQR 274–371) kcal/capita/day across ESC member countries, ranging from <200

kcal/capita/day in Kyrgyzstan, Syria, and Uzbekistan to >450 kcal/capita/day in Belgium, Denmark, Malta, and Poland (see Supplementary data online, *Figure S15*). Energy delivery remained stable between 2010 and 2020 and was higher in high-income countries compared with middle-income countries [345 (IQR 290–432) vs. 289 (IQR 227–333) kcal/capita/day] (see Supplementary data online, *Figure S16*).

Dietary sodium

ESC member country statistics on dietary sodium consumption that were presented previously have not been updated.[2,8]

A UK Biobank study found that a higher frequency of adding salt to food was associated with a higher hazard of all-cause premature mortality and lower life expectancy.[103] There is a positive association of sodium intake and blood pressure, with the largest effect observed in those consuming high sodium diets.[104] The increased risk of cardiovascular events associated with higher sodium intake is observed when intake exceeds 5 g/day. However, the association is J-shaped and moderate sodium intake (2.3–4.6 g/day) has been consistently associated with lower cardiovascular risk, compared to both high and low sodium intake.[105] Current guidelines recommend a sodium intake of <2.3 g/day but this low level has proved hard to achieve in population studies and may need revising in light of contemporary evidence.[106] Meanwhile the WHO has adopted a global target of a 30% reduction in mean population intake of salt/sodium by 2025.[107]

Dietary fruit and vegetables

Increasing the dietary intake of fruit and vegetables up to 800 g/day is associated with progressive reductions in the risk of CVD and all-cause mortality.[108,109] Data from the Nurses' Health Study and the Health Professionals Follow-Up Study support public health recommendations to increase fruit and vegetable intake for the prevention of CVD, with maximum benefit obtained from five servings per day.[110]

National 2020 data for fruit and vegetable consumption are available for 29 high-income and 1 middle-income ESC member country (Türkiye).

- **National statistics.** Across ESC member countries a median of 54.6% (IQR 45.6%–59.0%) of people aged ≥15 years ate fruit at least once per day ranging from <40% in Latvia, The Netherlands, and Romania, to >70% in Israel and Italy. For vegetable consumption a median of 52.3% (IQR 45.9%–62.3%) of the population aged ≥15 years consumed at least one portion per day, ranging from <40% in Latvia, Luxembourg, The Netherlands, and Romania, to >70% in Belgium, Ireland, and Israel. Fruit supplied to ESC member countries was 81.8 (IQR 67.9–101.25) kg/capita/year, ranging from <60 kg/capita/year in Bulgaria, Latvia, Lithuania, and Slovakia to >100 kg/capita/year in Greece, Israel, Italy, The Netherlands, Portugal, Romania, Slovenia, and Türkiye. Vegetables supplied were 93.8 (IQR 85–107) kg/capita/year, ranging from <80 kg/capita/year in Czech Republic, Iceland, Ireland, The Netherlands, Norway, and Slovakia to >200 kg/capita/year in Croatia and Türkiye.

Clinical risk factors

Clinical risk factors for CVD, including hypertension, dyslipidaemia, diabetes, and obesity, are amenable to control or elimination with the potential to make a substantial reduction in incident CVD at population level.[111] Clinical trials have usually focused on middle-aged or older patients, and guidelines rarely offer specific treatment recommendations for persons younger than 40 years. Recently, however, data in cohorts aged <40 years have shown that modestly abnormal lipid values are associated with higher risk for myocardial infarction over a median follow-up of 5.2 years.[112] Although the absolute risk is low during this short time-frame, it increases with progressively higher non-HDL cholesterol categories out to 30 years.[113] Data from children (3–19 years) are now available confirming that risk factors individually and in combination during childhood associate with incident CVD beginning as early as 40 years of age.[114] This has implications for lifetime risk assessment and CVD prevention strategies.

Blood pressure

High blood pressure is on of the leading risk factor for the global burden of CVD.[115] In adults aged 40–89 years, systolic and diastolic blood pressure show log-linear associations with death from IHD and stroke, with no apparent threshold below which no further reduction in risk is observed.[116] Irrespective of baseline mortality risk, there is evidence of substantial long-term morbidity associated with raised blood pressure.[117] Treatment to a lower systolic target (120 mmHg) than recommended in guidelines provides further protection against cardiac events at the expense of a small number of additional drug side-effects.[118] The benefits of a comprehensive risk reduction programme involving pharmacotherapeutic and lifestyle measures to lower blood pressure, non-HDL cholesterol, and other determinants of cardiovascular risk are well established.[119]

- **National statistics stratified by sex**. In 2019, the median age-standardized prevalence of hypertension among people aged 30–79 years was 36% (IQR 26%–41%) for females and 41% (IQR 35%–48%) for males across all ESC countries (*Figure 7*). Prevalence in males exceeded 50% in Croatia, Hungary, Lithuania, Poland, and Romania. Among people with hypertension, 57% (IQR 48%–61%) of females and 45% (IQR 36%–52%) of males were receiving antihypertensive treatment.
- **Stratification by national income status.** The median age-standardized prevalence of hypertension in middle-income ESC member countries was 41% (IQR 40%–42%) for females and 44% (IQR 38%–48%) for males with treatment rates 53% (IQR 45%–60%) and 35% (IQR 30%–45%), respectively (*Figure 6*). In high-income ESC countries, the prevalence was lower, both for females [27% (IQR 25%–36%)] and males [37% (IQR 34%–48%)], while treatment rates were higher at 58% (IQR 52%–65%) and 51% (IQR 46%–56%), respectively.
- **Time series data (1990–2019).** During this period, the median age-standardized prevalence of hypertension across all ESC member countries trended downwards in both females [40% (IQR 35%–46%) to 36% (IQR 26%–41%)] and males [42% (IQR 39%–49%) to 41% (IQR 35%–48%)]. It is worth noting that despite predominant decrease the prevalence of elevated blood pressure has increased in middle-income countries' males from 41% (IQR 35%–48%) to 44% (IQR 38%–48%) (*Figure 8*). During the same period, the prevalence of treated hypertension increased in both females [32% (IQR 26%–37%) to 57% (IQR 48%–62%)] and males [19% (IQR 15%–22%) to 45% (IQR 36%–52%)].

Cholesterol

There have been no further updates on population cholesterol concentrations across ESC member countries since those from the NCD Risk Factor Collaboration.[120] *The data we reported previously showed declines in non-HDL cholesterol concentrations over the last 40 years that were largely confined to high-income countries.*[2]

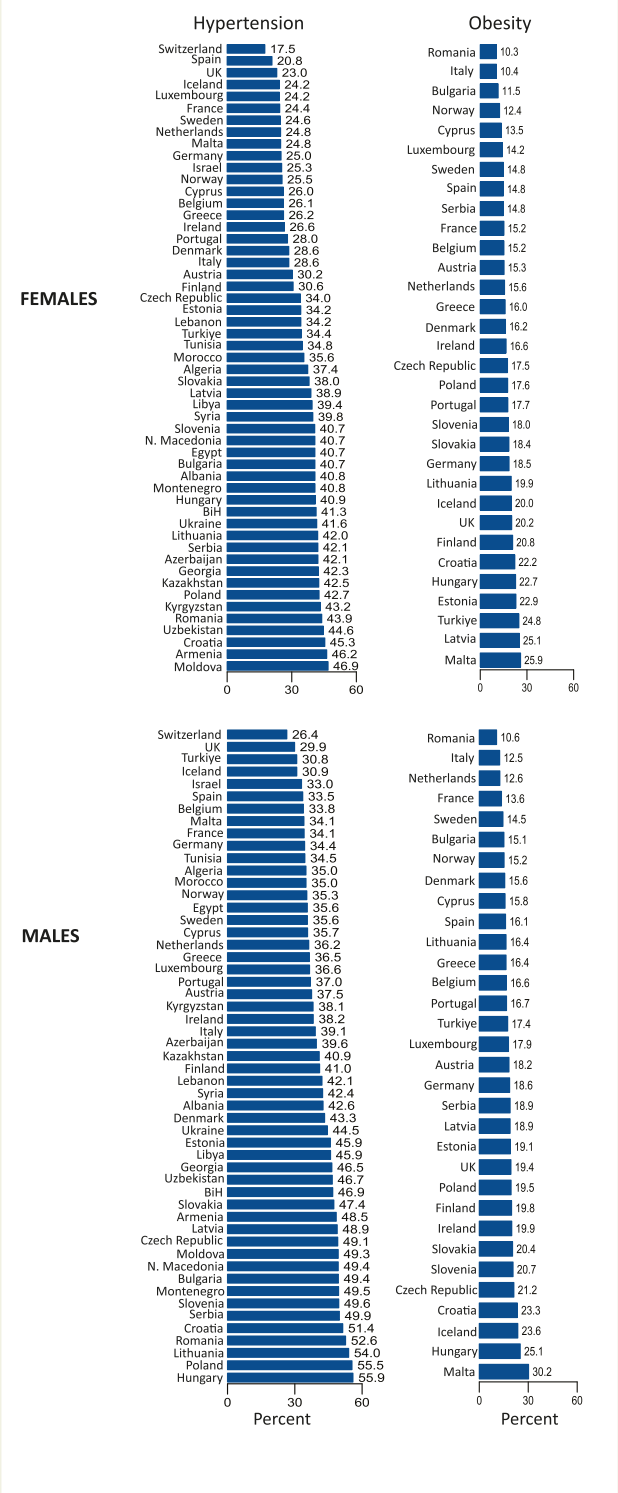


Figure 7 Age-standardized prevalence of hypertension and proportion of obese population in European Society of Cardiology member countries, in females and males, stratified by national income status. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

Non-HDL cholesterol is a major determinant of CVD risk which increases with cumulative exposure during young adulthood and middle age.[121,122] It is a major target for population risk reduction with statin therapy which is recommended for secondary prevention of CVD and for primary prevention in those with a 10-year risk of myocardial infarction or death that exceeds 10%.[123] This comes to include everyone with advancing age and is justified by data showing that absolute risks of cardiovascular events increase steeply beyond age 70 years when lipid lowering therapy with statins can lower risk substantially.[124–126] More potent cholesterol lowering can be achieved with proprotein convertase subtilisin/kexin type 9 (PCSK9) inhibitors which are now finding an important role in patients with familial hypercholesterolaemia when target lipid levels are not achieved with statin therapy.[127] However, these drugs remain under-used with a recent European study reporting that low-density lipoprotein cholesterol levels at initiation of PCSK9 inhibitor treatment were three times higher than recommended thresholds.[128]

Epidemiological studies show that over the last four decades non-HDL cholesterol levels have fallen in the high-income countries of western Europe, North America and Australasia but have increased elsewhere, particularly in the middle-income and low-income countries of east and southeast Asia.[120] Nevertheless, the prevalence of elevated total cholesterol exceeds 50% in high-income countries[111] and treatment often falls short—in the European Surveys of Cardiovascular Disease Prevention and Diabetes (EUROASPIRE) survey more than half those with dyslipidaemia failed to achieve treatment targets.[129]

Obesity

Overweight and obesity, defined by a body mass index (BMI) of ≥25 kg/m^2 and ≥30 kg/m^2, respectively, rank fourth behind high blood pressure, dietary risks, and tobacco use in causing more than 13% of deaths across the European region.[130] In the last decade, no country has reported a decline in the prevalence of obesity and none is on track to meet the WHO's target of 'no increase on 2010 levels by 2025'.[131] On current trends, it is estimated that over half the world population will be overweight by 2035 and nearly a quarter will be obese.[131] Obesity is linked with hypertension, dyslipidaemia, insulin resistance, coagulability, endothelial dysfunction, and inflammation which together increase the risk of CVD and death.[132] However, EUROASPIRE investigators report that even among patients with established CVD a substantial proportion of overweight and obese patients fail to lose weight having received no advice to do so by healthcare professionals.[133] Children are also affected with nearly 8% of children younger than 5 years and one in three school-aged children living with overweight or obesity.[134] Obesity in adolescents increased during the COVID-19 pandemic in association with decreases in physical activity and increases in the consumption of foods high in fat, sugar, and salt.[135] Among people hospitalized with COVID-19, obesity was identified as a major risk factor for death.[136,137] Population solutions to the obesity epidemic should lie in lifestyle modification and policy initiatives to encourage exercise and healthy living. Meanwhile a range of treatment options are now available including novel sodium–glucose cotransporter-2 (SGLT2) inhibitors and glucagon-like peptide-1 (GLP-1) receptor agonists that are effective in reducing weight and treating glycaemia.[138]

Overweight and obesity for 2019 data are available for 27 high-income and 3 middle-income ESC member countries (Bulgaria, Serbia, Türkiye).

- **National statistics**. In 2019, 54.8% (IQR 49.6%–56.7%) of people in ESC member countries were overweight and 17.0% (IQR 14.9%–20.1%) obese, ranging from <15% in Bulgaria, Cyprus, Italy, France, Norway, The Netherlands, Romania, and Sweden, to >20% in Croatia, Estonia, Finland, Hungary, Iceland, Latvia, Malta, and Türkiye (*Figure 7*).
- **Stratification by sex.** A greater proportion of males in ESC member countries were overweight compared with females [59.6% (IQR

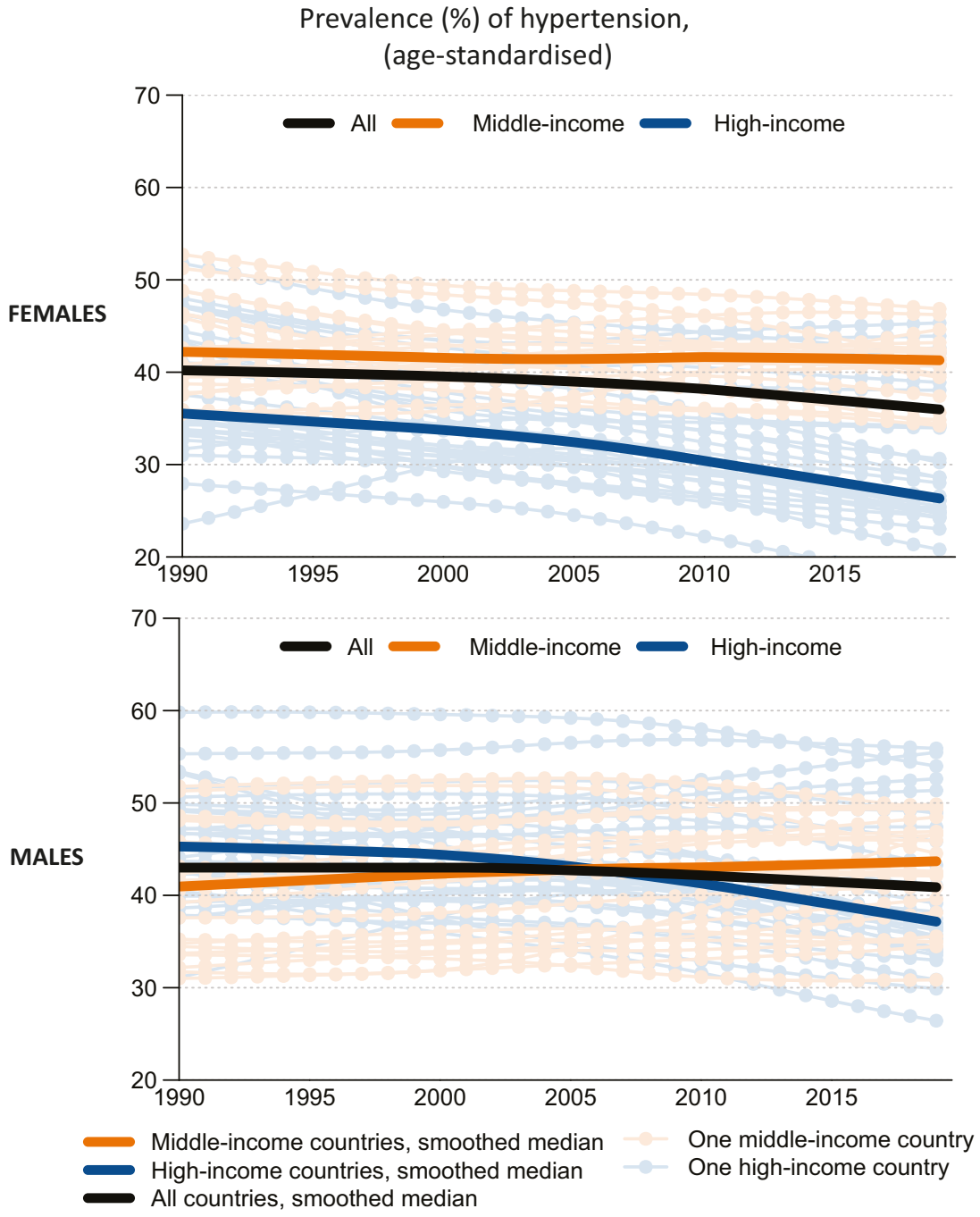


Figure 8 Time series: smoothed trends for prevalence of hypertension in European Society of Cardiology member countries, in females and males (1990–2019)

56.7%–65.0%) vs. 48.3% (IQR 43.6%–51.7%)], but the prevalence rates for obesity were similar across sexes [17.7% (IQR 15.7%–19.7%) vs. 16.9% (IQR 14.8%–20.0%)].

- **Stratification by national income status.** In middle-income countries, proportions of overweight and obese people [53.4% (IQR 52.9%–54.8%) and 16.8% (IQR 15.0%–19.0%)] were similar to proportions in high-income countries [55% (IQR 49.2%–57.2%) and 17.2% (IQR 15.1%–19.9%)] (*Figure 6*).
- **Time series data (2014–19).** During this relatively short period, prevalence rates of overweight and obesity increased only slightly from 53% (IQR 47.8%–54.7%) to 54.8% (IQR 49.6%–56.7%) and from 16.4% (14.4%–18.4%) to 17.0% (IQR 14.9%–20.1%).

Diabetes

The WHO estimates there are ~60 million people with diabetes in the European Region, or ~10.3% of men and 9.6% of women aged 25 years and over.[139] The prevalence is increasing, particularly in low- and middle-income countries, mostly due to ageing populations, increased diagnostic testing, obesity, and lifestyle factors including physical

inactivity and unhealthy diet.[140,141] In observational studies, having diabetes increases threefold the risk of death by CVD compared with people without diabetes[142] although in more contemporary studies the excess mortality is lower.[143] Reducing trends in type 2 diabetes (T2D) mortality the last 30 years have been observed in many EU countries, likely driven by improved medical management of its major complications, particularly CVD.[144] Treating diabetes and its complications is expensive and cost the National Health Service (NHS) in the UK an estimated £14 billion in 2018, representing 10% of the annual budget for England and Wales.[145] Public health measures should focus on primary prevention of T2D given its significant costs, morbidity and mortality. Screening for diabetes can be cost-effective[146] and evidence from the UK and The Netherlands confirms the efficacy of prevention programmes.[147,148]

- **National statistics.** In 2021, the median prevalence of diabetes in people aged 20–79 across all ESC member countries was 6.5% (IQR 5.6%–8.4%), ranging from <4% in Belgium, Ireland, and Norway, to >10% in Albania, Egypt, Spain, Syria, and Türkiye (*Figure 9*).
- **Stratification by national income status.** The median prevalence of diabetes was lower in high-income ESC countries [6.0% (IQR 5.2%–6.9%)] compared to middle-income countries [7.7% (IQR 6.2%–9.1%)] (*Figure 8*).
- **Time series data (2011–21)**. During this period, there was no change in the estimated median prevalence of diabetes across ESC member countries [6.35% (IQR 5.2%–7.7%) vs. 6.5% (IQR 5.6%–8.4%)].

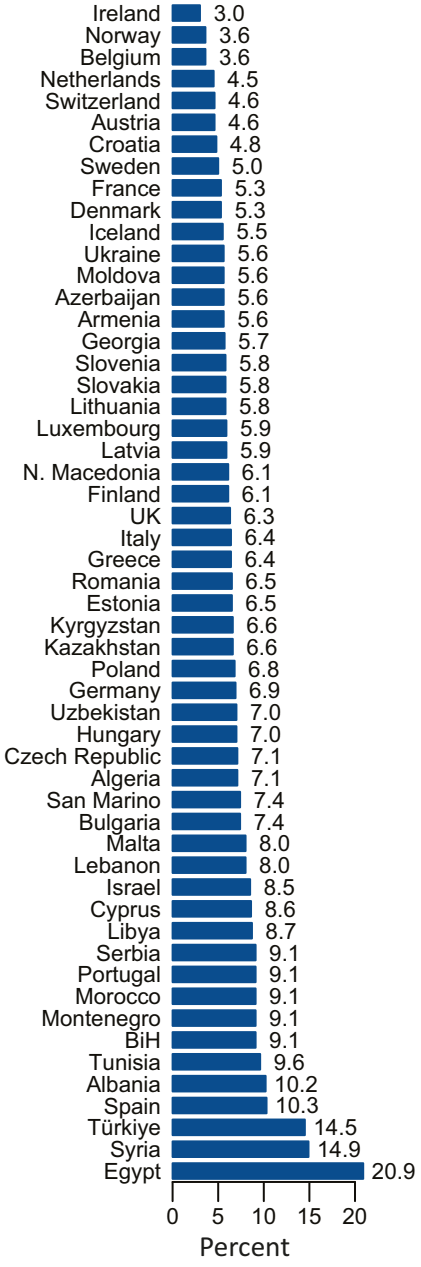


Figure 9 Age-standardized prevalence (%) of type 1 or type 2 diabetes among adults aged 20–79 in European Society of Cardiology member countries. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

Summary

Sociodemographic and environmental risk factors

- Across ESC member countries, median life expectancy at birth increased from 69.1 to 76.4 years between 1970 and 2021. During the same period, the proportion of population aged >65 years increased from 9.1% to 18.1%.
- The median proportion of people in ESC member countries who lived in urban environments increased from 52.2% in 1970 to 69.6% in 2021.
- Low- and middle-income countries share the greatest burden of air pollution because of transition to industrial economies and reliance on solid fuels for cooking.
- Across ESC member countries, 71.1% of females completed upper-secondary education; the proportion was lower in middle-income vs. high-income countries (64.5% vs. 75.9%).
- In 2021, an estimated 6.8% of the labour force across all ESC countries was unemployed.

Lifestyle and cardiovascular disease risk

- In 2020, 25.4% of persons aged ≥15 years in ESC member countries were current users of tobacco products, females 19.7% and males 33.4%.
- In 2019, median pure alcohol consumption *per capita* was nearly twice as high in high-income compared with middle-income ESC member countries (10.3 vs. 4.4 L/year).
- Insufficient physical activity caused more DALYs per 100 000 in middle-income compared with high-income ESC member countries (275 vs. 160).
- Energy delivery from sugar consumption in 2020 was higher in high-income countries compared with middle-income countries (345 vs. 289 kcal/capita/day).

Clinical risk factors

- In 2019, the median age-standardized prevalence of hypertension among adults was 36% for females and 41% for males across all ESC member countries.
- In 2019, 54.8% of people in ESC member countries were overweight and 17.0% obese.

- In 2021, the median prevalence of diabetes in people aged 20–79 across ESC member countries was 6.5%, lower in high-income ESC countries compared to middle-income countries (6.0% vs. 7.7%).

Cardiovascular disease mortality

According to the WHO in 2019, CVD was the leading cause of death globally and responsible for an estimated 17.9 million deaths worldwide.[149] Registration of death and cause of death are legal requirements in most countries, which make mortality data a useful measure of disease burden within a population that is widely used in epidemiological studies. Here, we present age-standardized mortality data for 2022 or the or latest available year using the 2013 European Standard Population update to allow international comparisons taking into account national differences in age structures.[150,151] We also present potential years of life lost (PYLL), which is a summary measure of premature mortality. PYLL estimates the years of potential life lost due to premature death, giving greater weight to deaths at a younger age compared with deaths at an older age.[152] PYLLs are calculated by multiplying the number of deaths at each age by the number of remaining years of life left, normally taken from the standard life expectancy. This allows measurement of the proportion of total PYLL in a population caused by a specific disease.

Key metrics in cardiovascular disease mortality

IHME definition: Disorders of the heart and blood vessels, led by IHD, stroke, and hypertensive heart disease, as well as disability due to heart failure. Both atherosclerotic and non-atherosclerotic CVD are included.[153]

CVDs are the leading cause of death globally and in 2019 accounted for 32% of all deaths, of which 85% were due to heart attack and stroke. The majority of CVD deaths take place in low- and middle-income countries where rates could be reduced by addressing behavioural risk factors such as tobacco use, unhealthy diet and obesity, physical inactivity, and harmful use of alcohol.

Cardiovascular disease: number of deaths

- **National statistics stratified by sex.** CVD has remained the most common cause of death within ESC member countries with over 3 million deaths in the most recent year of available data, including more than 1.6 million deaths in females and nearly 1.5 million deaths in males. These accounted for 40% of all deaths in females and 35% of all deaths in males. IHD was the most common cause of CVD death, accounting for 33% and 40% of all CVD deaths in females and males, respectively (*Figure 10*). Stroke was the second most common cause of CVD death, accounting for 21% and 19% of all CVD deaths in females and males, respectively.
- **Stratification by national income status.** The proportion of CVD deaths among all deaths in middle-income countries was higher than in high-income countries both for females (53% vs. 34%) and for males (46% vs. 30%). Still, there were large variations in the proportion of CVD deaths as well as crude CVD mortality rates between countries within income classifications. The median crude mortality rates for CVD per 100 000 people were similar for males from middle-income countries compared to those from high-income countries [293.4 (IQR 194.2–543.9) vs. 294.5 (IQR 208.6–426.0)]. On the contrary crude rates for females were higher in high-income [326.2 (IQR 219.4–445.4)/10 000] than middle-income countries [261.9 (IQR 193.9–567.7)/100 000], perhaps reflecting longer life expectancy in high-income countries.

Cardiovascular disease: premature deaths

The incidence of CVD as well as the risk of death from CVD is higher with increasing age. Therefore, ageing of the population results in increasing CVD prevalence and mortality. Effective cardiovascular prevention delays the development of CVD and thus, prevents premature CVD death. Premature CVD mortality is, therefore, an important index of unfulfilled life expectancy that identifies the need for increased prevention efforts. Herein, we define premature death as death before the age of 70 years.

- **National statistics stratified by sex.** In both females and males, CVD accounted for a smaller proportion of premature deaths than deaths across all ages. In individuals aged <70 years old, CVD accounts for 27% of all deaths in females, and 31% of all deaths in males. This equates to around 239 000 premature deaths among females and 500 000 premature deaths in males (>2.1 times higher).
- **Stratification by national income status.** Median crude mortality rates from CVD per 100 000 people <70 years of age were higher for middle-income countries [154.8 (IQR 65.9–206.7) in males, and 81.3 (IQR 37.0–94.7) in females] compared with high-income countries [68.4 (IQR 50.1–136.0) in males, and 26.7 (IQR 20.5–50.7) in females]. Still, there were large variations within those groups, with the lowest crude rates of premature CVD death in females (<20 per 100 000) in both middle-income (Morocco and Tunisia) and high-income countries (Cyprus, France, Iceland, Israel, Luxembourg, Norway, and Switzerland). The same was found for males with rates below 50 per 100 000 in both middle-income (Libya, Morocco, Syria, and Tunisia) and high-income countries (France, Iceland, Israel, Luxembourg, The Netherlands, Norway, Republic of San Marino, and Switzerland). The highest crude rates of premature CVD death in both females and males (above 100 and 250 per 100 000 persons, respectively) were reported mostly in middle-income countries (Bulgaria, Moldova, and Ukraine for both sexes, Egypt and Serbia for females only).

Cardiovascular disease: potential years of life lost

- **National statistics stratified by sex.** In 2019, CVD accounted for approximately 27 million PYLLs in females and 33 million PYLL in males within ESC member countries, equivalent to 37% of all years lost for females and 33% for males.
- **Stratification by national income status.** CVD accounted for almost 26 million PYLL in high-income countries (54% amongst males) and approximately 34 million PYLL in middle-income countries (56% amongst males). Median proportions of PYLLs due to CVD among all PYLLs were higher in middle-income countries compared with high-income countries both in males (39% vs. 29%) and females (43% vs. 31%). In males, only one country (Bulgaria) had more than 50% of total PYLL attributable to CVD. In females, countries, where more than 50% of total PYLL were attributed to CVD, included three high-income (Latvia, Lithuania, and Romania) and six middle-income countries (Bulgaria, Georgia, Moldova, Montenegro, Republic of North Macedonia, and Ukraine). The median age-standardized PYLL rate per 100 000 across all ESC member

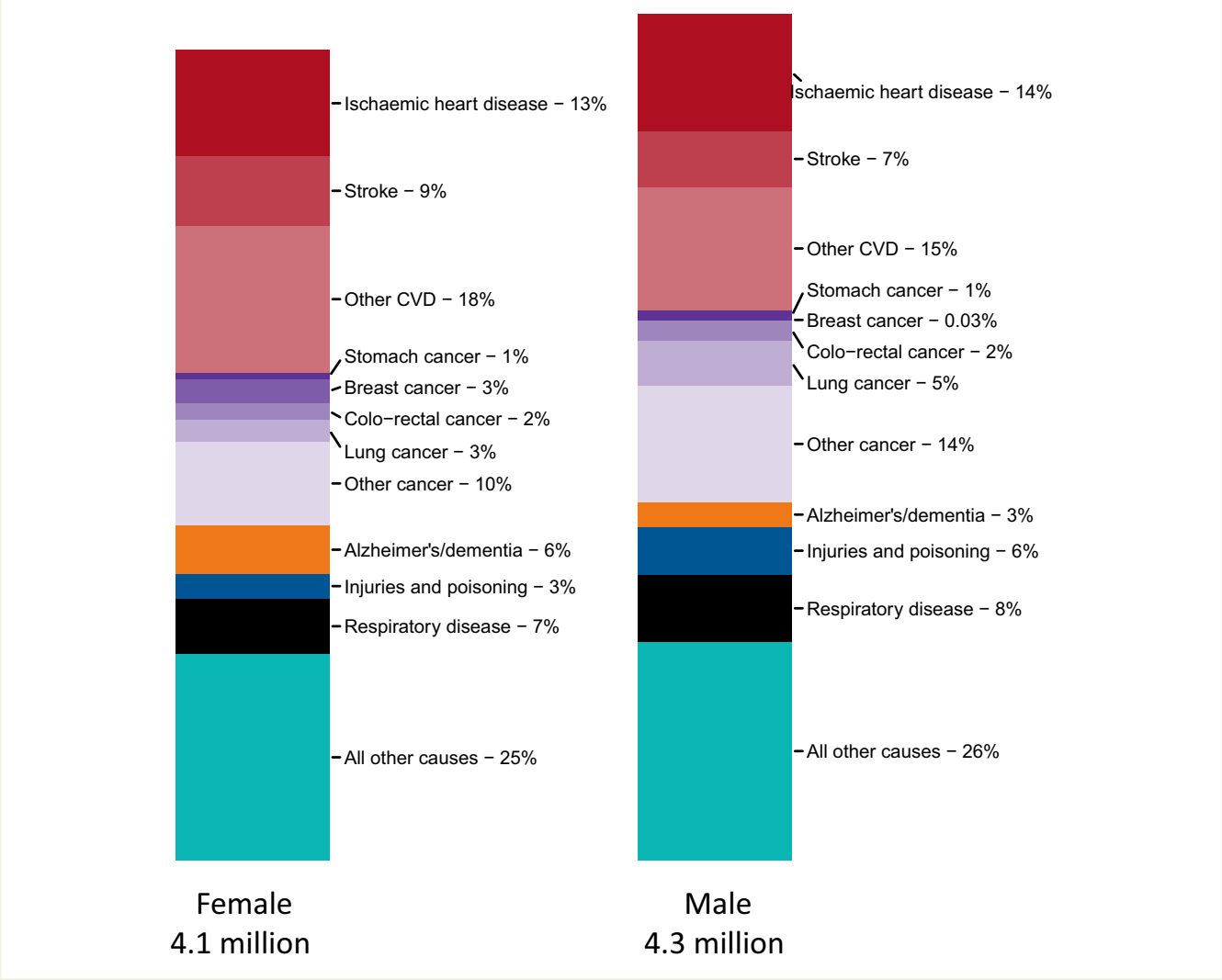


Figure 10 National causes of death in females and males in European Society of Cardiology member countries

countries was 4066 (IQR 1919–6334); and was more than three times higher in middle-income countries [7516 (IQR 5641–8684)] than in high-income countries [2079 (IQR 1707–3511)]. Fourteen of 24 middle-income countries had age-standardized PYLLs' rates higher than the upper quartile for all ESC countries (6334), while none of the high-income countries did.

Cardiovascular disease: age-standardized mortality rate

- **National statistics stratified by sex.** Using the most recent year of data across ESC member countries, median estimates for age-standardized mortality rates (ASMRs) per 100 000 due to CVD were higher for males than females [395.1 (IQR 287.1–873.5) vs. 322.0 (IQR 228.8–673.0)] (*Figure 11*).
- **Stratification by national income status.** Median ASMRs per 100 000 due to CVD in middle-income compared with high-income countries were more than twice higher in males [873.5 (IQR 519.0–1212.2) vs. 364.0 (IQR 284.8–612.6)] and three times higher in females [722.8 (IQR 388.5–911.0) vs. 244.7 (IQR 201.6–419.2)] (*Figure 12*). Median ASMRs due to CVD in females from middle-income countries were almost twice as high as median ASMRs in males from high-income countries.
- **Time series data.** Between 1990 and 2021 (or the closest data available to these years within countries), CVD-related ASMRs in both sexes decreased in all high-income countries by a median of 57% in females and 59% in males (*Figure 13*). In middle-income countries, the median decrease in CVD ASMRs during the same period was smaller for both males (11%) and females (6%) and there were a number of countries which showed little change, or even an increase, including Azerbaijan (11%), Egypt (11%), Kyrgyzstan (8%), Libya (22%), and Syria (6%) in females and Kyrgyzstan (7%), Libya (30%), and Ukraine (4%) in males.

Ischaemic heart disease

IHME definition

Disease of the coronary arteries, usually from atherosclerosis, leading to myocardial ischaemia often associated with angina or myocardial infarction[154] *as defined by the Fourth Universal Definition.*[155]

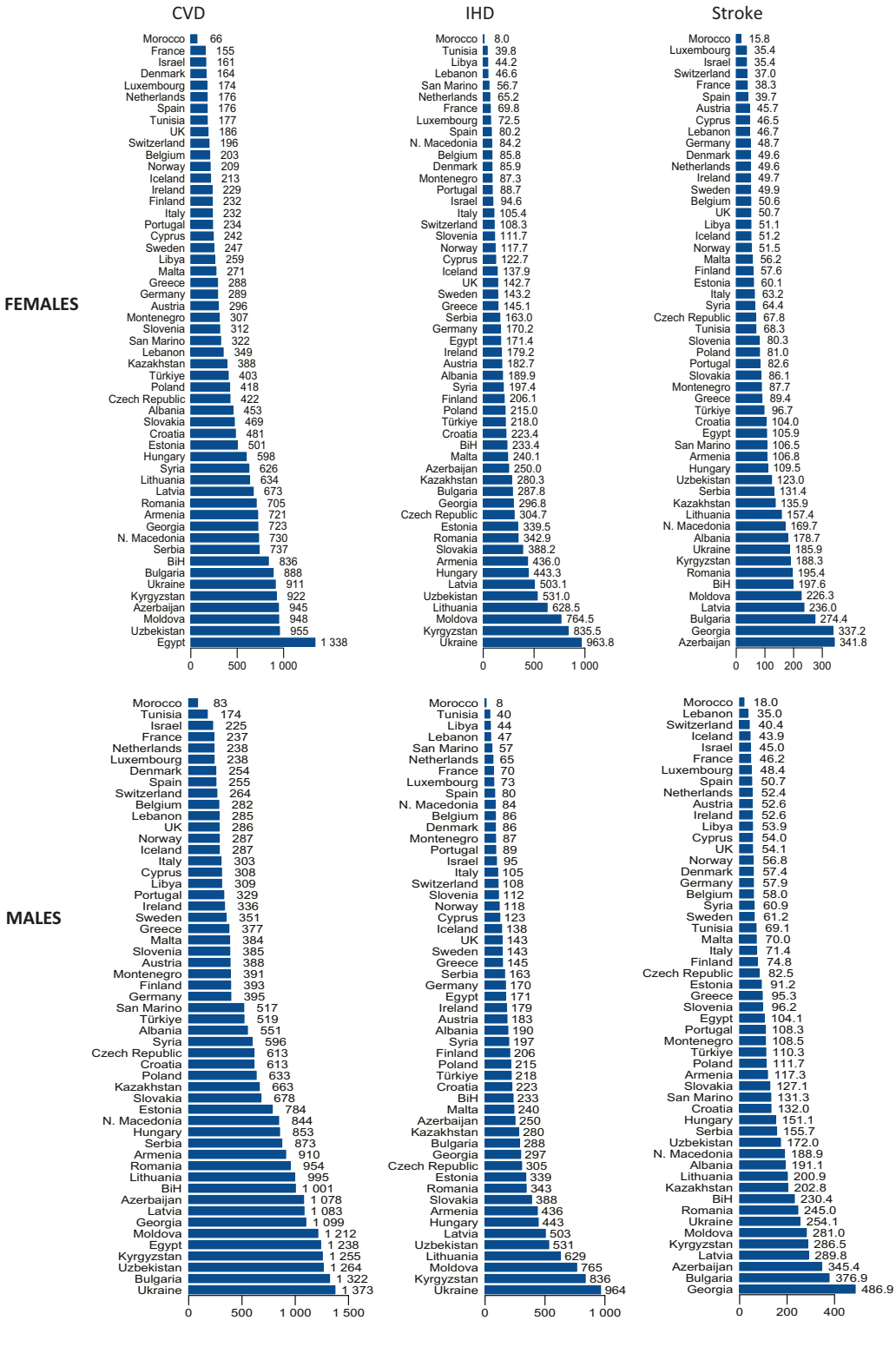


Figure 11 Age-standardized mortality rate per 100 000 due to cardiovascular disease (CVD), ischaemic heart disease (IHD), and stroke mortality in European Society of Cardiology member countries, in females and males. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

Ischaemic heart disease remains the largest contributor to CVD mortality and although mortality rates in high-income countries are declining they are often increasing in less economically developed countries.[156–158] Risk factors and unhealthy behaviours are potentially reversible, and this provides huge opportunity to address these regional inequalities in IHD mortality.

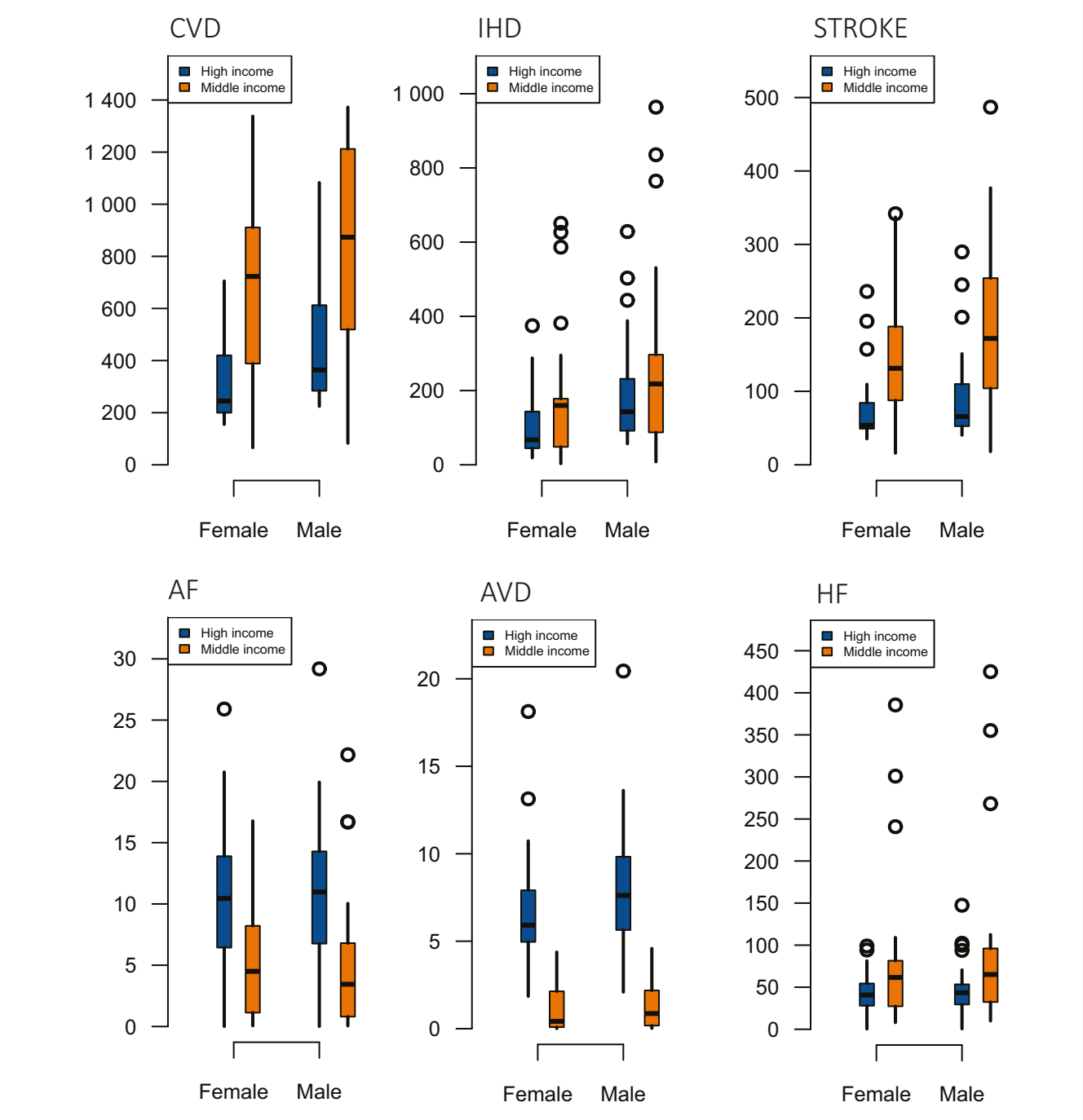


Figure 12 Age-standardized mortality rate per 100 000 due to cardiovascular disease (CVD), ischaemic heart disease (IHD), stroke, atrial fibrillation (AF), non-rheumatic calcific aortic valve disease (AVD), and heart failure (HF) in European Society of Cardiology member countries, stratified by sex and national income status

Ischaemic heart disease: age-standardized mortality rate

- **National statistics stratified by sex.** Median ASMRs due to IHD in ESC member countries were 1.8 times higher for males than females [171.4 (IQR 88.7–287.8) vs. 90.8 (IQR 47.8–171.9) per 100 000] (*Figure 11*). This gender difference in median ASMRs was less evident in middle-income than high-income countries (median ASMRs from IHD 2.1 times higher in males than females in high-income countries, and 1.4 times higher in males than females in middle-income countries).
- **Stratification by national income status.** The median ASMRs for IHD in middle-income countries was greater than in high-income countries, for both sexes, with this disparity greater for females [159.9 (IQR 48.3–178.1) vs. 67.2 (IQR 46.2–142.6) per 100 000] than males [218.0 (IQR 87.3–296.8) vs. 142.9 (IQR 93.1–227.6) per 100 000] (*Figure 12*). Of note, females from middle-income countries had higher median ASMRs from IHD than males from high-income countries. The lowest IHD ASMRs in males were reported in four middle-income countries (ASMRs

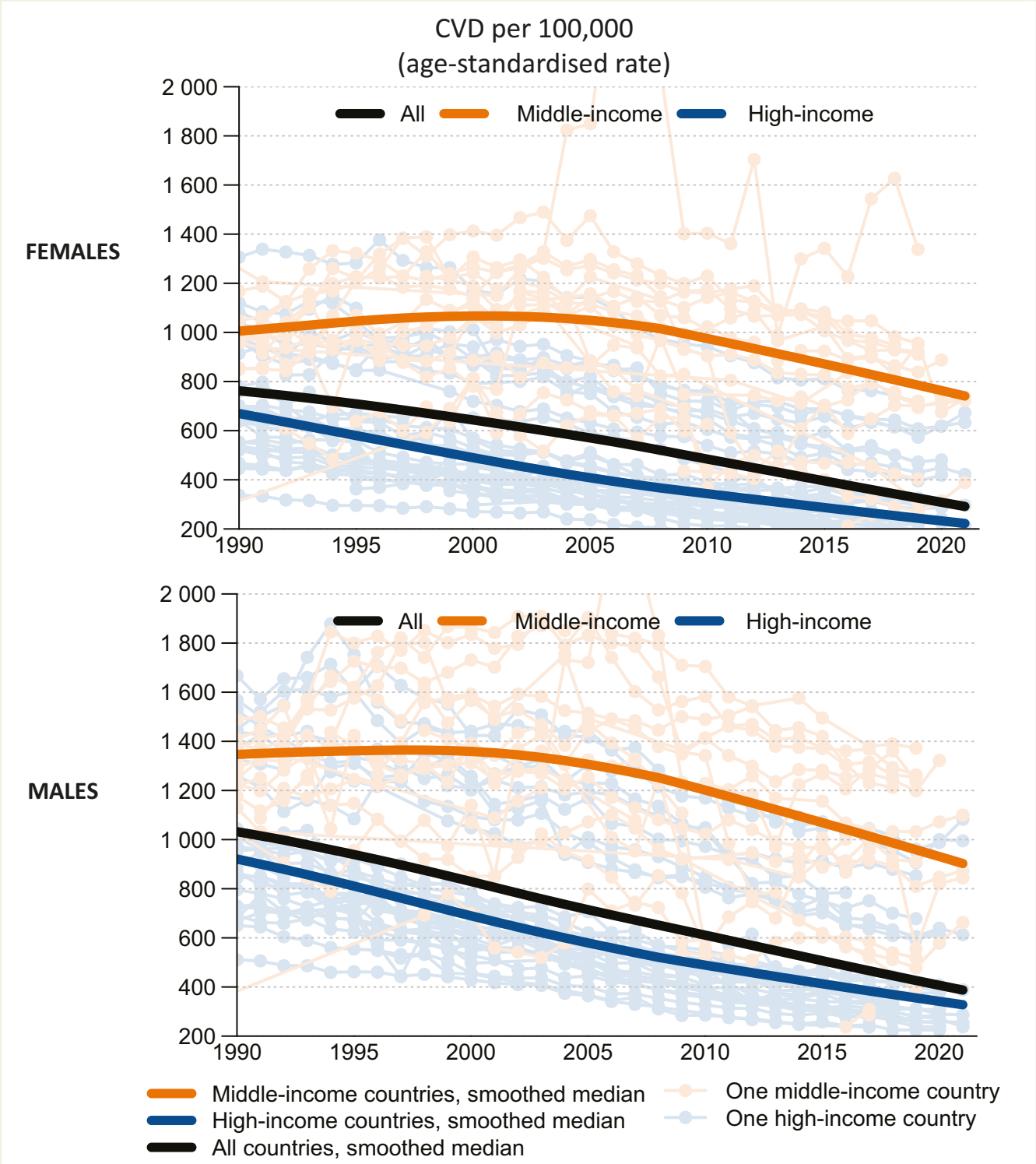


Figure 13 Time series: age-standardized mortality rate from cardiovascular disease per 100 000 people in females and males in European Society of Cardiology member countries (1990–2021)

per 100 000: Morocco, 8.0; Tunisia, 39.8; Libya, 44.2; Lebanon, 46.6), while the lowest ASMRs for females included middle- and high-income countries (ASMRs per 100 000 women: Morocco, 3.2; Republic of San Marino, 18.9; Tunisia, 26.8; France, 27.5). The highest IHD ASMRs per 100 000 were observed in the same countries for males and females: Kyrgyzstan (835.5 for males, 650.7 for females), Moldova (764.5 for males, 586.5 for females), and Ukraine (963.8 for males, 626.4 for females).

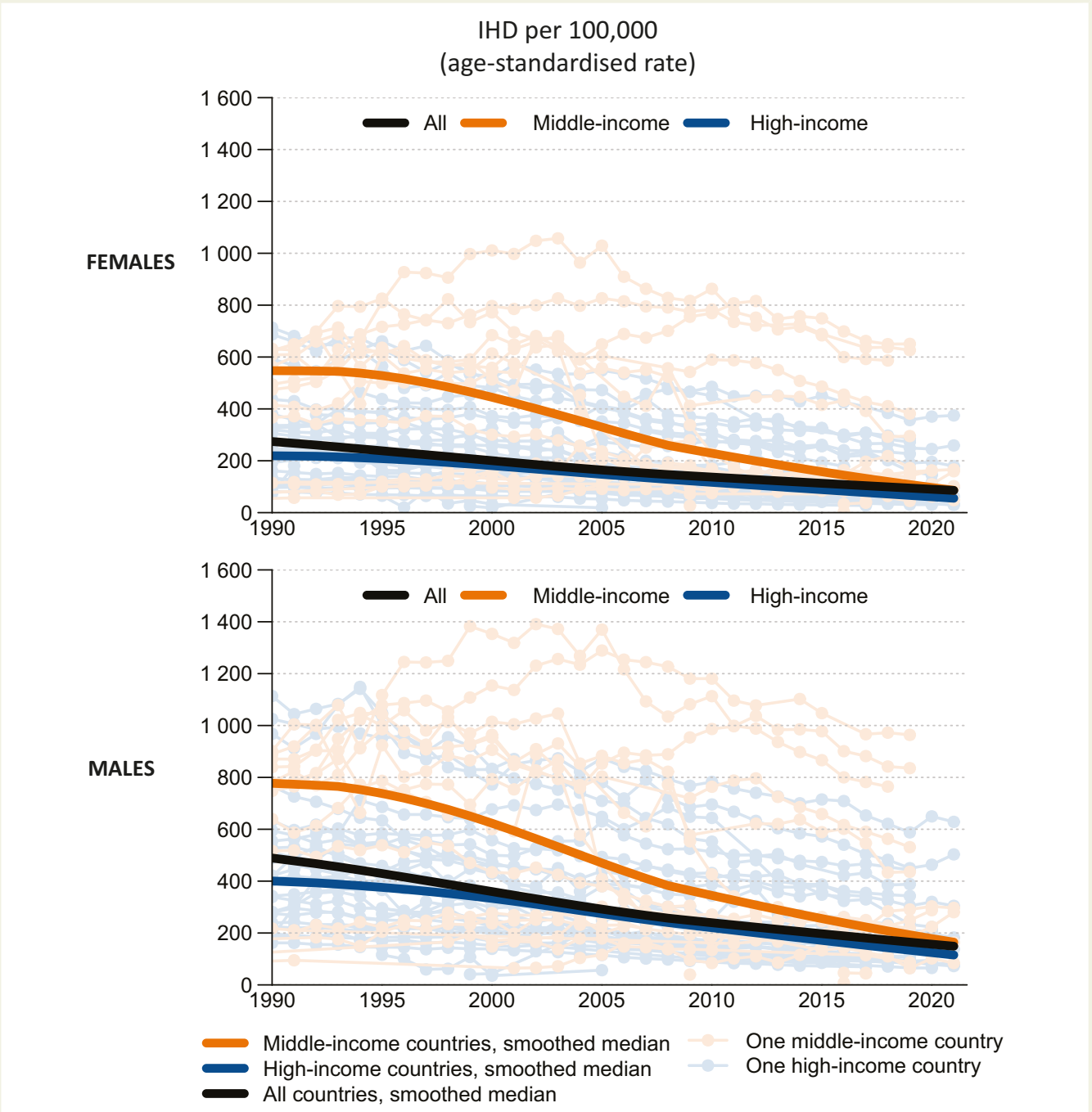


Figure 14 Time series: age-standardized mortality rate from IHD per 100 000 people in females and males in European Society of Cardiology member countries (1990–2021)

- **Time series data.** Most high-income countries saw reductions in IHD ASMRs, between 1990 (or the closest year of data) and 2021 (or the most recent year of data). However, in Poland IHD ASMRs in women increased by 10% and in Croatia and Cyprus IHD ASMRs increased in both sexes: Croatia (males 22%, females 97%) and Cyprus (males 200%, females 137%) (*Figure 14*). During the same period middle-income countries saw around 5% reduction in IHD ASMRs in both males and females but in over half of these countries IHD ASMRs increased, particularly in Egypt (males 81%, females 201%), Kyrgyzstan (males 31%, females 57%), and Ukraine (males 29%, females 27%), with large increases in females also seen in Albania (56%) and Syria (53%).
- **Potential years of life lost due to IHD.** In 2019, IHD caused 34 million PYLL, accounting for 57% of all PYLL due to CVD (61% in males and 53% in females). Of the 34 million PYLL due to IHD, 21 million (62%) were lost in middle-income countries (61% in males and 62% in females).

Stroke

IHME definition

Rapidly developing clinical signs of (usually focal) disturbance of cerebral function lasting >24 h or leading to death.[159]

Stroke is the second most common cause of death in Europe and a leading cause of adult disability.[160] In 2017, the cost associated with stroke was estimated at €45 billion, including direct and indirect costs of care provision and productivity loss.[160] The number of people living with stroke in Europe is estimated to increase by almost one third by 2047, mainly because of population ageing and improved survival rates, with stroke deaths expected to decrease by 17%.[161] The Action Plan for Stroke in Europe calls for preventive strategies aimed at reducing stroke numbers, treating patients in dedicated stroke units, developing national plans encompassing the entire chain of care, and implementing in full national strategies for multisector public health interventions.[162]

- **National statistics stratified by sex.** Data from the most recent available year show that median ASMRs per 100 000 for stroke were higher for males than females [95.3 (IQR 54.1–172.0) vs. 80.3 (IQR 49.9–131.4)] in ESC member countries (*Figure 11*). Among all ESC member countries, Morocco had reported the lowest ASMRs due to stroke in both males and females (18.0 and 15.8 per 100 000, respectively). Highest ASMRs for all countries were observed in Georgia for males (486.9 per 100 000) and in Azerbaijan and Georgia for females (341.8 and 337.2 per 100 000).
- **Stratification by national income status.** Median ASMRs per 100 000 for stroke in middle-income countries were more than twice those in high-income countries with disparities greater in males [172.0 (IQR 104.1–254.1) vs. 65.6 (IQR 52.6–109.1)] than in females [131.4 (IQR 87.7–188.3) vs.53.8 (IQR 49.4–83.5)] (*Figure 12*). Of note, females from middle-income countries had median ASMRs for stroke twice as high as males from high-income countries. In males, the lowest quartile values for ASMRs from stroke (<56 per 100 000) were observed in 11 of 32 high-income countries but only 3 of 23 middle-income countries (Lebanon, Libya, and Morocco). In females, the lowest quartile values for ASMRs from stroke (<50 per 100 000) were reported in 12 of 32 high-income countries but only two of 23 middle-income countries (Lebanon and Morocco). Conversely, the highest ASMRs above the upper quartile levels for stroke occurred in 11 of 23 middle-income countries for both males and females, but in only 3 high-income countries (Latvia, Lithuania, and Romania).
- **Time series data.** Between 1990 and 2021, all high-income countries except Republic of San Marino saw a decrease in median stroke ASMRs of 65% for males and 64% for females (see Supplementary data online, *Figure S17*). Although middle-income countries also saw declines in median stroke ASMRs in both males and females (20% and 25%), Azerbaijan and Libya saw large increases affecting both males (44% and 26%) and females (77% and 23%). Egypt also saw large increases in median stroke ASMRs in females (31%).
- **Potential years of life lost due to stroke.** In 2019, stroke caused 14.8 million PYLL in ESC member countries, accounting for 25% of all PYLL due to CVD, 28% in females and 22% in males. Of the 14.8 million PYLL caused by stroke, 8.2 million (55%) were lost in middle-income countries.

Lower extremity artery disease

IHME definition

Lower extremity artery disease (LEAD), also referred to as peripheral artery disease in IHME and other publications, is defined as having an ankle-brachial index (ABI) < 0.90, whether or not symptomatic.[163,164]

After CHD and stroke, LEAD is the third most prevalent form of atherosclerotic CVD. It is a global disorder with increasing prevalence over recent years.[165] The risk of LEAD increases sharply with age and with exposure to major cardiovascular risk factors. LEAD is rarely a cause of death by itself but is highly associated with total and CVD mortality related to comorbidities and, more importantly, widespread atherosclerosis. It is estimated that LEAD regardless of symptoms, increases cardiovascular morbidity and mortality risks by 80%–90%.[166] Outcomes are particularly severe in patients with diabetes[167] although there is evidence that among patients with LEAD rates of cardiovascular complications are showing signs of decline,[168] perhaps due to the application of guideline recommended preventive strategies.[159] However, implementation is lower than in patients with IHD.[169,170] Beyond the increased risk of mortality and CVD events, LEAD is associated with disability related to intermittent claudication, other atypical pains and walking disturbances, as well as amputation when the severity of atherosclerosis makes effective revascularization impossible.[170]

- **National statistics stratified by sex.** Data show that median ASMRs per 100 000 due to LEAD were 1.3 times higher for males than females across ESC member countries [2.3 (IQR 1.1–4.3) vs. 1.8 (IQR 0.7–2.8)] (see Supplementary data online, *Figure S18*). This gender difference in median ASMRs was driven mainly by the difference in middle-income countries where median ASMRs from LEAD were twice as high in males compared with females. In high-income countries, ASMRs were higher by only 10% in males vs. females.
- **Stratification by national income status.** In both males and females, median ASMRs for LEAD were lower in middle-income countries compared with high-income countries [1.3 (IQR 0.2–2.6) vs. 2.7 (IQR 1.8–5.0) per 100 000 in males and 0.6 (IQR 0.2–1.0) vs. 2.4 (IQR 1.6–3.3) per 100 000 in females] (see Supplementary data online, *Figure S19*). These relatively low ASMRs due to LEAD in middle-income countries might reflect underdiagnosis or premature death from other causes such as IHD and stroke. Very low ASMRs from LEAD, below 0.1 per 100 000 were reported in Finland, Egypt, Morocco, and Uzbekistan (for both sexes), Slovenia (for females), and Libya (for males), with the lowest ASMRs in Morocco for females (0.01/100 000) and Uzbekistan for males (0.01/100 000). The highest ASMRs estimates from LEAD were reported in Poland (35.4 and 42.2 per 100 000 for females and males), exceeding by far the second and third most burdened countries: Estonia and Croatia for females (6.6 and 5.8 per 100 000 women, respectively), and Latvia and Malta for males (12.5 and 9.74 per 100 000 men, respectively).
- **Potential years of life lost due to LEAD.** In 2019, LEAD was responsible for 379 000 PYLLs across ESC member countries (58% among males), consistent with 0.6% of all PYLLs due to CVD, 0.7% in males and 0.6% in females. Unlike IHD and stroke, most PYLLs due to LEAD (81%) were in high-income countries, with this disparity slightly greater in females than in males (83% vs. 80%).

Atrial fibrillation

IHME definition

A supraventricular arrhythmia due to progressive atriopathy, defined by surface ECG diagnosis based on irregular RR intervals (in the absence of complete atrioventricular block) and no distinct P waves.[171]

Atrial fibrillation (AF) is prevalent across all high-income countries and increasingly across many middle- and low-income countries.[156] Besides age, major risk factors include hypertension, high body mass index, and alcohol use.[156] AF worsens quality of life[172] and increases cardiovascular mortality due to stroke and heart failure—with non-cardiovascular death, mainly malignancy, and infection, yet more common.[173]Anticoagulation guided by risk prediction scores protects against stroke in patients with AF[174] but treatment and adherence rates are often sub-optimal.[175–177] The prevalence of AF across Europe is expected to rise substantially as the population ages and this will increase rates of AF-related strokes and hospitalizations with knock on effects for healthcare costs.[178] In 2020, AF was predicted to directly cost the UK between 0.9% and 1.6% of NHS expenditure.[179]

- **National statistics stratified by sex.** In 2021 or most recent available year, median ASMRs per 100 000 for AF were similar for females compared with males [8.3 (IQR 3.2–13.1) vs. 8.3 (IQR 3.0–13.3)] (see Supplementary data online, *Figure S20*). In middle-income countries ASMR estimates were higher in females compared with males [4.5 (IQR 1.1–8.2) vs. 3.5 (IQR 0.8–6.8)] but in high-income countries they were slightly higher in males [11.0 (IQR 6.8–14.3)] than in females [10.4 (IQR 6.4–13.9)].
- **Stratification by national income status.** Median AF-related ASMRs in females and males were, respectively, 2.3 times higher and >3 times higher in high-income compared with middle-income countries (*Figure 12*).
- **Potential years of life lost due to AF.** In 2019, AF accounted for 1.02 million PYLL (59% in females), corresponding to 1.7% of all PYLLs due to CVD within ESC member countries. 81% of all AF-related PYLL were in high-income countries, 80% in females and also 80% in males. Median age-standardized PYLL per 100 000 across ESC member countries were 56.9 (IQR 48.0–68.9).

Rheumatic heart disease

IHME definition

A chronic autoimmune valvulitis due to rheumatic fever, diagnosed clinically by a physician.[180]

Rheumatic heart disease (RHD) is the most common cause of acquired heart disease in children and young adults globally.[181] A 2019 report estimated a prevalence rate of 11.3% by WHO criteria, higher in females compared with males and varying inversely with national income. Clinically silent RHD was substantially more prevalent than clinically manifest disease.[182] Increasing trends in the incidence and prevalence of RHD have been observed worldwide from 1990 to 2017, particularly in low resource settings while in many high-income countries the trends have been downward.[183] However, a European study reports evidence of a recent up-tick in incidence rates in some countries, perhaps driven by immigration. In these countries, effective healthcare planning requires that attention is given to immigrants' health status on arrival, their housing conditions, and their healthcare access.[184]

- **National statistics stratified by sex.** In 2019, median ASMRs per 100 000 for RHD were higher in females compared with males [1.7 (IQR 1.0–2.6) vs. 1.2 (IQR 0.8–2.3)] across ESC member countries (see Supplementary data online, *Figure S21*).
- **Stratification by national income status.** Median ASMRs due to RHD were higher in high-income ESC member countries compared with middle-income countries in females [1.8 (IQR 1.4–2.7) vs. 1.4 (IQR 0.8–2.0)] and in males [1.5 (IQR 0.9–2.4) vs. 1.1 (IQR 0.5–1.2)] (see Supplementary data online, *Figure S22*).
- **Potential years of life lost due to RHD.** In 2019, RHD caused 0.5 million PYLL (59% in females) accounting for 0.9% of all PYLL due to CVD among ESC member countries. Median age-standardized PYLL per 100 000 were 27.4 (IQR 18.0–37.9), with higher values for middle-income compared with high-income countries [48.4 (IQR 29.0–59.9) vs. 21.9 (IQR 13.7–29.3)].

Calcific aortic valve disease

IHME definition

A clinical diagnosis of stenosis or regurgitation due to progressive calcification of the valve, excluding congenital, rheumatic, or infectious causes but including stenosis of a bicuspid aortic valve.[185]

In developed countries, calcific aortic valve disease (AVD) is the most prevalent heart valve disorder and affects 0.4% of the general population and 1.7% of the population >65 years old.[186] Incidence rates have doubled during the last 20 years[187] but evidence suggests that this reflects population ageing rather than population growth.[188] Older age and bicuspid aortic valve are the most potent risk factors for calcific AVD but associations with low socioeconomic status and elevated plasma level of lipoprotein(a) have also been reported.[189,190] There have been large increases in the prevalence of heart failure due to calcific AVD across all global regions but with no evidence-based medications to slow disease progression, calcific AVD remains a public health concern with significant health and economic consequences.[191] International guidelines are consistent in recommending valve replacement in severe symptomatic aortic stenosis either by surgery or transcatheter intervention.[192]

- **National statistics stratified by sex.** Across ESC member countries, median ASMRs per 100 000 for calcific AVD were lower in females compared with males [4.6 (IQR 1.5–6.6) vs. 5.2 (IQR 1.9–8.2)] (see Supplementary data online, *Figure S23*).
- **Stratification by national income status.** Median ASMRs per 100 000 for calcific AVD were higher in high-income countries compared with middle-income countries in males [7.6 (IQR 5.6–9.8) vs. 0.9 (IQR 0.2–2.1)] and females [5.9 (IQR 5.0–7.9) vs. 0.4 (IQR 0.1–2.1)] (*Figure 12*).
- **Potential years of life lost due to calcific AVD.** In 2019, calcific AVD accounted for 0.67 million PYLL in people from ESC member countries. Median age-standardized PYLL per 100 000 were higher in high-income compared with middle-income countries [46.3 (IQR 35.2–58.4) vs. 13.1 (IQR 7.4–21.6)], with rates higher in males than females in both high-income [55.8 (IQR 41.3–62.1) vs. 39.4 (IQR 29.2–49.6)] and middle-income [15.9 (IQR 9.9–23.6) vs. 10.9 (IQR 5.5–19.1)] countries.

Degenerative mitral valve disease

IHME definition

Myxomatous degeneration of the mitral valve leading to at least moderate mitral regurgitation, excluding disease due to congenital, rheumatic, or

infectious causes. Also excluded is 'functional' mitral regurgitation consequent to left ventricular dilatation.[193]

Like calcific AVD, degenerative mitral valve disease (MVD) is primarily a disease of the elderly and if severe it reduces survival substantially.[194] In a Swedish population study, the incidence rate for mitral regurgitation was 21.3 per 100 000,[195] with 61% of cases caused by degenerative disease by EuroHeart survey estimates.[196] Incidence rates have changed little over the last 18 years.[197] Surgical valve repair or replacement can improve quality of life with evidence that it may also be associated with a survival benefit.[197] Variable symptomatic improvement and mortality reduction has also been reported for percutaneous mitral valve repair.[198,199] However, international guidelines offer little consensus on choice between surgical and transcatheter treatment strategies.[200]

- **National statistics stratified by sex.** Median ASMRs per 100 000 for degenerative MVD were similar across ESC member countries for females and males [0.9 (IQR 0.4–1.4) vs. 1.0 (IQR 0.5–1.6)]. ASMRs per 100 000 for both sexes were highest in Georgia (females 4.3, males 4.9) and lowest in Morocco (females 0.02, males 0.02).
- **Stratification by national income status.** Median ASMRs per 100 000 for degenerative MVD were higher in high-income than middle-income countries for both males [1.1 (IQR 0.8–1.7) vs. 0.3 (IQR 0.1–1.3)] and females [0.9 (IQR 0.7–1.6) vs. 0.3 (IQR 0.2–1.0)].
- **Potential years of life lost due to degenerative MVD.** In 2019, degenerative MVD accounted for an estimated 0.2 million PYLL across ESC member countries, representing 0.3% of all PYLL due to CVD. Median age-standardized MVD PYLLs per 100 000 were 10.9 (IQR 7.0–13.6), higher in females compared with males [11.2 (IQR 6.5–15.1) vs. 9.3 (IQR 7.1–12.0)] and higher in high-income compared with middle-income countries [10.9 (IQR 7.5–13.5) vs. 9.6 (IQR 4.0–15.2)].

Heart failure

IHME definition

Heart failure defined clinically by studies that used structured, symptom-based criteria (Framingham or European Society of Cardiology definition for congestive heart failure).[201]

European Society of Cardiology definition

Clinical syndrome consisting of symptoms (e.g. breathlessness, ankle swelling, and fatigue) that may be accompanied by signs (e.g. elevated jugular venous pressure, pulmonary crackles, and peripheral oedema). It is due to a structural and/or functional abnormality of the heart that results in elevated intracardiac pressures and/or inadequate cardiac output at rest and/or during exercise.[202]

Heart failure (HF) represents the end-point of a variety of CVDs and is a major global health problem.[203,204] As populations age so the prevalence of HF increases despite declines in the incidence of CVD in many Western countries.[205] Primary care data from the UK show that prognosis remains poor in patients with HF with the 5-year survival increasing only modestly from 41.0% in 2000 to 48.2% in 2012.[206] Survival is worse in females compared with males and worse in those admitted to hospital around the time of diagnosis.[206] Disease-modifying and device therapies have the potential to improve outcomes in patients with HF, but these are often under-used.[207,208]

- **National statistics stratified by sex.** HF accounted for 5.8% of total deaths across ESC member countries (14.6% of CVD deaths) in females and for 4.4% of total deaths (12.5% of CVD deaths) in males. The absolute number of HF-related deaths was 27% higher in females than in males (237 000 vs. 186 000) but median estimated ASMRs per 100 000 was higher for males [47.3 (IQR 30.3–73.8) vs. 43.1 (IQR 27.8–66.7)] (see Supplementary data online, *Figure S24*).
- **Stratification by national income status.** In 2021 or most recent available year, median estimated ASMRs per 100 000 for HF were higher in middle-income compared with high-income countries in both females [61.6 (IQR 27.3–81.6) vs. 40.7 (IQR 28.0–54.4)] and males [65.1 (IQR 32.4–96.1) vs. 43.5 (IQR 29.5–53.4)] (*Figure 12*). Among middle-income countries, the age-standardized ASMRs were highest in Bulgaria and Egypt exceeding 300 per 10 000 in females and 350 per 100 000 in males. In high-income countries, ASMRs for females were highest in Poland and Croatia where they exceeded 90 per 100 000, while for males in Poland and Czech Republic they exceeded 100 per 100 000.

Out-of-hospital cardiac arrest

Definition

Cessation of cardiac mechanical activity that is confirmed by the absence of signs of circulation and that occurs outside of a hospital setting.[209]

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death in Europe, caused by acute myocardial infarction in ~50% of cases.[210] Data on incidence, management, and outcomes mainly come from the European Registry of Cardiac Arrest (EuReCa).[211,212] In the most recent report data for 37 054 OHCAs from 28 European countries were presented.[212] The incidence of started resuscitation ranged from 27 to 91/100 000/year with survival to hospital discharge ranging from 0% to 18%. Bystander cardiopulmonary resuscitation was initiated in 13%–82% of cases and was associated with higher survival. The data highlight the extent to which OHCA is a public health burden across Europe. The large variation between countries in incidence and outcomes is cause for concern.

EuReCa statistics on national outcomes have been summarized previously[2] *and have not been updated.*

Summary

General cardiovascular disease mortality

- CVD has remained the most common cause of death in ESC area with over 3 million deaths in 2021 including >1.6 million deaths in females and 1.5 million deaths in males.
- Across ESC member countries, CVD accounted for proportionately more deaths in middle-income compared with high-income countries in both females (53% vs. 34%) and males (46% vs. 30%).
- In 2021, CVD caused 239 000 premature deaths among females in ESC member countries and more than twice as many among males.
- Between 1990 and 2021, CVD ASMRs in both sexes decreased by >50% in all high-income ESC member countries but in middle-income countries the decrease was <12%.
- CVD accounted for 26 million PYLL in high-income countries and approximately 34 million PYLL in middle-income countries.

Specific cardiovascular disease phenotypes mortality

- In 2021, median ASMRs for IHD across ESC member countries were higher for males than females (171.4 vs. 90.8 per 100 000) and in both sexes were higher in middle-income compared with high-income countries.

- In 2019, IHD caused 34 million PYLLs, accounting for 57% of all PYLLs due to CVD (61% in males and 53% in females).
- ASMRs for stroke in 2021 were higher for males than females (95.3 vs. 80.3 per 100 000) and more than twice as high in middle-income compared with high-income ESC member countries.
- Between 1990 and 2021 stroke ASMRs declined by ∼65% in both females and males across high-income ESC member countries. Declines across middle-income countries were smaller (<30%). In Azerbaijan and Libya, stroke ASMRs increased in both sexes and in Egypt there was an increase specifically in men.
- ASMRs per 100 000 for lower extremity artery disease were lower in middle-income countries compared with high-income countries for males (1.3 vs. 2.7) and females (0.6 vs. 2.4). These low ASMRs in middle-income countries might reflect underdiagnosis or premature death from other causes such as IHD and stroke.
- Atrial fibrillation-related ASMRs in females and males were, respectively, 2.5 times higher and >3 times higher in high-income compared with middle-income countries.
- ASMRs for rheumatic heart disease were higher in females compared with males (1.7 vs. 1.2 per 100 000) across ESC member countries.
- In 2021, ASMRs per 100 000 for calcific AVD were lower in females compared with males (4.6 vs. 5.2) across ESC member countries. ASMRs were higher in high-income vs. middle-income countries in males (7.6 vs. 0.9 per 100 000) and females (5.9 vs. 0.4 per 100 000).
- In 2021, ASMRs for HF across ESC member countries were higher in males compared with females (47.3 vs. 43.1 per 100 000). ASMRs were also higher in middle-income compared with high-income countries in males (65.1 vs. 43.5 per 100 000) and females (61.6 vs. 40.7 per 100 000).

Cardiovascular healthcare delivery

For all the common CVD disorders, contemporary management is aimed at disease prevention and timely delivery of treatments to alleviate symptoms and improve prognosis. To meet these aims, diagnostic and therapeutic technologies have increasingly come to dominate cardiological practice. This has brought with it a substantial financial burden, with CVD accounting for the largest share of healthcare budgets in countries across Europe.[11–13] The sums involved are huge and challenging for many middle-income countries where the healthcare spend is on average only about a quarter of that in high-income countries. Effects of this funding shortfall on cardiovascular healthcare delivery are hard to gauge but are likely unfavourable based on the Atlas survey data presented in this section. The data collected in the 2023 survey describe human and capital resource statistics and cardiovascular procedure rates in ESC member countries during 2022.

Cardiologists

Cardiology staffing requirements to meet national needs are ill defined and for any given country depend on an appropriate balance between the supply and demand of human resource. Major determinants of supply include recruitment rates into cardiology training programmes, the quality of the training, and staff retention issues.[213] Also important is sex and racial imbalance and there is general recognition of the need for more female and ethnically diverse cardiologists.[214,215] Demand is largely determined by the burden of cardiovascular disease and the increasing development of subspecialty treatment options. These complex considerations make international workforce comparisons hard to interpret and although specialist involvement in CV care and admission to a cardiac ward can improve outcomes,[216,217] there is no simple relation between the number of cardiologists working within a country and the quality of CV healthcare.

- **Number of cardiologists**. In the 2023 survey of ESC member countries, there was a median of 95.0 (IQR 50.9–123.4) cardiologists per million people, with numbers ranging from <30 per million in Ireland, Uzbekistan and UK to >250 per million in Georgia and Greece (*Figure 15*).
- **Females in cardiology**. Females comprised 38.6% (IQR 25.2–48.3) of cardiologists working in ESC member countries. Underrepresentation of females was greatest in Republic of Kosovo and Israel where they comprised <15% of cardiologists. Exceptions to this trend were Kyrgyzstan, Latvia, Lithuania, Georgia, and the Republic of Moldova where >70% of cardiologists were females (*Figure 15*).
- **Stratification by national income status**. The median number of cardiologists per million inhabitants of middle-income ESC member countries was lower compared with high-income countries [54.8 (IQR 45.4–135.6) vs. 100.4 (IQR 65.9–119.1)]. Female cardiologists comprised 49.4% of the cardiological workforce in middle-income countries compared with 30.3% in high-income countries. These averaged data, however, conceal considerable variation across ESC member countries.
- **Trends.** The median number of cardiologists per million people has increased across biennial surveys of ESC member countries from 80.9 in the 2019 survey to 85.1 in 2021 survey and to 95.0 in the 2023 survey. This increase has been mainly driven by the increasing number of cardiologists in high-income countries, from a median of 90.8 per million people in 2019 to 100.4 in 2023 surveys. In middle-income countries, numbers have declined from a median of 61.8 per million people in 2019 to 54.8 in 2023 surveys. The gender gap, however, is narrowing, with the proportion of women increasing from 28% in 2019 to 38.6% in 2023 surveys.

Diagnostic coronary angiography

Coronary angiography is widely regarded as the diagnostic gold-standard for obstructive coronary artery disease.[218] However, a normal coronary angiogram with unobstructed arteries is not necessarily a benign finding and in some patients with typical angina pectoris may indicate small vessel disease, spasm, or other ischaemic disorders with adverse effects on quality of life.[219,220] Computed tomography coronary angiography (CTCA) is now finding an increasing role for non-invasive diagnosis of coronary artery disease with the potential to significantly cut costs.[221–223]

- **Infrastructure.** In the 2023 survey of ESC member countries, a median of 3.0 (IQR 2.3–4.2) hospitals per million inhabitants of ESC member countries reported having facilities for cardiac catheterization. Provision ranged from <1.5 hospitals per million in Slovakia, Uzbekistan, Algeria to >4.5 in Egypt, Germany, Italy, Ireland, Greece, Cyprus, Bulgaria, Georgia.
- **Service delivery.** A median of 3629 (IQR 2645–5596) diagnostic coronary angiograms per million people were performed across ESC member countries, ranging from <1000 in Kyrgyzstan, Egypt, and Uzbekistan to >7000 in Belgium, Türkiye, Lithuania, Germany, and Bulgaria.
- **Stratification by national income status.** The median number of hospitals per million inhabitants of ESC member countries that provided facilities for diagnostic cardiac catheterization was similar in middle-income compared with high-income countries [3.0 (IQR

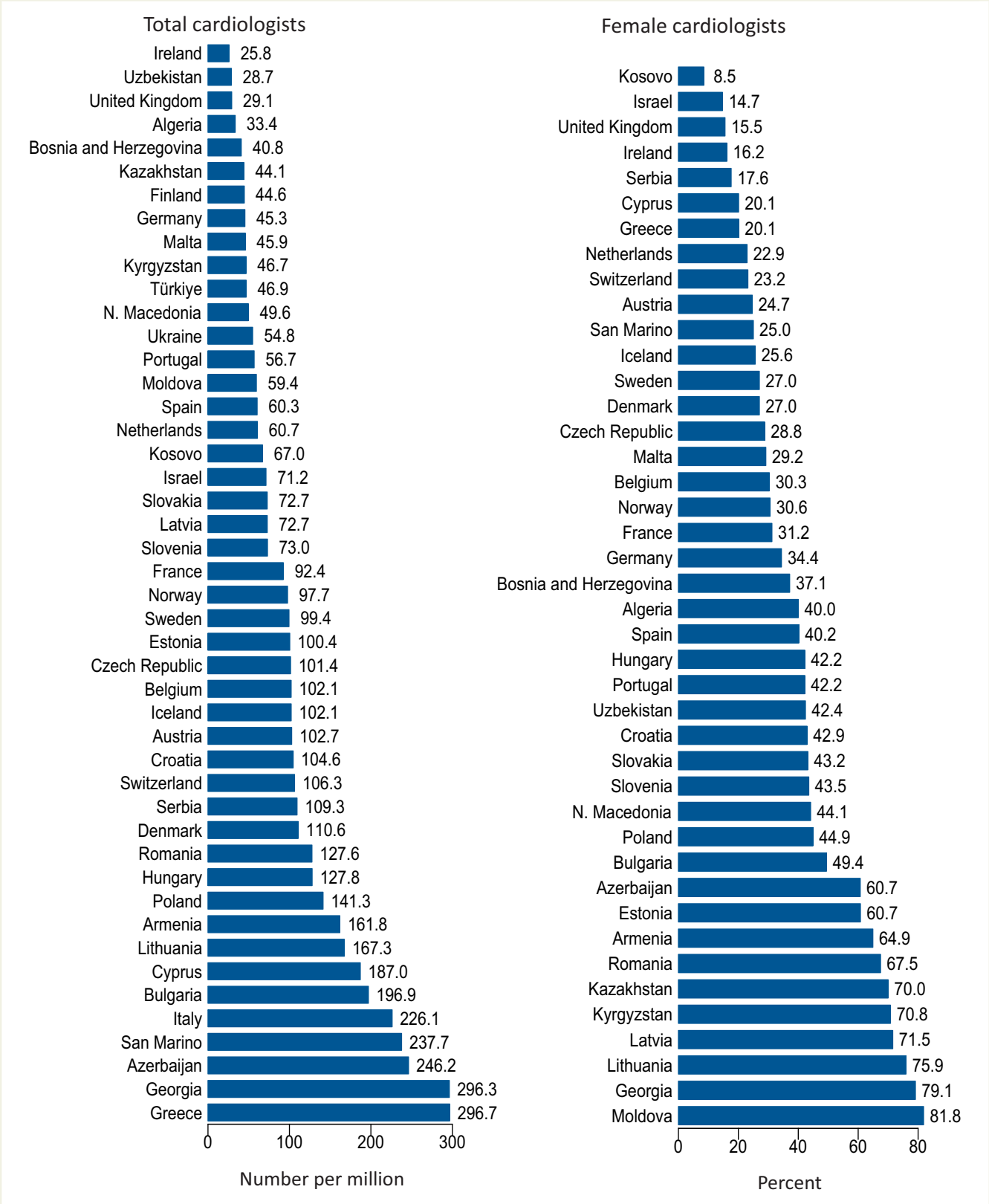


Figure 15 Cardiologists total and proportion of female cardiologists (%) per million people in European Society of Cardiology member countries. (UK, United Kingdom; BiH, Bosnia and Herzegovina)

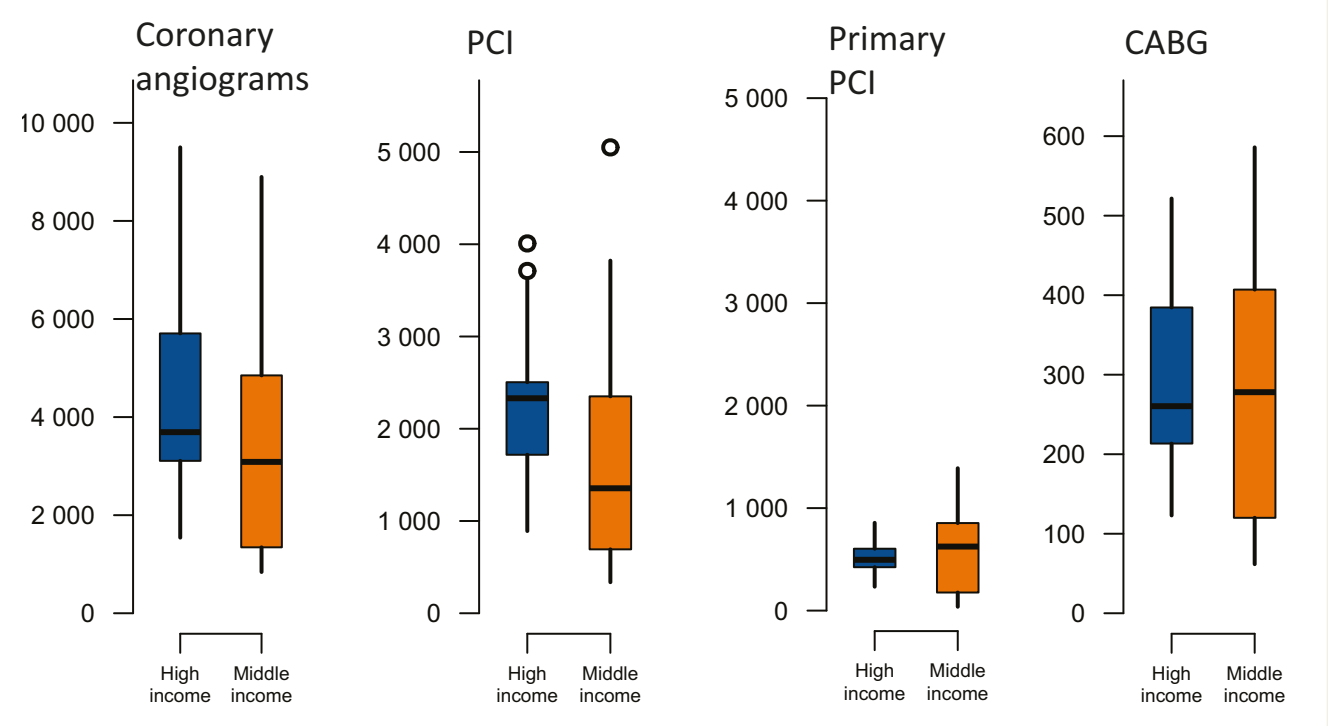


Figure 16 Coronary angiograms, percutaneous coronary interventions (PCI), primary percutaneous coronary interventions (pPCI), and coronary artery bypass graft surgery (CABG) procedures per million people in European Society of Cardiology member countries, stratified by national income status

2.6–4.2) vs. 3.1 (IQR 2.2–4.2)]. Despite similar facilities in terms of catheter laboratories, the median number of diagnostic catheter procedures per million people was lower in middle-income compared with high-income countries 3086 (IQR 1361–4439) vs. 3773 (IQR 3164–5706), although these averaged data concealed important differences with Serbia, Bosnia and Herzegovina Georgia, Armenia, Türkiye, and Bulgaria among middle-income countries performing >4000 procedures per million people, comparable to rates in many high-income countries (*Figure 16*).

- **Trends.** The median number of hospitals per million inhabitants of ESC member countries that provide facilities for diagnostic cardiac catheterization in middle-income countries increased from 1.8 in the 2019 survey to 2.4 in 2021 and to 3.0 in 2023. Conversely, the median number of diagnostic catheter procedures per million individuals fell from 4601 in the 2019 survey to 4084 in 2021 and to 3629 in the 2023 surveys, driven largely by a 30% reduction in diagnostic catheter procedures in high-income countries. This perhaps reflects the impact of the COVID-19 pandemic on procedure rates[224] plus a switch towards non-invasive imaging with CTCA.[225,226]

Percutaneous coronary intervention

PCI has revolutionized the management acute coronary syndrome (ACS) and timely disobliteration of the infarct-related coronary artery by primary PCI allows myocardial reperfusion with reduction of infarct size and mortality.[227] In the context of chronic coronary syndrome (CCS), balloon dilatation and stenting of obstructed coronary arteries allows to relief symptoms and decrease cardiovascular mortality without reduction all-cause mortality.[228,229] Compared with coronary artery bypass surgery, PCI is cost-effective in the acute setting and in stable disease when the SYNTAX score is ≤22 or in left main artery disease. In multivessel disease, however, coronary artery bypass surgery has superior long-term cost-effectiveness.[230]

- **Number of interventional cardiologists**. In the 2023 survey of ESC member countries, the median number of interventional cardiologists per million inhabitants of ESC member countries was 13.1 (IQR 9.2–18.4), with numbers ranging from <5 per million in Ukraine, Uzbekistan, Azerbaijan, Algeria to >20 per million in Serbia, Slovenia, Switzerland, Greece, Bulgaria, Türkiye, Malta, Austria, Georgia, and Croatia.
- **Females in interventional cardiology**. Females comprised 9.7% (IQR 4.7–14.4) of interventional cardiologists working in ESC member countries. Under-representation of females was greatest in 23 ESC member countries, where they comprised <10% of interventional cardiologists. Exceptions to this trend were Malta, Italy, Ukraine, Azerbaijan, Iceland where >25% of interventional cardiologists were females.
- **Infrastructure.** The median number of hospitals per million inhabitants of ESC member countries that offered a 24 h/7-day facility for primary PCI was 2.1 (IQR 1.5–2.8), ranging from <1 hospital per million people in Slovenia, UK, Denmark, Egypt, Algeria, Uzbekistan, Republic of San Marino, and Moldova to >4 in Italy, Poland, Belgium, Germany, Armenia, Cyprus, and Bulgaria.
- **Service delivery.**
  (a) **Percutaneous coronary intervention**. The median number of PCI procedures per million inhabitants was 2186 (IQR 1383–2494) across the ESC member countries. Numbers ranged from <1000 procedures per million people in Republic of San Marino, Azerbaijan, Egypt, Ukraine, Kyrgyzstan, Algeria,

and Uzbekistan to >3000 in Switzerland, France, Armenia, Lithuania, Germany, Latvia, Türkiye, and Bulgaria.

(b) **Primary percutaneous coronary intervention**. The median number of primary PCI procedures per million inhabitants was 498.5 (IQR 420.2–636.3) across the ESC member countries. Numbers ranged from <50 procedures per million people in Azerbaijan and Uzbekistan to >900 in Türkiye.

- **Stratification by national income status.** The median number of interventional cardiologists per million inhabitants of ESC member countries was somewhat similar between middle-income and high-income countries [10.6 (IQR 5.6–17.1) vs. 13.3 (IQR 10.7–18.9)], while similarity was also observed in hospitals with 24 h/7-day primary PCI availability [2.0 (IQR 1.5–2.8) vs. 2.1 (IQR 1.5–2.6)]. The median numbers of PCI procedures per million inhabitants of ESC member countries were lower in middle-income compared with high-income countries [1355 (IQR 708.4–2316) vs. 2330 (IQR 1790–2499)] (*Figure 16*). However, the numbers of primary PCI procedures per million inhabitants were greater in middle-income countries [624.8 (IQR 414.9–793.1)] vs. high-income countries [476.8 (IQR 433.4–603.8)] (*Figure 16*).
- **Trends.** The median number of interventional cardiologists per million inhabitants in middle-income countries increased from 6.3 in the 2019 survey to 8.6 in 2021 survey, followed by a further rise to 13.1 in the 2023 survey. In contrast, there was no similar dynamics in high-income countries where numbers showed a slight decrease (15.1 in the 2019 survey, 14.6 in 2021, and 13.3 in 2023 surveys). The median number of hospitals offering 24/7-day facility for primary PCI also notably increased in middle-income countries from 1.4 per million inhabitants in 2019 to 1.7 in 2021 and 2.0 in 2023 surveys to reach high-income countries numbers (2.1 per million inhabitants). PCI procedures per million inhabitants showed little increase between 2019 and 2023 surveys (2047 vs. 2186) but an increase, in primary PCI procedures was observed from 462.1 in the 2019 survey, to 522.8 in 2021 and 498.5 in 2023 surveys.

Interventional heart valve procedures

Transcatheter aortic valve implantation

The only effective treatment for severe aortic stenosis, regardless of symptoms,[231] is heart valve replacement by TAVI or surgical aortic valve replacement (SAVR). Meta-analyses of randomized trials show more favourable short-term mortality outcomes for TAVI as compared to SAVR, regardless of baseline risk status, but for longer term outcomes the relative benefits are less clear.[232–234] Nevertheless, TAVI compared with SAVR appears to be a cost-effective intervention in severe aortic stenosis, even in low surgical risk patients,[235,236] and indications are rapidly expanding. In a 2018 analysis, it was estimated that there are 115 000 potential annual candidates eligible for TAVI in Europe—or 177 000 if low-risk patients are included.[237,238] These statistics are having a major impact on healthcare resource planning.

Transcatheter mitral valve repair

Patients with secondary mitral regurgitation that is severe and symptomatic are often not referred for surgery due to high surgical risk.[239] Transcatheter MV repair has emerged as a less invasive treatment option in this population. Two randomized trials examining the additive benefits of mitral transcatheter edge-to-edge repair (TEER) on top of medical therapy have now reported. COAPT showed a relative risk reduction for hospitalization with HF as well as lower mortality after 2 years for the transcatheter mitral valve repair group with these benefits sustained through 5 years of follow-up. The smaller MITRA-FR study found no significant difference between groups.[240,241] In patients with severe secondary mitral regurgitation, guidelines are consistent in recommending management in a multidisciplinary heart team with optimization of medical therapy complemented by MV surgery or TEER,[242] but there is less consensus on the choice of surgical treatment.[243] In addition, following the results of the EVEREST II trial,[199] TEER can also be proposed in patients with symptomatic primary MR judged inoperable or at high risk for surgery.[200] As a result, transcatheter MV repair treatment volumes are increasing and a US study found that within institutions adopting the technology for treatment of degenerative MR there was a decrease in higher-risk surgical operations and improved survival outcomes.[244]

Transcatheter tricuspid valve repair

Surgical repair has a guideline indication in severe tricuspid regurgitation (TR) at the time of left heart surgery or in severe and symptomatic isolated TR.[245] Surgery is challenging with early mortality in a recent meta-analysis of 3.9%.[246] Now available is a transcatheter edge-to-edge repair procedure for TR in which a transvenous approach is used to deploy a clip to hold the valve leaflets together. Currently only the European guidelines makes a weak, class IIb indication for the use of transcatheter treatment of TR in symptomatic, inoperable patients.[247] However indications may increase following recent publication of a randomized trial that found TEER safe for patients with severe TR with improvement in quality of life compared with medical therapy.[248]

- **Infrastructure**. In the 2023 survey of ESC member countries, the median number of hospitals that reported having catheter laboratories equipped for interventional valve procedures was 1.1 (IQR 0.6–1.5) per million inhabitants across ESC member countries. Numbers ranged from <0.5 hospitals per million people in Azerbaijan, Serbia, Moldova, Ukraine, Kyrgyzstan, Uzbekistan, Algeria, and Republic of San Marino to >3 in Cyprus, Italy, Tukiye.
- **Service delivery**

(a) **Transcatheter aortic valve implantation (TAVI)**. A median of 91.5 (IQR 9.6–170.9) TAVI procedures per million inhabitants of ESC member countries were performed across all ESC member countries, ranging from <1 procedure per million people in Republic of Kosovo, Bosnia and Herzegovina, Azerbaijan, Kyrgyzstan, and Uzbekistan to >200 in Denmark, Malta, Austria, Cyprus, Switzerland, Slovenia, Israel, France, and Germany.

(b) **Transcatheter mitral valve interventions.** A median of 8.5 (IQR 0.3–19.2) procedures per million people per year were performed across ESC member countries in 2021 and 2022 with Switzerland and Germany the most active in doing 46.6 and 90.3 procedures per million people, respectively. Albania, Armenia, Bosnia and Herzegovina, Georgia, Iceland, Republic of Kosovo, Kyrgyzstan, Moldova, Ukraine, and Republic of San Marino reported zero procedures.

(c) **Transcatheter tricuspid valve interventions.** A median of 0.5 (IQR 0.0–2.5) procedures per million people were performed in the ESC member countries with Slovenia, Cyprus, Switzerland reporting more than seven procedures per million people.

- **Stratification by national income status**. The median number of hospitals per million inhabitants of ESC member countries that had catheter laboratories equipped to perform interventional valve procedures was lower in middle-income compared with high-income

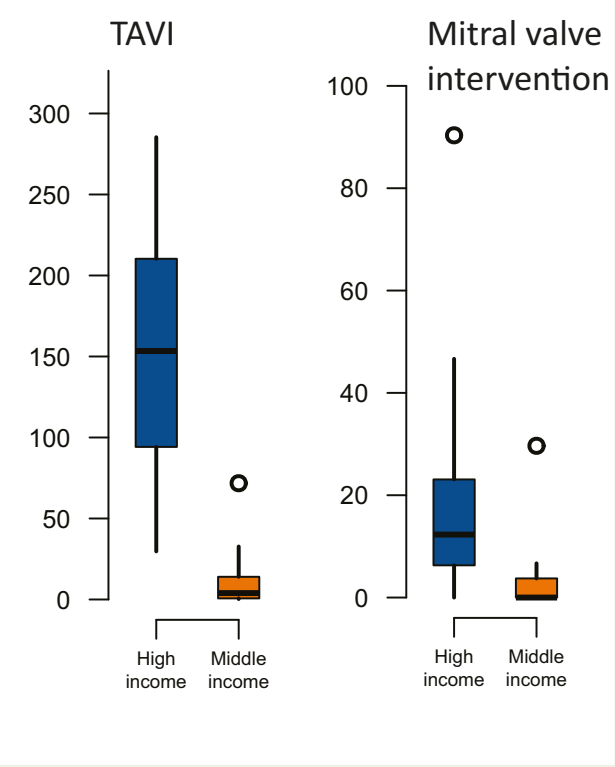


Figure 17 Transcatheter aortic valve implantation (TAVI) and percutaneous mitral valve procedures per million people in European Society of Cardiology member countries, stratified by national income status

countries [0.59 (IQR 0.41–1.35) vs. 1.24 (IQR 0.76–1.94)]. Procedure rates per million people in middle-income countries were strikingly lower for TAVI [4.0 (IQR 0.9–12.9) vs. 153.4 (IQR 99.8–210.3)], transcatheter mitral valve interventions [0.0 (IQR 0.0–3.19) vs. 12.3 (IQR 6.7–22.4)] and transcatheter tricuspid valve interventions [0.0 (IQR 0.0–0.0) vs. 2.1 (IQR 0.75–3.0)] compared with high-income countries (*Figure 17*).

- **Trends**. The median number of TAVI procedures per million increased from 25.5 in 2019 survey to 60.0 in 2021 survey, and to 91.5 by 2023 survey. This primarily reflects activity in high-income countries where numbers of TAVI procedures per million nearly matched surgical aortic valve replacements (153.4 vs. 145.2). A similar trend was observed for transcatheter mitral valve interventions procedures, which more than doubled from 2.7 per million in 2019 survey to 8.5 in 2023 survey.

Catheter ablation procedures and device implants

Catheter ablation

Is now the most widely performed electrophysiological procedure providing definitive treatment of atrioventricular nodal re-entrant tachycardia, atrioventricular re-entrant tachycardia, unifocal atrial tachycardia, and atrial flutter, with increasing application in ventricular tachyarrhythmias. However, its major application is in patients with persistent or paroxysmal AF where it is more effective than antiarrhythmic drug therapy for reducing risk of AF recurrence, improving quality of life, and lowering healthcare utilization.[249–252] A national study from Australia/New Zealand reported a fivefold increase in AF ablations during the period 2008–17 but despite rising patient risk profiles, complications following the ablation procedures declined by 30% during the same period with procedure related death in <0.1% of cases. Complication rates were 25% higher in females compared with males, a disparity that has persisted over time.[253,254]

Device implants

Pacemaker therapy is central to the management of bradycardias, particularly in elderly patients presenting with dizziness and syncope.[255,256] Pacemakers that deliver cardiac resynchronization and/or defibrillation have guideline indications for restoring synchronous biventricular activation in patients with HF and protecting against sudden death in certain high-risk populations.[257,258] Despite the high initial cost, the cost-effectiveness of device therapy has been confirmed in a variety of different settings.[259,260] Nevertheless, there is evidence of substantial regional variation in the utilization of device therapy that almost certainly reflects underuse.[261,262]

- **Number of cardiac electrophysiologists.** The median number of cardiac electrophysiologists per million people was 4.7 (IQR 2.4–7.9), ranging from <1 in Uzbekistan, Azerbaijan, Kyrgyzstan, and Republic of San Marino to >10 in Belgium, Croatia, Estonia, Bulgaria, UK, Iceland, and Switzerland. Switzerland reported >35 cardiac electrophysiologists per million people.
- **Infrastructure.** Across the ESC member countries, there was a median of 1.5 (IQR 0.9–2.4) hospitals per million people undertaking electrophysiology procedures and a median of 1.4 (IQR 0.8–2.1) hospitals per million people undertaking advanced electrophysiology procedures. In general, the number of hospitals per million performing electrophysiology procedures was lower in middle-income compared with high-income countries [0.9 (IQR 0.7–1.4) vs. 1.9 (IQR 1.1–2.6)]. The same applied to the number of hospitals performing advanced electrophysiology procedures [0.6 (IQR 0.4–1.2) vs. 1.7 (IQR 1.0–2.4)].
- **Service delivery**
  - (a) **Ablation procedures**. A median of 279.0 (IQR 123.9–493.9) ablation procedures per million inhabitants of the ESC member countries were performed for treatment of AF and/or atrial flutter [159.1 (IQR 65.2–327.3)], atrial focal and atrioventricular nodal tachycardias [110.8 (IQR 64.0–183.0)] and ventricular tachycardia [22.8 (IQR 11.6–37.0)]. Rates ranged from <25 procedures per million people in Algeria and Republic of Kosovo, to >750 procedures per million people in Croatia, Denmark, France, Germany, Belgium, and Switzerland.
  - (b) **Pacemaker implants.** A median of 607.3 (IQR 251.7–874.0) pacemaker implants per million inhabitants of ESC member countries were reported. Rates ranged from <40 implants per million people in Uzbekistan to >1000 per million people in Italy, Sweden, France, Portugal, and Lithuania.
  - (c) **Implantable cardioverter–defibrillator implants.** A median of 121.1 (IQR 76.4–160.3) Implantable cardioverter–defibrillator implant (ICD) implants per million inhabitants of ESC member countries were reported. Rates ranged from <6 implants per million people in Kyrgyzstan and Uzbekistan to >200 per million people in Sweden, Denmark, Italy, Belgium, The Netherlands, Czech Republic, and Germany.
  - (d) **Cardiac resynchronization therapy implants.** A median of 81.2 (IQR 30.5–116.4) Cardiac resynchronization therapy (CRT) implants per million inhabitants of ESC member countries were reported. Rates ranged from <2 implants per million people in

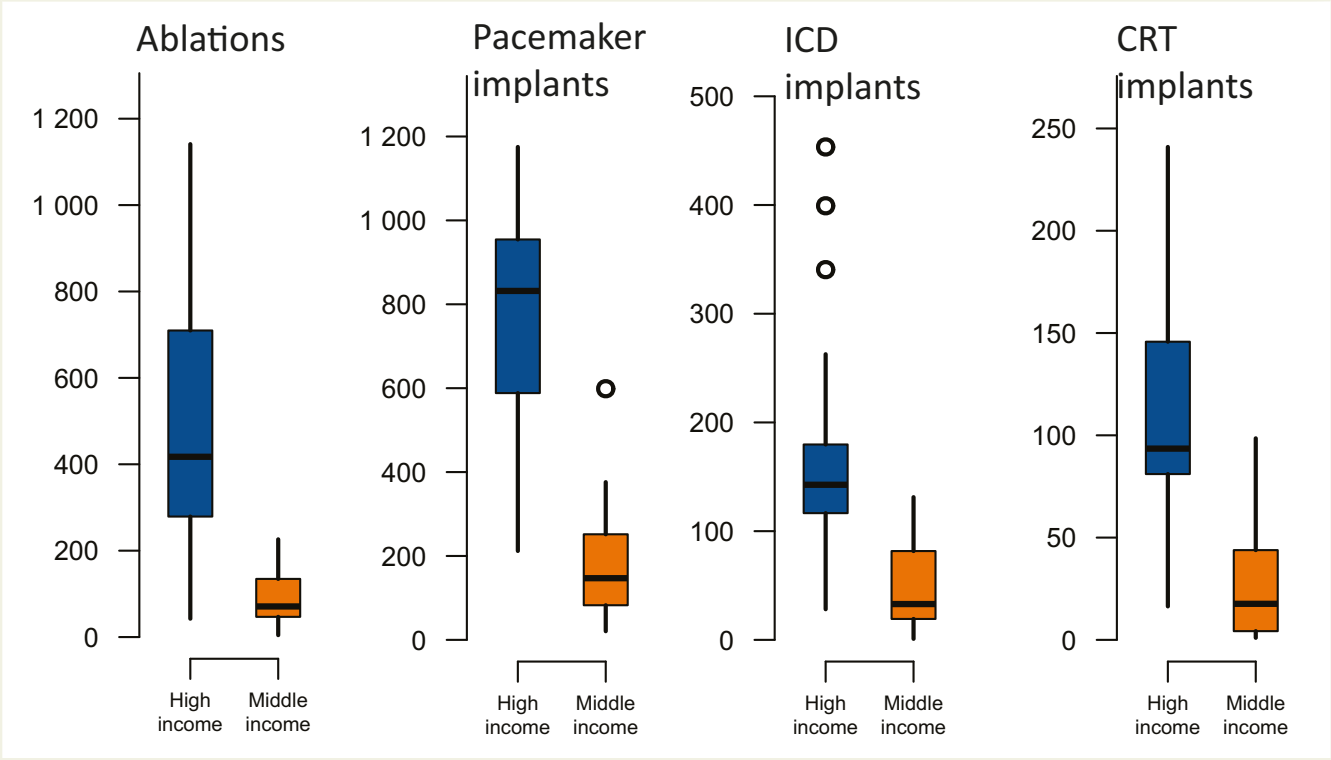


Figure 18 Ablation procedures, pacemaker implantations, implantable cardioverter–defibrillator implantations, and cardiac resynchronization therapy implantations per million in European Society of Cardiology member countries, stratified by national income status

Kyrgyzstan, Uzbekistan, and Republic of San Marino to >150 per million in Norway, UK, Italy, Denmark, Belgium, Czech Republic, and Germany.

- **Stratification by national income status.** Compared with high-income ESC member countries, the median number of procedures per million people was lower in middle-income countries where fewer ablation procedures were performed [70.9 (IQR 48.7–140.3) vs. 417.4 (IQR 279.0–709.7)] and fewer pacemakers [147.0 (IQR 82.6–251.7) vs. 831.9 (IQR 597.8–951.3)], ICDs [32.9 (IQR 19.2–81.7) vs. 142.7 (IQR 117.2–179.0)] and CRT devices [17.6 (IQR 4.7–40.5) vs. 88.5 (IQR 78.9–138.9)] were implanted. (*Figure 18*) Concealed within these averaged data, however, were some outliers with Bulgaria, for example, implanting more pacemakers than many high-income countries.
- **Trends.** The median number of ablation procedures per million people increased from 287.1 in the 2019 survey to 372.3 in 2021 survey before declining to 279.0 in 2023 survey. This recent decline is predominantly attributable to the growing involvement of middle-income countries in performing ablation procedures. The median number of pacemaker implantations performed per million inhabitants remained relatively stable between the 2019 and 2023 surveys, but there were small increases in the median numbers of ICD and CRT implantations per million from 100.2 to 121.1 and from 63.6 to 81.2, respectively.

Cardiac surgery

Coronary artery bypass graft surgery

Coronary artery bypass graft (CABG) surgery occupies a central role in the treatment of obstructive coronary artery disease, providing significant improvement in quality of life and angina frequency.[263] In left main and multivessel coronary artery disease, CABG can prolong life compared with medical therapy, and appears more cost-effective than PCI[264–266] particularly when left ventricular function is impaired.[267,268] Nevertheless, revascularization by PCI is often preferred in contemporary practice, and data from the UK confirm that surgical case volumes have declined in recent years while PCI volumes have increased.[269,270] For most patients, outcomes with PCI are comparable to those achieved with CABG but in patients with diabetes CABG outperforms PCI and is the procedure of choice.[271–273]

- **Number of cardiac surgeons.** In the 2023 survey of ESC member countries, the median number of cardiac surgeons per million people was 7.6 (IQR 5.9–10.8). Numbers ranged from <5 surgeons per million in France, Algeria, Ireland, Republic of San Marino, UK, Uzbekistan, and Armenia to >15 per million in Austria, Croatia, Lithuania, Türkiye, and Georgia.
- **Infrastructure.** A median of 1.2 (IQR 0.8–1.7) hospitals per million inhabitants of ESC member countries were reported to have facilities for cardiac surgery, ranging from <0.7 hospitals in Romania, Denmark, UK, Uzbekistan, Republic of San Marino, and Algeria to >2.0 in Azerbaijan, Switzerland, Belgium, Kazakhstan, Greece, Cyprus, and Georgia, whereas Iceland—country with the population of less than a million—reported one hospital.
- **Service delivery.** A median of 262.7 (IQR 201.3–384.7) CABG procedures per million inhabitants of ESC member countries were reported. Rates ranged from <100 CABG procedures per million people in Uzbekistan, Ukraine, Algeria and Kyrgyzstan to >500 in Georgia, Belgium, and Türkiye.
- **Stratification by national income status.** In middle-income countries, the median number of cardiac surgeons per million inhabitants was lower compared with high-income countries [6.3 (IQR

5.5–9.9) vs. 8.2 (IQR 6.2–11.4)], while the number of hospitals with cardiac surgical facilities per million inhabitants was higher [1.5 (IQR 0.8–1.8) vs. 1.1 (IQR 0.8–1.6)]. However, the median numbers of CABG procedures per million inhabitants in middle-income and high-income countries were similar [278.0 (IQR 120.0–407.0) vs. 260.4 (IQR 213.5–376.9)] (*Figure 16*) although there was some heterogeneity with Azerbaijan, Bulgaria, Georgia, and Türkiye among middle-income countries reporting >400 procedures per million people per year, more than those reported by many of the high-income ESC member countries.

- **Trends.** Surgical human resource and infrastructure across ESC member countries has remained relatively stable since the 2019 survey. The median number of coronary artery bypass procedures has fluctuated from 301 per million inhabitants in the 2019 survey, dropping to 272 in 2021 survey and to 262 in 2023 survey.

Heart transplant surgery and ventricular assist devices

Heart transplant surgery is a life-saving treatment for patients with end-stage HF, delivering improved quality and duration of life. Survival after heart transplantation compares well with the natural course of end-stage HF. In 2014, the registry of the International Society for Heart and Lung Transplantation reported a 1-year survival of 84.5% and a 5-year survival of 72.5% compared with 76.9% and 62.7% in the 1980s.[274] Moreover, there is a growing body of evidence suggesting that patients on the waiting list for heart transplantation are surviving longer with left ventricular assist devices (LVADs).[275] In patients ineligible for heart transplantation, ventricular assist devices can increase survival at 1 year to over 50% compared to 25% with medical therapy. Quality of life is significantly improved in the device group.[276]

- **Infrastructure.** In the 2023 survey of ESC member countries, the median number of hospitals that reported having heart transplant programmes was 0.18 (IQR 0.00–0.34) per million inhabitants. Only Croatia, Latvia, Belgium and Lithuania reported more than 0.5 hospitals per million inhabitants with transplant programmes.
- **Service delivery.** A median of 2.06 (IQR 0.0–4.3) heart transplant procedures per million people were reported. Fourteen ESC member countries reported no heart transplant programme, whereas only three countries (Czech Republic, Croatia, and Slovenia) reported >7 heart transplant procedures per million people. The variation in LVAD implants was even greater with a median rate among all countries of 1.3 (IQR 0.2–4.9) per million people per year. Thirteen ESC member countries reported <1 implant per million people, whereas only three countries (Slovenia, Republic of North Macedonia, and Germany) reported >8 LVAD implants per million people.
- **Stratification by national income status.** Heart transplant activity was considerably greater in high-income countries where a median of 3.4 (IQR 1.1–4.9) procedures per million people were reported in the 2023 survey, whereas in middle-income countries only Bulgaria, Kazakhstan, Republic of North Macedonia, and Ukraine reported transplant activity. Middle-income countries reported a median of 0.0 (IQR 0.0–0.2) procedures per million people.
- **Trends.** The median number of hospitals with heart transplant programmes remained stable (0.2 per million in all three recent surveys). The median number of heart transplant procedures fluctuated around 2 per million people in the 2019 and 2023 surveys.

Congenital heart disease

In an analysis of 25 EUROCAT registries in 14 European countries, the live birth prevalence of non-syndromic congenital heart disease for the period 2008–15 was 60.2 per 10 000 births and remained stable across the three severity groups (simple, moderate, and severely complex).[277] Without the ability to substantially alter the prevalence of congenital heart disease, interventions and resources must be used to improve survival and quality of life. Advances in treatment have led to a decrease in infant mortality and an increase in children and adults with congenital heart disease. Pressure on services for congenital heart disease survivors has been widely documented, as well as the need for careful monitoring during transition from paediatric to adult care.[278] An unfavourable quality of life in young adults with congenital heart disease is predicted by lower physical exercise capacity, female sex, less social support, and lower educational level. Special psychosocial care should be considered to improve outcomes in such cases.[279]

- **Infrastructure.** In the 2023 survey of ESC member countries 0.4 (IQR 0.2–0.6) hospitals per million inhabitants hospitals were reported to have catheter laboratory facilities for structural heart disease interventions in children. Only Croatia, recorded more than one such hospital per million people, whereas Malta and Iceland—countries with the population of less than a million—reported one hospital per country each. Surgical facilities for congenital heart disease were available in a median of 0.5 (IQR 0.3–1.1) hospitals per million people.
- **Service delivery.** Across the ESC member countries, a median of 37.9 (IQR 20.1–61.1) surgical procedures for congenital heart disease were reported in the 2023 survey. Rates ranged from <5 surgical procedures per million people per year in Algeria, Bosnia and Herzegovina, Malta and Luxembourg to >70 in Belgium, Slovenia, Kazakhstan, Moldova, Germany, Israel, Georgia, and Uzbekistan.
- **Stratification by national income status.** Facilities for interventional management of congenital heart disease were similar in those middle-income and high-income ESC member countries that returned data in the 2023 survey. A median of 0.4 (IQR 0.2–0.6) hospitals per million inhabitants of middle-income ESC member countries and 0.3 (IQR 0.2–0.5) hospitals per million inhabitants of high-income ESC member countries reported hospitals with catheter laboratory facilities for structural heart disease interventions in children. Surgical procedure rates per million people were lower in middle-income compared with high-income countries [25.6 (IQR 15.1–81.0) vs. 40.9 (IQR 29.5–58.8)].
- **Trends.** The number of hospitals with catheter laboratory and surgical facilities for structural heart disease interventions in children has remained relatively constant in recent years. The median number of surgical procedures has decreased from 49.4 in the 2019 survey to 37.9 in 2023.

Summary

- Across all ESC member countries in the 2023 survey, there was a median of 95.0 cardiologists per million people with almost twice as many in high-income than middle-income countries (100.4 vs. 54.8, respectively).
- In the 2023 survey, females comprised 38.6% of cardiologists working in ESC member countries.
- Between surveys of ESC member countries in 2019 and 2023, the number of cardiologists per million in high-income countries increased from a median of 80.9 in 2019 survey to 100.4 in 2023. In

middle-income countries the numbers have declined during the same period from a median of 61.8 per million people in 2019 survey to 54.8 in 2023 survey.
- The median number of PCI procedures per million people in the 2023 survey was lower in middle-income compared with high-income countries (1355 vs. 2330) but the number of primary PCI procedures was greater in middle-income countries (624.8 vs. 476.8), probably reflecting a greater burden of ST-elevation myocardial infarction.
- In the 2023 survey, procedure rates per million people for TAVI were lower in middle-income compared with high-income countries (4.0 vs. 153.4), where they matched the number of surgical aortic valve replacements (153.4 vs. 145.2).
- In the 2023 survey, procedure rates for cardiac ablation procedures (70.9 vs. 417.4), and implantations of pacemakers (147.0 vs. 831.9), ICDs (32.9 vs. 142.7), and CRT devices (17.6 vs. 88.5) were lower in middle-income compared with high-income countries.
- In middle-income countries, the median number of cardiac surgeons per million inhabitants in the 2023 survey was lower compared with high-income countries (6.3 vs. 8.2) but the median number of CABG procedures was similar (278.0 vs. 260.4).

Discussion

The ESC Atlas 2023 report shows continuing inequalities in the epidemiology and management of CVD between the middle-income and high-income ESC member countries. Nowhere are these inequalities clearer than in the changes in age-standardized CVD mortality rates during the last 30 years. In the high-income ESC member countries, ASMRs have been in steep decline during this period and in some of them cancer has begun to emerge as a more frequent cause of death.[157] On the contrary, in the middle-income countries declines have been very small with a number of these countries recording an increase in CVD ASMRs. Nevertheless, CVD remains the most common cause of death in both males and females across Europe with the burden falling most heavily on the middle-income ESC member countries where ASMRs for both sexes have been consistently higher compared with high-income countries. Causes of these inequalities between middle-income and high-income countries cannot be inferred with certainty from our observational data but they likely reflect heterogenous exposures to CVD risk factors and variable implementation of preventative strategies. Particularly relevant in the context of CVD is socioeconomic status which by definition is lower in middle-income ESC member countries as reflected by lower GDP *per capita*, lower educational attainment and higher rates of unemployment, all of which combine to reduce access to healthy life choices and high-quality healthcare. It is likely that many of the inequalities in CVD between middle-income and high-income ESC member countries, including lifestyle and clinical risk factors, can be attributed indirectly to differences in socioeconomic status (Graphical Abstract).[280,281]

Among lifestyle activities that associate with CVD, tobacco use has been identified as the single largest avoidable health risk.[76] Policy measures to reduce tobacco use and tobacco derivative commercialization have been promoted by the EU in the last 15 years and during this period there has been continuous decline in the prevalence of smoking across Europe.[77] However smoking rates remain particularly high among males in the middle-income ESC member countries >40% of whom use tobacco compared with <30% in high-income countries. This is likely to contribute importantly to the heightened CVD risk among males in middle-income countries where ASMRs are 2.5 times higher compared with high-income countries. These statistics provide a compelling rational for targeting smoking cessation policy measures at males in middle-income ESC member countries. Overall, novel solutions are needed and although the increasing use of e-cigarettes is the cause of some concern they may have a role to support smoking cessation.[80]

Other lifestyle factors that may contribute to inequalities in CVD between middle-income and high-income countries include insufficient physical activity which in the present report was the cause of over 25% more DALYs among men in middle-income compared with high-income ESC member countries. The benefits of exercise for cardiovascular health are beyond dispute and measures to increase physical activity represent a simple, widely applicable, low-cost global strategy for reducing deaths from CVD in middle age.[88] Many national governments have already developed physical activity policies and local governments have a crucial role to play in creating environments and opportunities for physical activity and active living.[90]

In most European countries, salt intake is above WHO recommended maximum levels,[282] and this has likely contributed to the high rates of elevated blood pressure identified in this report. Of the clinical risk factors elevated blood pressure probably associates most strongly with CVD, particularly myocardial infarction and stroke.[116,283] Consistent with the data in the Atlas 2023 report, international surveys show that rates of raised systolic blood pressure (≥140 mm Hg) have increased substantially over the last four decades particularly in middle-income countries with knock-on increases in DALYs and deaths attributable to hypertension.[284] Hypertension provides policy makers with a clear target for treatment in middle-income countries where prevalence rates in females and males are high and likely contribute to the inequalities in ASMRs documented in this report. Elevated blood pressure is readily treatable with benefits for cardiovascular outcomes yet the treatment rates we report for middle-income countries leave approximately half of females and two thirds of males untreated and at increased risk of cardiovascular mortality. This represents a major failure of healthcare that requires urgent correction. Treatment neglect is not confined to hypertension as evidenced by recent reports of missed opportunities to treat elevated non-HDL cholesterol.[285] Non-HDL cholesterol is a major determinant of CVD risk and while levels have been falling in the high-income countries of western Europe they have often been increasing in middle-income countries.[120] Yet under-treatment is common with more than half those with dyslipidaemia failing to achieve treatment targets in the EUROASPIRE survey.[129]

Treatment neglect of hypertension and dyslipidaemia needs targeting by clinicians and policy makers in the drive to reduce the CVD burden in ESC member countries, particularly in those middle-income countries where need is greatest. Obesity and diabetes, now a global epidemic, also needs targeting at a time when the prevalence of both disorders is rising relentlessly. Mortality rates for diabetes have shown small reductions in recent years, driven in part by improved medical management, but prevalence continues to rise particularly in low- and middle-income countries where it no doubt contributes importantly to the inequalities in cardiovascular outcomes highlighted in this report.[140,141] Population solutions involving policy initiatives to encourage exercise and healthy living are needed but implementation is undermined by increasing urbanization with adoption of western lifestyles in many middle-income countries.[31–33]

The inequalities in cardiovascular risk between middle-income and high-income ESC member countries are potential contributors to the inequalities in ASMRs emphasized in this report. However,

international variations in the quality of cardiovascular healthcare also merit consideration and are addressed by the Atlas survey data provided by the national cardiac societies of the ESC. In general, middle-income countries compared with high-income countries were substantially under-resourced in terms of specialist staffing and diagnostic and therapeutic procedure rates. Numbers of cardiologists per million inhabitants were lower by ~33% in middle-income countries reducing opportunities for the specialist supervision of cardiovascular care that associates with more favourable outcomes.[216,286] Rates of diagnostic, interventional and surgical coronary procedures were also substantially lower in middle-income countries and the same applied across the full range of ablation, device implantation and interventional valve procedures. The relative underuse of these procedures in middle-income ESC member countries does not necessarily imply under-treatment even though this seems likely given how consistent were the differences in procedure rates. Caution is further necessary in ascribing the inequalities in ASMRs between middle- and high-income countries to these differences in procedure rates, bearing in mind that, apart from primary PCI and aortic valve replacement, the symptomatic benefits of these cardiovascular procedures are not always associated with reductions in mortality. It would be unwise therefore to recommend that middle-income countries spend large sums they can ill-afford on investigational and therapeutic technology as a strategy for reducing inequalities in ASMRs. Population measures to prevent or delay the onset of CVD are almost certainly more cost-effective and are now centre stage in the recommendations being put forward by policy makers.[287]

Atlas data show that life expectancy—and with it the proportion of people older than 65—is increasing in many middle-income countries at rates similar to high-income countries, and this will accelerate the growing burden of CVD and end-of-life hospitalization costs.[288] These epidemiological shifts with an ever-increasing population of elderly people have generated concerns about the future funding of healthcare which is predicted to increase substantially throughout the next 100 years to levels that many countries will find hard to afford. In collaboration with the investigators at the Nuffield Department of Population Health, University of Oxford we have estimated the health and social care costs of CVD in the European Union to exceed €150 billion per year or 11% of total healthcare expenditure.[13] A large part of this expenditure is related to diagnostic and therapeutic CVD procedures which are predicted to become a more significant factor than population ageing in driving up healthcare costs during the next 50 years.[14] In seeking to resolve inequalities in ASMRs, therefore, the economic burden of CVD must be taken into account in choosing policy measures that are both effective and affordable. Population strategies including tobacco control, minimum pricing of alcohol, sugar and calorie reduction and diabetes screening programmes may be no less effective for delivering further reductions in CVD mortality than increased technological spending. CVD has been described as a population emergency,[289] and there is now an important need for advocacy programmes to inform policy makers of its societal harms and the need for targeted action especially in those ESC member countries where the burden of disease is greatest.

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Supplementary data

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

Declarations

Disclosure of Interest

All authors declare that they have no conflict of interest relevant to this study.

Data Availability

All the data presented in this report are available upon request to the corresponding author (A.T.). Access will be granted following review with ESC Atlas investigators and agreement with the authors of this manuscript.

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