ESC European Society of Cardiology

European Heart Journal (2022) **43**, 716–799
https://doi.org/10.1093/eurheartj/ehab892

SPECIAL ARTICLE

European Society of Cardiology: cardiovascular disease statistics 2021

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Received 13 September 2021; revised 7 December 2021; accepted 16 December 2021; online publish-ahead-of-print 8 January 2022

Aims This report from the European Society of Cardiology (ESC) Atlas Project updates and expands upon the widely cited 2019 report in presenting cardiovascular disease (CVD) statistics for the 57 ESC member countries.

Methods and results Statistics pertaining to 2019, or the latest available year, are presented. Data sources include the World Health Organization, the Institute for Health Metrics and Evaluation, the World Bank, and novel ESC sponsored data on human and capital infrastructure and cardiovascular healthcare delivery. New material in this report includes socio-demographic and environmental determinants of CVD, rheumatic heart disease, out-of-hospital cardiac arrest, left-sided valvular heart disease, the advocacy potential of these CVD statistics, and progress towards World Health Organization (WHO) 2025 targets for non-communicable diseases. Salient observations in this report: (i) Females born in ESC member countries in 2018 are expected to live 80.8 years and males 74.8 years. Life expectancy is longer in high income (81.6 years) compared with middle-income (74.2 years) countries. (ii) In 2018, high-income countries spent, on average, four times more on healthcare than middle-income countries. (iii) The median $PM_{2.5}$ concentrations in 2019 were over twice as high in middle-income ESC member countries compared with high-income countries and exceeded the EU air quality standard in 14 countries, all middle-income. (iv) In 2016, more than one in five adults across the ESC member countries were obese with similar prevalence in high and low-income countries. The prevalence of obesity has more than doubled over the past 35 years. (v) The burden of CVD falls hardest on middle-income ESC member countries where estimated incidence rates are ~30% higher compared with high-income countries. This is reflected in disability-adjusted life years due to CVD which are nearly four times

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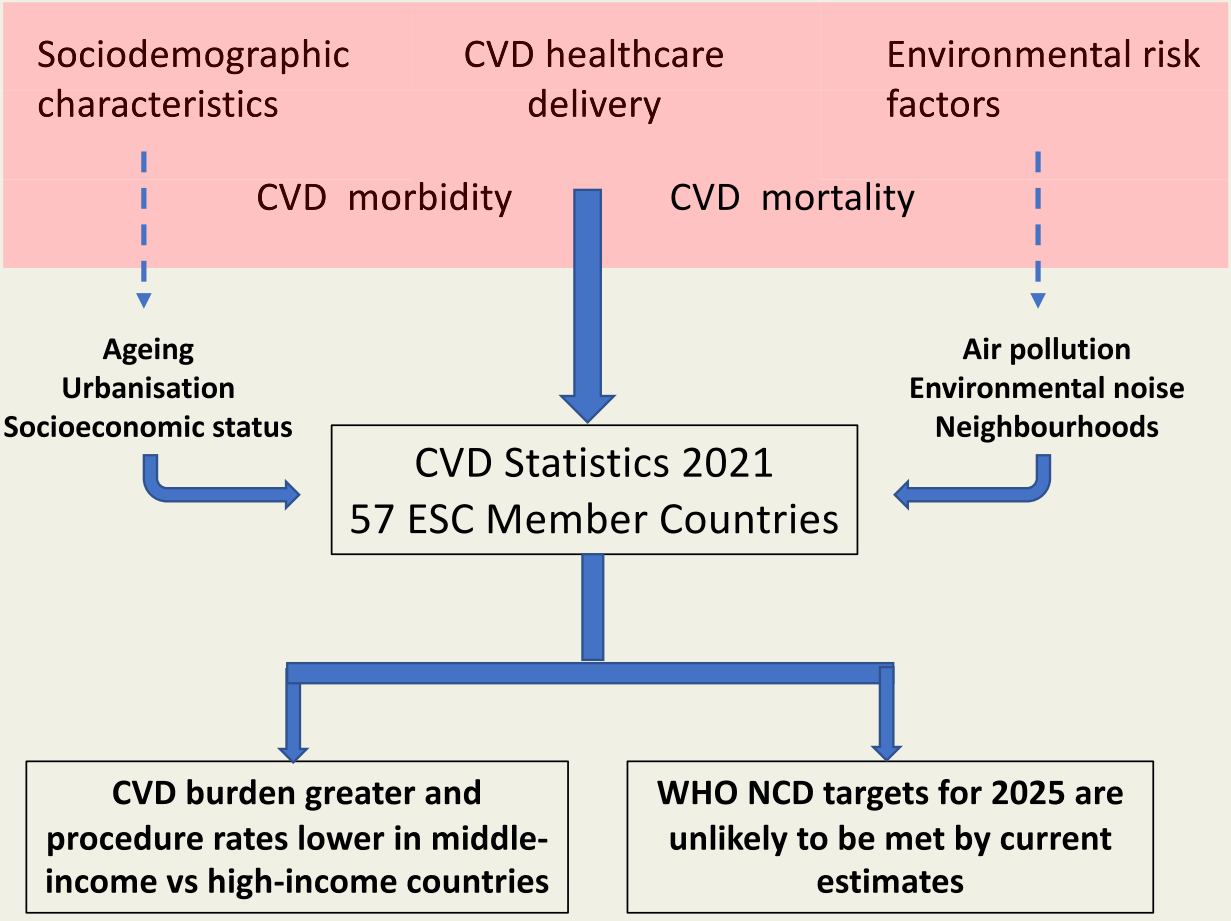
as high in middle-income compared with high-income countries. (vi) The incidence of calcific aortic valve disease has increased seven-fold during the last 30 years, with age-standardized rates four times as high in high-income compared with middle-income countries. (vii) Although the total number of CVD deaths across all countries far exceeds the number of cancer deaths for both sexes, there are 15 ESC member countries in which cancer accounts for more deaths than CVD in males and five-member countries in which cancer accounts for more deaths than CVD in females. (viii) The under-resourced status of middle-income countries is associated with a severe procedural deficit compared with high-income countries in terms of coronary intervention, ablation procedures, device implantation, and cardiac surgical procedures.

Conclusion Risk factors and unhealthy behaviours are potentially reversible, and this provides a huge opportunity to address the health inequalities across ESC member countries that are highlighted in this report. It seems clear, however, that efforts to seize this opportunity are falling short and present evidence suggests that most of the WHO NCD targets for 2025 are unlikely to be met across ESC member countries.



Graphical Abstract This 2021 report from the ESC Atlas Project provides contemporary cardiovascular disease (CVD) statistics for 57 ESC member countries. It builds on the 2017 and 2019 reports with presentation of new data on sociodemographic and environmental determinants of CVD. Huge inequalities in disease burden persist between high-income and middle-income ESC member countries and across all member countries evidence suggests that most of the World Health Organization noncommunicable disease targets for 2025 are unlikely to be met. Advocacy to increase awareness of policy makers, members of the public and other stakeholders about the continuing importance of CVD as the leading cause of death among ESC member countries is a responsibility for all who are involved in cardiovascular research and healthcare.

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

Abbreviations

AED	Automatic external defibrillator
ABI	Ankle–brachial index
AMI	Acute myocardial infarction
ASMR	Age-standardized mortality rate
AF	Atrial fibrillation
AVD	Aortic valve disease
BMI	Body mass index
CABG	Coronary artery bypass graft
CHD	Coronary heart disease
CHE	Current healthcare expenditure
COI	Cost of illness
CRT-P	Cardiac resynchronization pacemaker ('biventricular pacemaker')
CRT-D	Cardiac resynchronization pacemaker with implantable cardioverter defibrillator
CVD	Cardiovascular disease
DALYs	Disability-adjusted life years
Db[A]	A-weighted decibels
€	Euro
EHN	European Heart Network
EHRA	European Heart Rhythm Association
ESC	European Society of Cardiology
ESP	European Standard Population
EU	European Union
EuReCa	European Registry of Cardiac Arrest
EHN	European Heart Network
FAO	Food and Agriculture Organization of the United Nations
GBD	Global burden of disease
GDP	Gross domestic product
GNI	Gross national income
HEDIC	Health Expenditures by Diseases and Conditions
HIC	High-income countries
ICD	Implantable cardioverter-defibrillator
IHD	Ischaemic heart disease
IHME	Institute for Health Metrics and Evaluation
IQR	Inter-quartile range
LVAD	Left ventricular assist device
MIC	Middle-income countries
MVD	Mitral valve disease
NCDs	Noncommunicable diseases
NCD-RisC	Noncommunicable Diseases Risk Factor Collaboration
NCS	National cardiac societies
NHS	National Health Service
OECD	Organisation for Economic Co-Operation and Development
OHCA	Out-of-hospital cardiac arrest
PAD	Peripheral arterial disease
PCI	Percutaneous coronary intervention
PM2.5	Particulate matter $\leq$2.5 μm in diameter
PPP	Purchasing power parity
PPB	Parts per billion
PVD	Peripheral vascular disease
PYLL	Potential years of life lost
SES	Socioeconomic status
SHA	System of Health Accounts
TAVI	Transcatheter aortic valve implantation
UK	UK
USA	USA
USD	US dollars
WB	World Bank
WHO	World Health Organization

Executive summary

This third report from the European Society of Cardiology (ESC) Atlas Project updates and expands upon the 2019 report in presenting cardiovascular disease (CVD) statistics for the 57 ESC member countries.

Statistics pertaining to 2019, or the latest available year, are presented—2020 COVID-19 pandemic data will be detailed in a later report.

New material in this report includes:

- Sociodemographic determinants of CVD
- Environmental determinants of CVD
- Rheumatic heart disease
- Out-of-hospital cardiac arrest
- World Health Organization (WHO) 2025 targets for noncommunicable diseases
- CVD advocacy roadmap

(1) **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;
   - Provide a one-stop source of CVD statistics for academics, clinicians, and other stakeholders.

(2) **Data sources and presentation.** The ESC Atlas is a repository of CVD data collected by groups such as the 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 (CV) healthcare delivery obtained by bi-annual survey of the national CV professional societies of ESC member countries.

Throughout this report, ESC member countries are categorized according to 2020 WB definitions as high-income and middle-income (a composite of lower-middle-income and upper-middle-income countries that includes Syrian Arab Republic now designated as low-income) to permit stratified presentations of CVD statistics by national income status.

The data sources come with important limitations that include:

- adjustments to account for missing data applied by all data providers;
- differences in reporting practices causing variable precision of national data estimates;
- misclassification bias due to miscoding of diagnostic groups and death certificates;
- hidden within-country inequalities in disease burden and healthcare delivery;
- aggregation of 2020 WB national classifications as detailed above.

The limitations as they apply to the quality, precision, and availability of the data emphasize the need for agreed, standardized data collection systems throughout the region. Meanwhile, cautious interpretation of the CVD statistics presented in this report is recommended.

(3) **National sociodemographic factors.** Population ageing in high-income European countries, where fertility rates have fallen below replacement levels, leads to sustained high rates of CVD mortality. Populations are also ageing in many middle-income countries as life expectancy increases and this will exacerbate the growing burden of CVD. These epidemiological shifts are compounded by increasing urbanization across Europe which threatens CV health due to overcrowding, air pollution, social deprivation, and stress. The growth of the elderly population across ESC member countries increases the need for young immigrant groups to supplement national workforces. Socioeconomic deprivation is common in these groups and is associated with a range of health inequalities such as hypertension, diabetes, and premature coronary heart disease. Health inequalities are also associated with other deprivation metrics including unemployment and poor education which remain important drivers of ill health across all ESC member countries.

(4) **Financial and economic burden of cardiovascular disease.** In order to meet the economic challenges of CVD, policymakers need access to reliable information about CVD healthcare costs and the broader impacts on national economies. Information is incomplete but shows that current healthcare expenditure (CHE) per capita varies widely, with high-income European countries spending four times more on healthcare than many middle-income countries. Expenditure for CVD represents the highest component of healthcare cost, and in 2016 accounted for ~16% of the spend in a selection of 11 high-income European countries. The European Heart Network has estimated that CVD costs the EU economy more than €200 billion a year.

(5) **Risk factors and health behaviours**

- **Environmental risk factors.** These include air pollution and noise which account for over 75% of the CVD burden attributable to the environment. In 2019, air pollution with particulate matter ≤2.5 μm in diameter (PM2.5) 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.
- **Health behaviours.** Declines in the prevalence of smoking have made major contributions to CVD mortality reductions across ESC member countries but in many middle-income countries, where the prevalence of smoking among males remains high, declines in CVD mortality have been smaller. Physical inactivity (<150 min of moderate physical activity or <75 min of vigorous physical activity per week) affects an estimated one in three adults living in ESC member countries and is more common in high-income compared with middle-income countries. Dietary factors associated with heightened CVD risk include trans-fatty acids and sugar, both of which are consumed in greater quantity in high-income compared with middle-income ESC member countries. High-income countries also consume larger amounts of sugar-sweetened beverages and lower amounts of vegetables and fruit.
- **Clinical risk factors.** Rates of elevated blood pressure (≥140/90 mmHg) across ESC member countries have declined by 35% in the last 35 years, but almost one in four people remain affected. Systolic blood pressure is higher in males compared with females and in middle-income compared with high-income countries. During the last 40 years, declines in total and non-HDL cholesterol concentrations of about 15 and 20%, respectively, have been recorded in high-income countries but in middle-income countries, where concentrations remain lower, little change has occurred. The prevalence of obesity (BMI ≥30 kg/m^2) has increased steeply across all ESC member countries during the last 40 years and now affects more than one in five adults. This has been associated with an increased prevalence of diabetes which, in 2019, affected 6.9 and 5.8% of adults in middle-income and high-income countries. Obesity and diabetes have been described as one of the biggest global health crises of the 21st century.

(6) **Cardiovascular disease morbidity.** During the last 30 years, declines in the age-standardized incidence of CVD across ESC member countries have been small and in seven middle-income countries variable increases have been recorded. Age-standardized incidence estimates for the major components of CVD, ischaemic heart disease (IHD) and stroke, were twice as high in middle-income compared with high-income countries and for IHD were also twice as high in males compared with females. For stroke, incidence rates were similar by sex. Incidence estimates for both disorders have declined by >25% during the last 30 years, predominately in high-income countries, but the continuing impact of IHD and stroke on population health remains devastating for both females and males with these disorders accounting for an estimated 70 million disability-adjusted life years (DALYs) across ESC member countries in 2019. Rheumatic heart disease (RHD) is a disease of poverty driven by poor housing and overcrowding and although incidence rates across ESC member countries have declined by ~40%, in the last 30 years, they remain twice as high in middle-income compared with high-income countries. Unlike RHD, calcific aortic valve disease has been recorded with increasing

frequency in recent years, especially in high-income countries where estimated incidence is four times higher compared with middle-income countries. The morbidity statistics recorded in the ESC Atlas confirm persisting inequalities in disease burden by sex and national income status. The statistics emphasize the need for concerted application of CVD prevention policies, particularly in middle-income countries where the need is greatest.

(7) **Cardiovascular disease mortality.** Death is one of the most accurately ascertained CVD outcomes and provides a useful measure of disease burden. CVD is the most common cause of death in ESC member countries with IHD accounting for 45% of these deaths in females and 39% in males. The total number of CVD deaths across all ESC member countries far exceeds the number of cancer deaths for both sexes, but there are 15 ESC member countries in which cancer accounts for more deaths than CVD in males and five-member countries in which cancer accounts for more deaths than CVD in females. All of these countries are classified as high income. There are large disparities between high- and middle-income countries in the proportion of premature deaths (<70 years) caused by CVD. Disparity is greater for females, with a median of 36% of all premature deaths caused by CVD in middle-income countries compared with 16% in high-income countries. For males, the corresponding figures are 36 and 24% in middle- and high-income countries, respectively. Age-standardized mortality rates (ASMRs) for CVD have been in decline since 1990 by 47% in males and 42% in females. In high-income countries, reductions in ASMRs have exceeded 50% in both sexes but in middle-income countries, declines have been smaller, not exceeding 15%, with some countries experiencing increases in ASMRs.

(8) **Cardiovascular healthcare delivery.** This ESC ATLAS survey showed continuing heterogeneity in cardiological services in terms of human and capital resources and the delivery of high-quality healthcare. Variation in the availability of cardiologists suggests substantial under-provision in many countries, with a notable sex imbalance (females comprised fewer than a third of all cardiologists) potentially compromising care quality. Middle-income member countries were often under-resourced compared with high-income countries with numbers of cardiologists lower by a third, interventional cardiologists lower by nearly a half, 24 h/7 day catheter laboratory availability lower by a third and catheter laboratories for treatment of structural heart disease lower by nearly two-fold. This structural deficit affecting person power and facilities inevitably translated into a substantial procedural deficit in middle-income compared with high-income countries in terms of coronary intervention, device implantation, and cardiac surgical procedures. This mismatch between the therapeutic need of middle-income countries and the available therapeutic resource requires action through policy strategies to reduce the population burden of CVD while increasing spending on human and capital infrastructure.

(9) **World Health Organization noncommunicable disease targets.** The WHO has set noncommunicable disease (NCD) targets relevant to global CV health to be achieved by 2025 (with reference to 2010). The period 2010–2018 has seen small declines in alcohol consumption across ESC member countries but our linear forecasts predict the WHO target for a 10% relative reduction in harmful use of alcohol is unlikely to be met. Longitudinal data for smoking in ESC member countries were patchy and incomplete but appeared to show a 20% decline in smoking prevalence across ESC member countries between 2010 and 2018. This was largely confined to high-income countries where our linear forecasts suggest the WHO smoking target will be achieved—yet, in middle-income countries, smoking prevalence was higher and appeared to show little change between 2010 and 2018. The WHO target for a 25% reduction in the prevalence of elevated blood pressure is unlikely to be met based on data for the period 2010–2015 when the median prevalence of elevated blood pressure across ESC member countries declined by only 3.4%. However, declines of >10% were recorded in females and males living in high-income countries where our linear forecasts suggest the WHO target is feasible if current trends continue. Analysis of paired 2010 and 2016 national data showed a continuing upward trajectory in the prevalence of obesity affecting >20% of people living in ESC member countries, making it very unlikely the WHO call for a halt in the rise of obesity will be met by 2025. The WHO call for a halt in the rise of diabetes will also not be met based on data showing a nearly 30% increase in prevalence between 2010 and 2015.

(10) **The CVD advocacy roadmap.** One hundred and thirteen million people across ESC member countries continue to live with CVD. Notwithstanding declines in CVD mortality in many countries, CVD remains the most common cause of death within the region. Despite this, cancer is commonly perceived as a more important health concern and attracts more research funding compared with CVD. The ESC has called for advocacy programmes to inform policymakers of the societal harms of CVD and the need for targeted action to reduce the burden of disease in those ESC member countries where the burden is greatest. Five priorities have been identified in the ESC's advocacy roadmap:

- *Changing popular perceptions of CVD* to embrace the broad range of disorders, including degenerative valve disease and congenital heart disorders, in order to better understand the need for new therapeutic strategies in advocating for patients living with non-preventable CVD.
- *Making CVD a health priority*, calling upon the voices of patients and all stakeholders to be heard in bringing CVD onto the policy agendas of national decision-makers.
- *Getting involved with decision-makers* at the national level to establish regional advocacy structures aimed at improving CVD prevention and care.
- *Promoting research and innovation* by advocating for increased CVD research funding and reductions in the complexities of regulatory processes in order to facilitate translation of innovative research findings for clinical benefit of patients with CVD.

- *Coordinating and harmonizing ESC advocacy activities*, recognizing that the ESC is home to large numbers of dedicated scientists and clinicians with unique expertise in CV science and healthcare. Harmonization of this workforce provides huge potential for advocacy on behalf of the 113 million people living with CVD across ESC member countries.

(11) **Salient observations**

- Females born in ESC member countries in 2018 are expected to live 80.8 years and males 74.8 years. Life expectancy is longer in high-income (81.6 years) compared with middle-income (74.2 years) countries.
- In 2018, high-income countries spent, on average, four times more on healthcare than middle-income countries.
- The median $PM_{2.5}$ concentrations in 2019 were over twice as high in middle-income ESC member countries compared with high-income countries and exceeded the EU air quality standard in 14 countries, all middle income.
- In 2016, more than one in five adults across the ESC member countries were obese with similar prevalence in high- and low-income countries. The prevalence of obesity has more than doubled over the past 35 years.
- The burden of CVD falls hardest on middle-income ESC member countries where estimated incidence rates are ~30% higher compared with high-income countries. This is reflected in DALYs due to CVD which are nearly four times as high in middle-income compared with high-income countries.
- The incidence of calcific aortic valve disease has increased seven-fold during the last 30 years, with age-standardized rates four times as high in high-income compared with middle-income countries.
- Although the total number of CVD deaths across all countries far exceeds the number of cancer deaths for both sexes, there are 15 ESC member countries in which cancer kills more males than CVD and five-member states in which this is the case for females. All of these countries were classified as high income.
- The under-resourced status of middle-income countries is associated with a severe procedural deficit compared with high-income countries in terms of coronary intervention, ablation procedures, device implantation, and cardiac surgical procedures.

Introduction

The European Society of Cardiology (ESC) Cardiovascular Disease Statistics, a biennial publication of the ESC European Heart Agency in Brussels, is being published this year under unusual circumstances. The COVID-19 pandemic, apart from its many victims, has damaged and disrupted not only national economies, but perhaps more importantly their health systems, services, priorities, and planning for communicable disease and noncommunicable diseases (NCDs), with all the consequences that entails.[1,2]

Healthcare planning faces difficulties and dilemmas, since in addition to the current demands of the pandemic, and communicable diseases in general, the huge deficits in the management of NCDs, including cardiovascular (CV) and cerebrovascular diseases as well as cancer, are continuing to expand, necessitating new investments in infrastructure, human resources, and research. In these circumstances, decision-making needs to be based on reliable metrics that shed light on requirements and data relating to the epidemiology and trends of these diseases, extending to the realities associated with their management.

The purpose of ESC Cardiovascular Disease Statistics is to map all those factors that contribute to the development of cardiovascular diseases (CVD) as well as the data that characterize the quality of CV care in the 57 ESC member countries.[3] The statistics are drawn from the ESC Atlas of Cardiology that is regularly updated by the European Heart Agency in Brussels. The ESC Atlas is a repository of CVD-related statistics collected by groups such as 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 includes novel data on human and capital infrastructure provided by the national CV professional societies of ESC member countries and obtained through bi-annual surveys sponsored by the ESC.

The statistics reported in the ESC Atlas are the most recent that are currently available and relate to 2019 or the latest available year. They will provide, therefore, a comparator data set for future investigations of the CV consequences of the pandemic across ESC member countries.

The key objectives of the ESC Atlas 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;
- Provide a one-stop source of CVD statistics for academics, clinicians, and other stakeholders.

ESC Cardiovascular Statistics 2021 is the third report from the European Heart Agency ESC Atlas programme.[4,5] It builds on previous reports in providing the most recently available 2019 CVD statistics with new sections on national sociodemographic factors and environmental risk factors that provide important context to the epidemiological heterogeneity of CVD across ESC member countries. The economic burden of CVD gets further consideration and there is a more detailed description of the morbid manifestations of CVD with new data on RHD, left-sided valvular disease, and out-of-hospital cardiac arrest. Progress towards meeting the WHO's NCD 2025 milestones is presented and there is a discussion of the advocacy potential of the ESC Atlas.

We hope that those who study the evidence in this report—healthcare policymakers, healthcare professionals, healthcare administrators, media professionals, patients' organizations, health advocates, and researchers—will recognize the importance of the metrics presented, but also of the overall project, as a lever to improve CVD prevention and treatment, and to reduce the

healthcare gaps and inequalities among the 57 ESC member countries.

Data sources and presentation

The CVD statistics that constitute this report were compiled as part of the ESC's ATLAS project by the European Heart Health Institute in Brussels. Key data sources include:

- European Society of Cardiology: statistics on national CV infrastructure and procedures derived from a 2020 survey of the National Cardiac Societies (NCS) of all 57 ESC member countries.
- World Health Organization: risk factor and mortality statistics.
- Institute for Health Metrics and Evaluation: morbidity and disease burden statistics from the Global burden of disease (GBD) study.
- World Bank: economic indicators.

For each CVD statistic and economic indicator, provenance and completeness are defined in the data provenance table (see Supplementary material online, *Table S1*).

European Society of Cardiology Cardiovascular Healthcare data

The ESC Atlas contains more than 100 variables relating to human and capital infrastructure and major CV interventions and services from 57 ESC member countries. Specific variables developed by a task force were included in a questionnaire circulated biennially to the NCS of participating ESC member countries. The data collected were then subject to quality control procedures, including comparison with other data sources to identify outliers and illogical values. These values were discussed with the source NCS and corrected where necessary. The data were reviewed by independent experts before final approval by the NCS. All original data sources were recorded for tracking purposes.[3] The survey yields absolute numbers for resources and procedures. Crude rates per million people are computed from WB population estimates.[6]

World Health Organization data

Mortality data come from the WHO Mortality Database using the December 2019 update of age- and cause-specific mortality data by country.[7] These data are publicly available. This manuscript presents mortality data for 54 of the 57 ESC member countries. No data are presented for Algeria, Libya, or the Republic of Kosovo.

The WHO database collates data on the absolute number of medically certified deaths from national authorities based on their vital registration systems. From these primary data, mortality rates are calculated using country-level data on population size, obtained from the same database, as denominators. Age-standardized rates are estimated using the direct method with the 2013 European Standard Population (ESP) to control for cross-national differences in population age structures. The 2013 ESP was developed as an update to the 1976 ESP by the European Commission for the EU27 and European Free Trade Association countries to reflect better the age structure of the current European population.[8] Where rates are presented, mortality and population data for the same year are required.

The data presented in the WHO Mortality Database and in this article are as submitted by individual countries to the WHO. No adjustments have been made to account for potential bias in reporting. As a result, the quality of mortality data varies between countries, with more accurate data for countries with well-functioning vital registration systems compared with those with weaker systems. Even for countries with strong vital registration systems, regional patterns of clinical diagnosis may limit cross-country comparability.

In general, the mortality data are up-to-date, with the most recent data for only 10 of the 54 countries dating from 2014 or before. However, in some cases, individual countries are yet to provide their most recent statistics, with the result that the information obtained from the WHO might not be as up-to-date as that available from the databases of these individual countries.

National data on major risk factors are based on aggregated population data derived from the WHO and Noncommunicable Diseases Risk Factor Collaboration (NCD-RisC). Estimates are age-standardized to facilitate international comparisons. Details of methods and data sources are described in more depth elsewhere.[9–11]

Global Burden of Disease—Institute for Health Metrics and Evaluation data

Estimates of CVD prevalence come from the GBD study, conducted by the IHME.[12] The estimates are derived using modelling software and data from health surveys, prospective cohorts, health system administrative data, and registries.[13,14] The GBD study also provides estimates of disability-adjusted life years (DALYs) from estimates of years living with CVD and years of life lost due to CVD mortality. The accuracy of modelled estimates is heavily dependent on the original data used. This can be a challenge where only sub-national, or small sample data are available, or in instances in which recent data have not been collected. Such estimates are, therefore, open to concerns regarding accuracy when describing the national level of CVD burden. In particular, it is possible that estimates may change, as more recent data become available and methods are modified, as has been found with other GBD health indicators.[15] Furthermore, DALYs provide a useful but limited tool to standardize and evaluate health status. Criticism has extended to the implicit use of discounting (present health status weighed more than future) and age weights (lower value given to younger and older ages).[16] The GBD has also received criticism in recent years on methodology, culture, and qualitative difference in addition to a lack of homogeneity in access to resources.[17]

Further criticism has focused on the difference in the population estimates used by IHME to those used by UN agencies. The complexity and computational intensity of imputation and modelling used by IHME makes it challenging for others to explain how outputs relate to country data or to replicate the methods followed.[15,18,19]

World Bank data

Data on various economic indicators come from the WB.[20] These data are drawn from official sources. In converting estimates of gross national income (GNI) and GNI per capita from national

currencies to US dollars (USD), the WB uses a specific conversion factor to help reduce the impact of exchange rate fluctuations in cross-country comparisons. The WB also provides national population data used for calculating rate estimates for ESC member countries.

Data presentation and analysis

Data from the ESC Atlas are presented for 57 ESC member countries, stratified according to the 2020 WB definitions of income status as shown in *Figure 1*.[21] The WB's 2020 list of economies defines countries according to their 2019 GNI per capita, which aligns appropriately with the 2019 presentation of CVD statistics in this report.

- high income: GNI per capita USD ≥12 535;
- upper-middle-income GNI per capita USD 4046–12 535;
- lower-middle-income GNI per capita USD 1036–4045; and
- low income: GNI per capita USD <1036.

Throughout the manuscript, the term 'middle-income countries' represents a composite of upper- and lower-middle-income ESC member countries and includes Syrian Arab Republic which is now classified as a low-income country. Data presentation is descriptive, illustrated by tables and charts from the ESC Atlas, with only limited interpretation in the short commentary paragraphs at the end of each section. No attempt is made to attach statistical significance to differences observed in stratified analyses and there is no assumption of causation when associations are identified. For consistency, measures of central tendency across groups of countries are presented as medians in the manuscript and values >1000 are not decimalized. National CVD statistics for the most recently available year are illustrated using bar charts or choropleths, while time-series data are illustrated using a locally weighted polynomial smoother (LOWESS)—a popular tool to visualize the relationship between variables in a scatter plot—as implemented in R stats package with bandwidth 2/3 and 3 'robustifying' iterations.[22] Box plots are used almost exclusively 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. Any countries outside this range are defined as

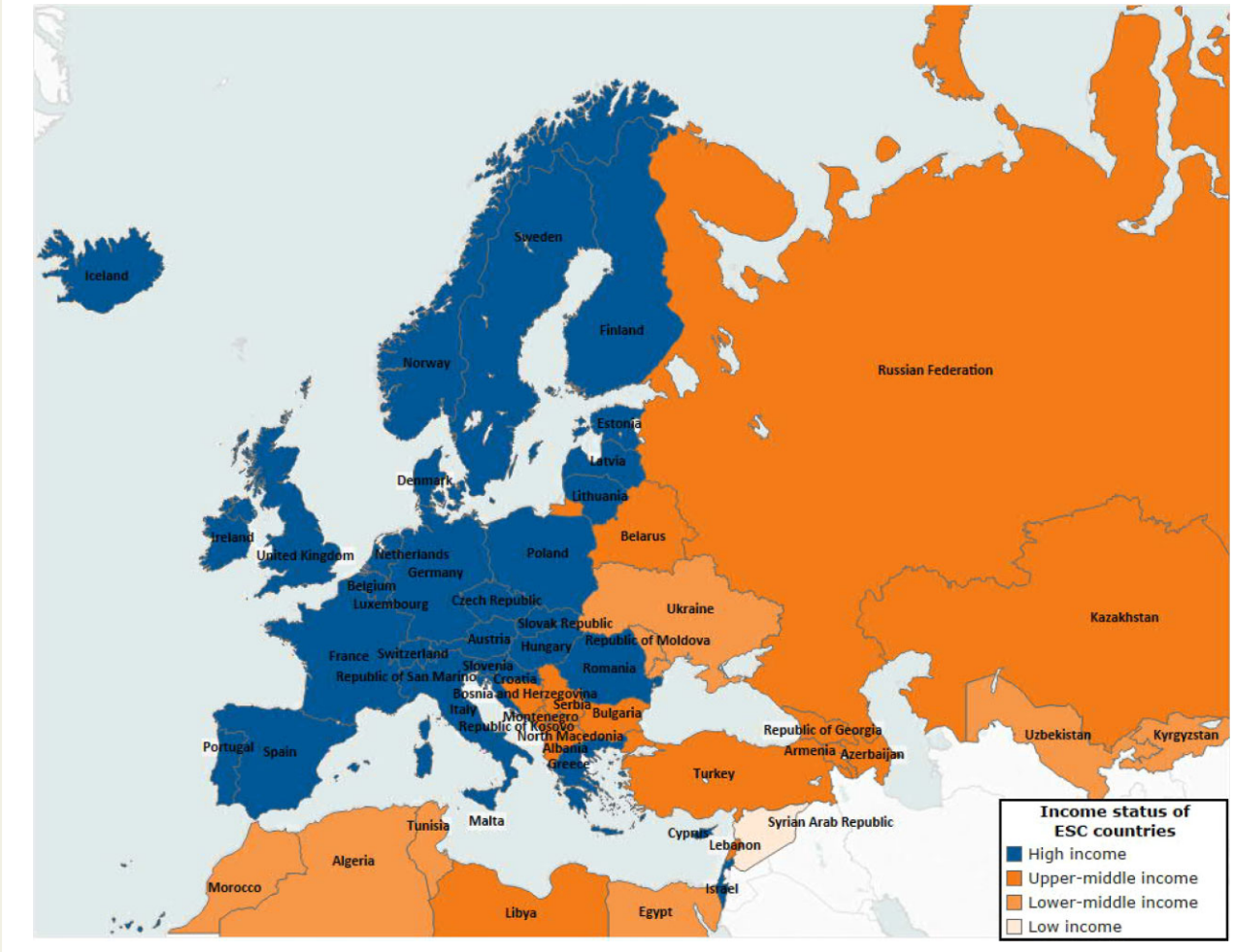


Figure 1 European Society of Cardiology member countries stratified by the 2020 World Bank definitions of income status.

outliers and are plotted individually. For all figures, the provenance of the data and its completeness is detailed in the table (see Supplementary material online, *Table S1*).

Limitations

Much of the data in the ESC Atlas are from the WHO, IHME, and WB, which together constitute the most credible sources of national estimates of CVD and 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 (see Supplementary material online, *Table S1*). 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 the 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 material online, *Table S1*). The ESC Atlas does not provide information about within-country inequalities.[23,24] Moreover, inequalities between high- and middle-income countries are determined by comparing national medians averaged across the groups, which obscures within-category inequalities. The presentation of the first and third quartile values around group medians helps mitigate this issue.

The limitations as they apply to 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. Nevertheless, we emphasize the need for cautious interpretation of the CVD statistics presented in this report.

National sociodemographic characteristics

Population age structure

Cardiovascular disease in females and males becomes progressively more common as age increases. Reasons for this are complex but include:

- Extended exposure to risk factors such as hypertension and dyslipidaemia that accrues with advancing years and increases CVD risk.
- Beneficial effects of interventions that delay CVD onset and prolong survival in patients with established disease.

Since older people are more likely to develop CVD, national age structures have an important modifying influence on the burden of disease. In comparing CVD mortality statistics between ESC member countries, therefore, age-standardized rates must be applied using the European Standard Population (ESP) to allow for differences in national age structures.[25] Age standardization in this manuscript uses the 2013 ESP update which provides greater weighting for older age groups compared with the 1976 ESP.[8]

Mortality due to CVD has declined in high-income ESC member countries during the last five decades but continues to increase in many of the middle-income countries where a substantial proportion of the disease burden now resides.[5] These epidemiological shifts have been influenced by the ageing of populations accompanied by their urbanization and globalization.[26]

National age structures can be visualized using population pyramids which illustrate the transitions that occur between middle-income and high-income countries (*Figure 2*).[27] The width of the pyramid represents the size of the population at a given age, with females on the right and males on the left. It is useful to compare the population pyramids for Egypt and the UK which can be taken to represent extreme exemplars in the age structures that characterize ESC member countries. The pyramid for Egypt has a broad base representing large numbers of newborns which in turn reflect high birth rates and high fertility rates. Beyond the first year of life, there is rapid attrition of population numbers as age increases such that the proportion of over 70s is very low. Contrast this with the UK pyramid, with its narrow base representing a relatively low birth rate and a low percentage of younger people. With advancing age, the population shows little attrition and remains stable into old age.

National age structures are not binary and across ESC member countries exist in various phases of transition. In all high-income countries and many middle-income countries, age structures, as exemplified by the UK data in *Figure 2*, are characterized by a high proportion of older people while in Egypt and some of the less prosperous member countries, it is often the young who predominate. As ageing increases in the middle-income countries of the ESC, it will accelerate the growing burden of CVD driven by urbanization, hypertension, and lifestyle changes. Ageing will also increase in high-income countries and across Europe, the proportion of the population aged >65 years is predicted to exceed 30% by the end of the century (*Figure 3*). This will have important consequences for healthcare and national economies.

These national age structures are reflected in the sociodemographic statistics for ESC member countries that are recorded in the ESC Atlas.

Population age

- **National statistics, stratified by sex.** In 2019, 17.2% [interquartile range (IQR) 12.1–20%] of the population across all ESC member countries was aged >65 years, comprising 19.4% (IQR 14.0–22.5%) of the female population and 14.6% (IQR 10.1–17.3%) of the male population (see Supplementary material online, *Figure S1*). The median population age in 2020 was 41.1 (IQR 35.9–43.2) years, ranging from <30 years in Algeria, Egypt, Kyrgyzstan, Lebanon, Libya, and Syrian Arab Republic to >45 years in Germany, Greece, Italy, Lithuania, and Portugal.
- **Time-series data.** With ageing of the population of ESC member countries between 1970 and 2019, the proportion of over 65s increased from 9.2% (IQR 5.6–11.2%) to 17.2% (IQR 12.1–20.0%). Increases were similar in females [10.7% (IQR 6.7–13.0%) to 19.4% (IQR 14.0–22.5%)] and males [7.8% (IQR 4.7–9.4%) to 14.6% (IQR 10.1–17.3%)]. The median population age, across ESC member countries, increased from 29.6 (IQR 22.0–32.5) years in 1970 to 41.1 (IQR 35.9–43.2) years in 2020 (*Figure 4*).

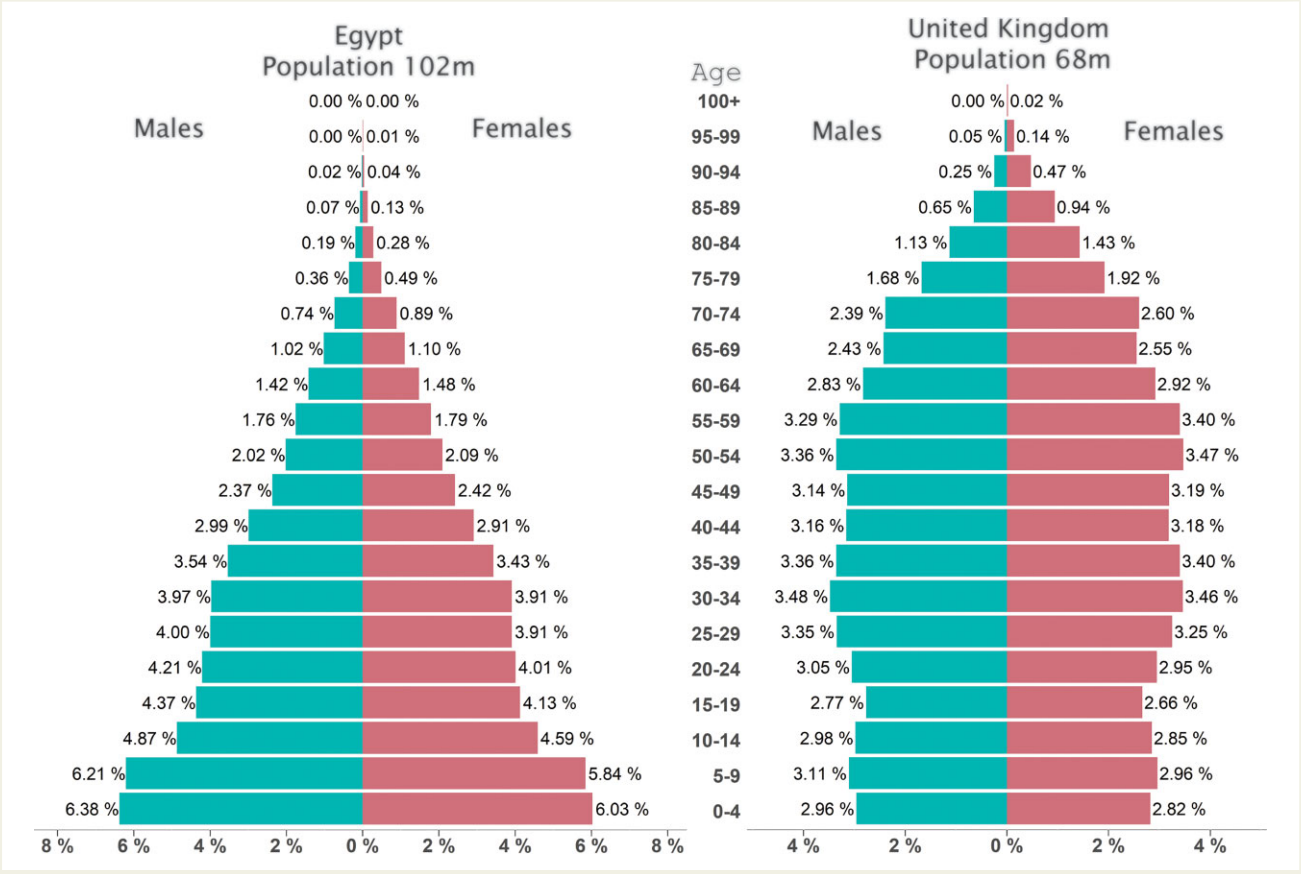


Figure 2 Population pyramid. Exemplar age structures in low–middle-income (Egypt) and high-income (UK) countries. Source: PopulationPyramid.net. Population Pyramids of the World 1950–2100. https://www.populationpyramid.net/united-kingdom/2020/

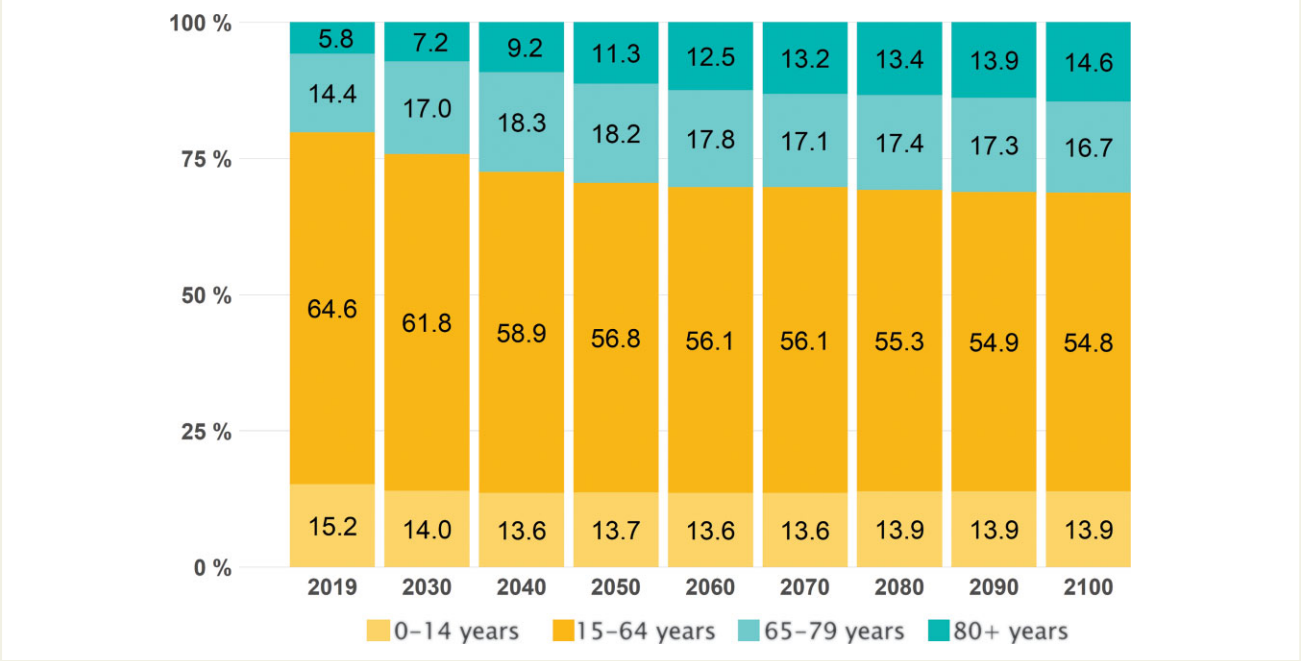


Figure 3 European population structure by major age groups (2019–2100). Source: Eurostat. Population Structure and Ageing. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Population_structure_by_major_age_groups,_EU-27,_2019-2100_(%25_of_total_population).png&oldid=494823 (accessed September 2020)

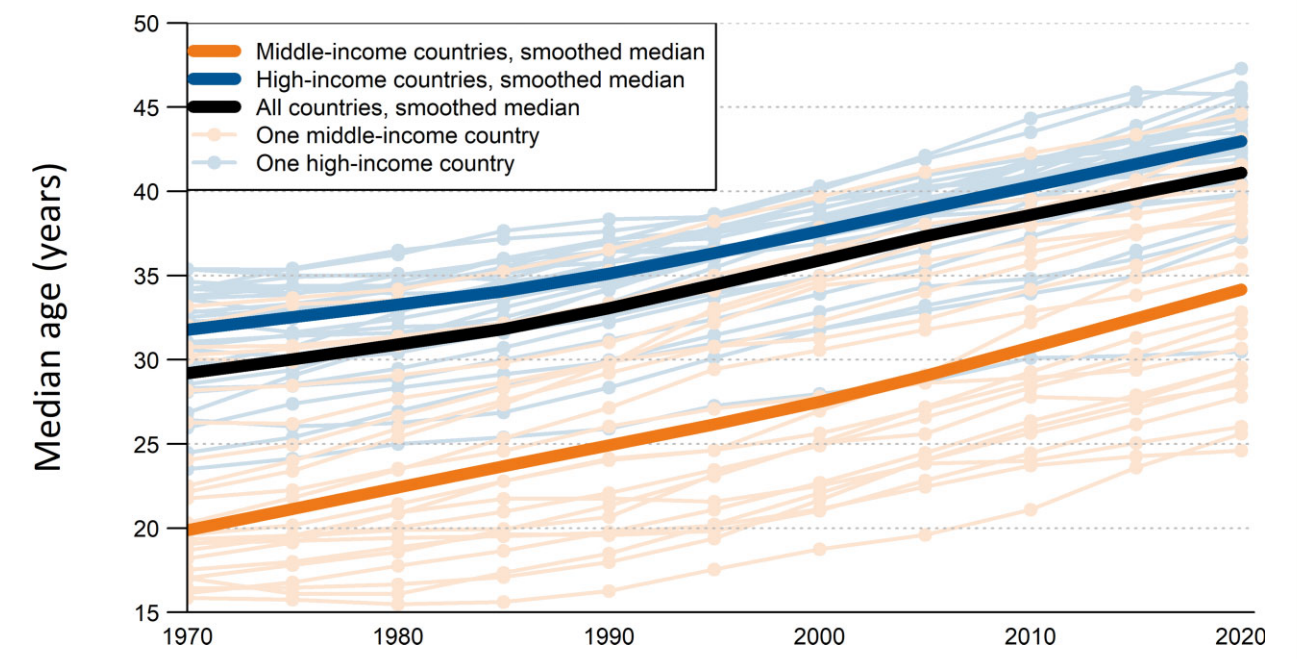


Figure 4 Time series: median age (years) of the population of all European Society of Cardiology member countries (1970–2020).

- **Stratification by national income status.** Between 1970 and 2019, the proportion of over 65s increased similarly across middle-income countries in females [6.5% (IQR 4.7–7.9%) to 11.6% (IQR 7.3–18.2%)] and males [4.6% (IQR 3.4–5.1%) to 8.6% (IQR 5.5–12.2%)]. Increases across high-income countries were also similar in females [12.2% (IQR 11.0–14.7%) to 21.8% (IQR 20.2–24.0%)] and males [9.0% (IQR 8.0–10.2%) to 17.0% (IQR 14.7–18.4%)] (*Figure 5*). In 2019, the median population age for middle-income countries was 34.1 (IQR 29.4–39.3) years and exceeded 40 years only in Belarus, Bosnia and Herzegovina, Bulgaria, Serbia, and Ukraine. In high-income countries, populations were older with a median population age of 43.1 (IQR 41.2–44.1) years. Only in Cyprus, Iceland, Ireland, Israel, Luxembourg, and Norway, the median population age was <40 years.

Life expectancy

- **National statistics, stratified by sex.** In 2018, the median life expectancy at birth across all ESC member countries was 77.5 (IQR 74.9–81.7) years, ranging from <72 years in Egypt, Kyrgyzstan, Republic of Moldova, Syrian Arab Republic, Ukraine, and Uzbekistan to >83 years in Italy, Spain, and Switzerland. The median life expectancy was higher for females 80.8 (IQR 78.0–84.2) years compared with males 74.8 (IQR 70.8–79.4) years (see Supplementary material online, *Figure S2*).
- **Time-series data.** The median life expectancy, averaged across ESC member countries, has increased from 69.9 (IQR 66.2–71.2) years in 1970 to 77.5 (IQR 74.9–81.7) years in 2018. Absolute increases in the median life expectancy have been similar in females compared with males (7.5 vs. 8.4 years) and in middle-income compared with high-income countries (9.2 vs. 10.7 years) (*Figure 6*).

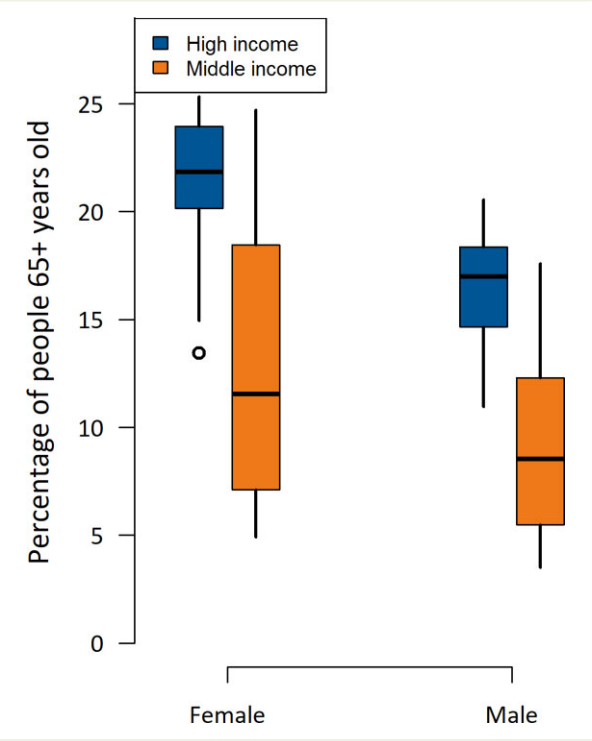


Figure 5 Proportion (%) of over 65s in European Society of Cardiology member countries, stratified by sex and national income status.

- **Stratification by national income status.** The median life expectancy for middle-income countries was 74.2 (IQR 72.2–76.5) years in 2018, exceeding 78 years only in Albania and Lebanon. In high-income countries, the median life

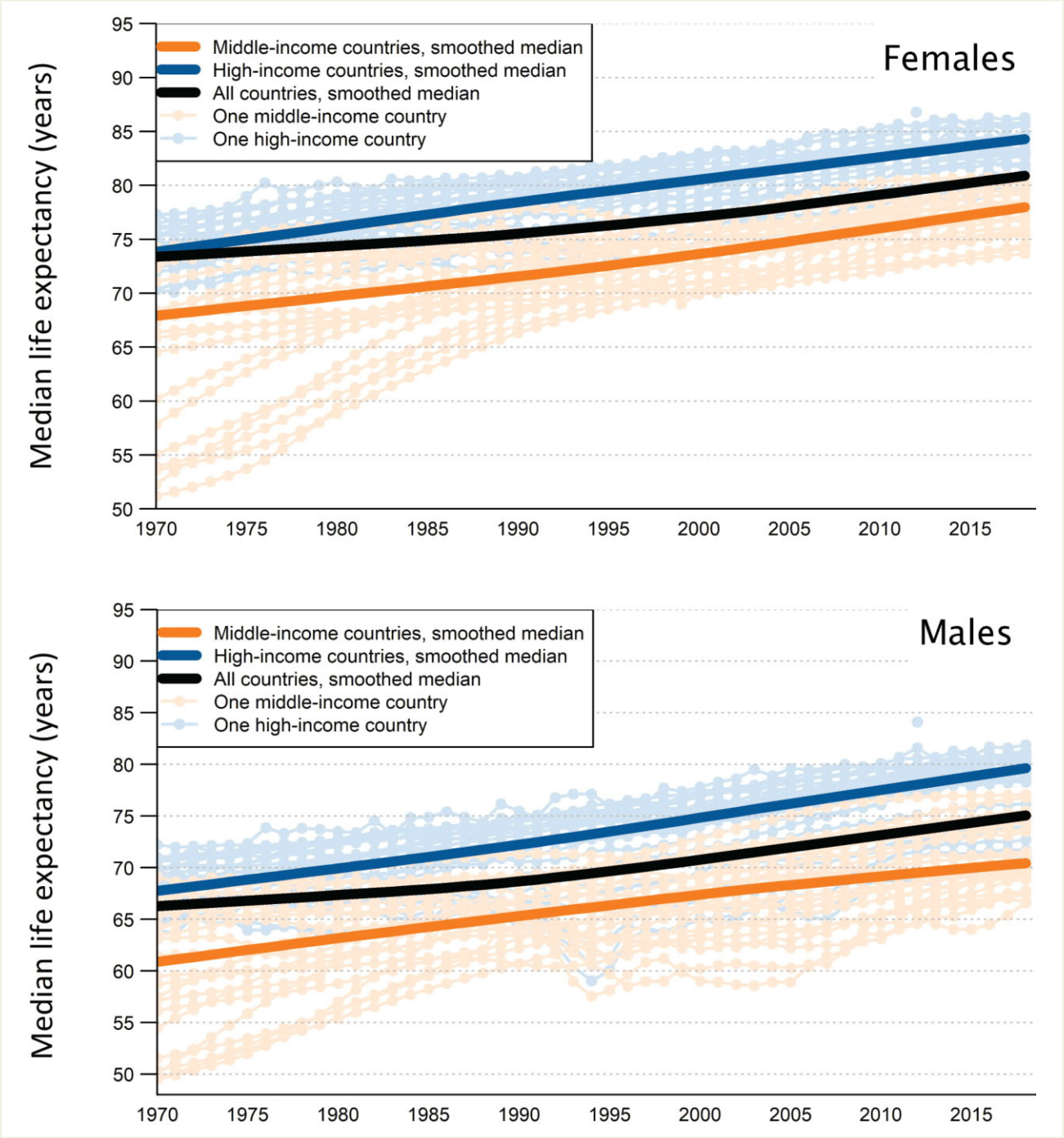


Figure 6 Time series: median life expectancy across European Society of Cardiology member countries in females and males.

expectancy was longer at 81.6 (IQR 78.6–82.5) years falling below 76 years only in Latvia, Lithuania, and Romania (*Figure 7*). Cardiovascular disease is the main cause of premature death (<70 years) in middle-income countries, but in many high-income countries, cancer is now more common.

Fertility

- **National statistics.** In 2018, the median number of live births per woman across ESC member countries was 1.6 (IQR 1.5–1.9), ranging from up to 1.3 in Italy, Malta, Spain, Republic of Moldova, and Bosnia and Herzegovina to >3 in Egypt, Kyrgyzstan, and Israel (see Supplementary material online, *Figure S3*).
- **Time-series data.** The median number of live births per woman, averaged across ESC member countries, has declined from 2.6 (IQR 2.2–3.7) in 1970 to 1.6 (IQR 1.5–1.9) in 2018. Declines have been much greater in middle-income compared with high-income countries (−59 vs. −8%) (*Figure 8*).
- **Stratification by national income status.** An average of 2.1 live births per woman is needed for each generation to exactly

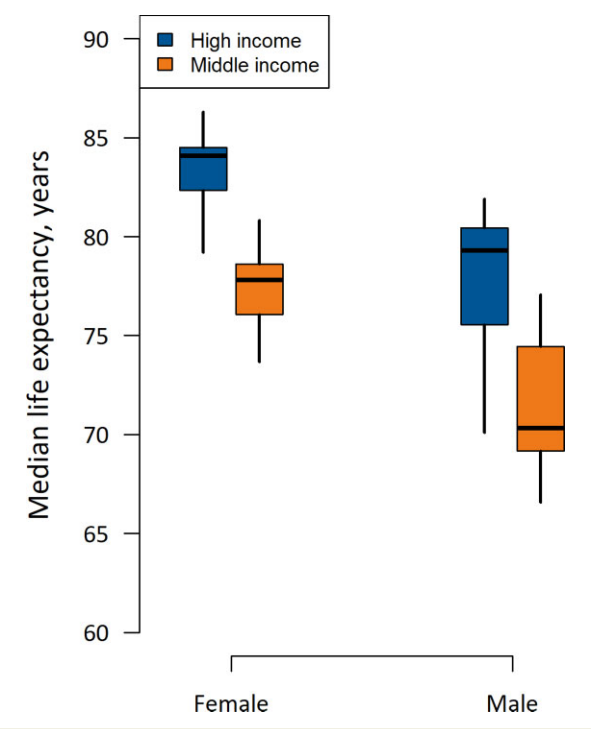


Figure 7 Median life expectancy in European Society of Cardiology member countries, stratified by sex and national income status.

replace itself without international immigration. In 2018, this was achieved by 9 of the 25 middle-income ESC member countries where the median number of live births per woman was 2.0 (IQR 1.6–2.4). This was higher compared with high-income countries where the median fertility was 1.6 (IQR 1.4–1.7) live births per woman with only Israel achieving replacement level fertility. In the remaining 31 high-income ESC member countries, fertility was <2.1 live births per woman causing the native populations to decline.

Infant mortality

- **National statistics.** In 2019, the median infant mortality per 100 000 live births across ESC member countries was 3.8 (IQR 2.7–8.5), ranging from <2 in Cyprus, Estonia, Finland, Iceland, Republic of San Marino, and Slovenia to >15 in Algeria, Azerbaijan, Egypt, Kyrgyzstan, Morocco, Syrian Arab Republic, and Uzbekistan (see Supplementary material online, *Figure S4*).
- **Time-series data.** The median infant mortality per 100 000 live births across ESC member countries has declined considerably from 25 (17.9–47.1) in 1970 to 3.8 (2.7–8.5) in 2019. Absolute declines in the median infant mortality have been similar in middle-income compared with high-income countries (−92 vs. −84%).
- **Stratification by national income status.** In 2019, the median infant mortality per 100 000 live births was 9.0 (IQR 5.5–

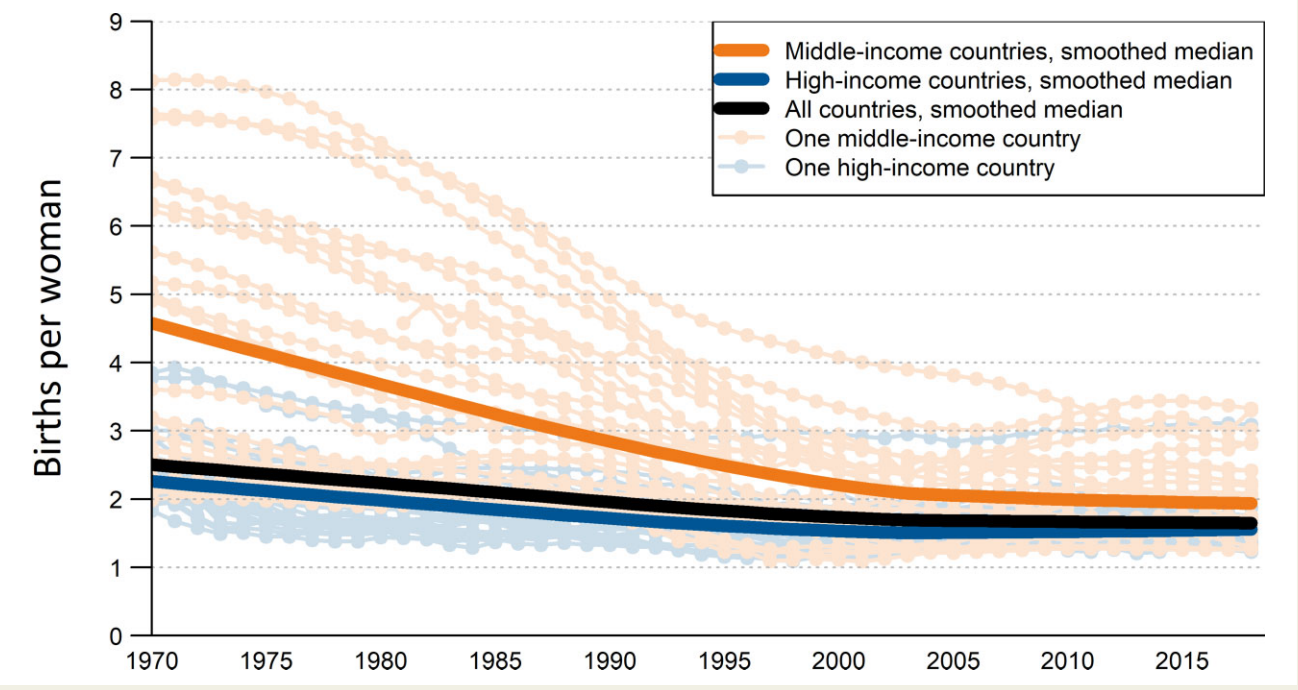


Figure 8 Time series: smoothed fertility trends in live births 1970–2018. Data are population medians for all European Society of Cardiology member countries, stratified by national income status.

15.8) in middle-income ESC member countries, exceeding 15 in Algeria, Azerbaijan, Egypt, Kyrgyzstan, Morocco, Syrian Arab Republic, and Uzbekistan. In high-income countries, infant mortality per 100 000 live births was 3.0 (IQR 2.2–3.5) and was <2 in Cyprus Finland, Estonia, Iceland, Republic of San Marino, and Slovenia (*Figure 9*).

Ethnicity

Health inequalities are almost universal among ethnic minority groups. They have been well characterized among South Asian people and people of African and Afro-Caribbean origin living in the UK and North America among whom the prevalence of CVD is substantially higher compared with indigenous white populations.[28,29] Associations are complex with South Asian immigrant groups, particularly prone to coronary heart disease (CHD) internationally. Blacks are similarly affected in the USA, but not in the UK where people of African and Afro-Caribbean origin appear relatively protected against coronary disease while exhibiting high rates of hypertension and stroke compared with the white population.[29] Inequalities among ethnic minority groups have been attributed to the interplay of multiple factors, including deprivation,[30] diminished access to healthy life choices[31,32] exaggerated exposure to CVD risk factors,[29,33] health illiteracy,[33] limited access to care,[35] language barriers,[36] and under-investigation and under-treatment[37–39] all of which are underpinned by chronic stress driven by discrimination and racism.[40]

- **National statistics stratified by national income status.** Ethnicity statistics for ESC member countries are patchy, and in 36% of ESC member countries, there have been no updates in the last 10 years. This limits the contemporary validity of the statistics which show that for the 25 high-income ESC member countries, the median proportion of indigenous peoples was 83.1% (IQR 75.2–86.4%), ranging from <70% in Czech Republic, Switzerland, Estonia, Latvia, and Luxembourg to >90% in Croatia, Cyprus, Greece, and Poland. In the 25 middle-income ESC member countries, the median proportion of indigenous peoples was 83.3% (IQR 73.5–95.0%) ranging from ≤50% in Bosnia and Herzegovina, Montenegro, and Syrian Arab Republic to >95% in Algeria, Armenia, Egypt, Libya, Morocco, and Tunisia (see Supplementary material online, *Figure S5*).

Urbanization

Urbanization is increasing worldwide.[41] 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 (*Figure 10*). Urbanization is often associated with economic growth and poverty reduction, but it also threatens CV health due to overcrowding, 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. These threats to CV health are likely contributors to the plateauing of life expectancy currently being observed in some western economies.[42]

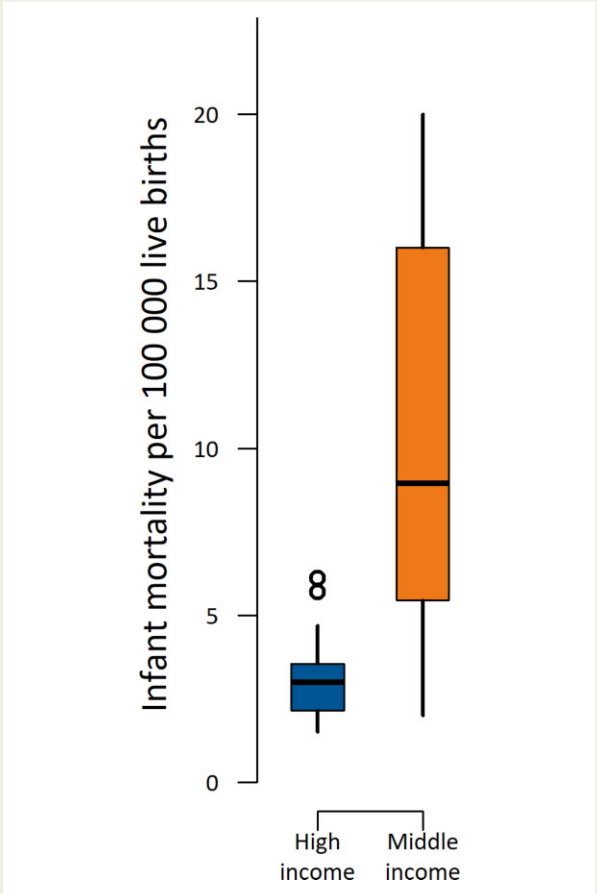


Figure 9 Infant mortality per 100 000 live births across European Society of Cardiology member countries, stratified by national income status.

The health challenges for urban populations are exemplified in comparisons with rural populations. A study from northern India, for example, reported that hypertension, diabetes, obesity, and physical inactivity were significantly more common among urban dwellers in whom the prevalence of CHD among males was 7.4% compared with 1.7% in village dwellers.[43] A Chinese study of a recently urbanized population showed positive time trends over a 7-year period for CVD risk factors, including body mass index, waist circumference, and blood pressure.[44] The World Heart Federation 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.[45]

- **National statistics.** In 1970, a median of 52.3% (IQR 40.9–65.1%) of people across ESC member countries lived in urban environments, but by 2019, this had increased to 69.4% (IQR 58.4–80.6%) ranging from <50% in Bosnia and Herzegovina, Egypt, Kyrgyzstan, and Republic of Moldova to >90% in Belgium, Iceland, Israel, Luxembourg, Malta, The Netherlands, and Republic of San Marino.
- **Stratification by national income status.** In 2019, a median of 62.1% (IQR 55.7–73.5%) of people from middle-income ESC

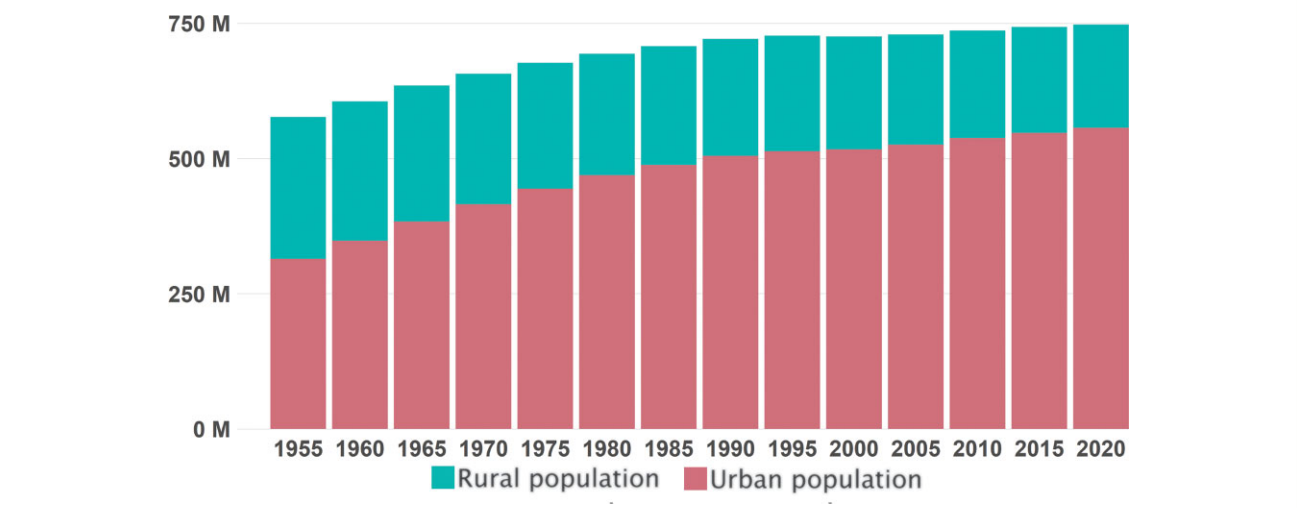


Figure 10 Distribution of urban and rural populations across Europe 1955–2020. Source: Worldometer. Europe Demographics. https://www.worldometers.info/demographics/demographics-of-europe/

member countries lived in urban environments, ranging from <50% in Bosnia and Herzegovina, Egypt, Kyrgyzstan, and Republic of Moldova to >80% in Lebanon and Libya. In comparison, 75.6% (IQR 66.5–87.8%) of people in high-income countries lived in urban environments, ranging from <60% in Austria, Croatia, Slovakia, Slovenia, and Romania to >90% in Belgium, Iceland, Israel, Luxembourg, Malta, The Netherlands, and Republic of San Marino (see Supplementary material online, *Figure S6*).

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. It has a consistent association with CVD and can be considered as a modifiable risk factor and a target for intervention.[42] Low SES groups often have unfavourable risk factor profiles,[46] but one of the largest studies using data from more than 1.7 million individuals found that the association between SES and CVD mortality was independent of major risk factors and comparable in strength to the associations of tobacco use, insufficient physical activity, raised blood pressure, obesity, and diabetes.[47] Other factors, apart from risk factor profiles, that may contribute to increased CVD risk in low SES groups include health illiteracy,[48] difficulties in accessing healthcare,[49] under-treatment,[50] reduced physical and mental health,[51] and environmental attributes of disadvantaged neighbourhoods.[52]

Income level

Many studies have shown an increased CVD risk in groups with lower SES defined by income. The GINI index too, a measure of the national income divide, has been associated with adverse outcomes in patients with CVD.[53] The 2017 Health Survey for England reported CVD in 22% of adults from households with the lowest incomes compared with 16% of adults from households with the highest incomes.[54] A Danish registry study of patients hospitalized with atrial fibrillation showed that those with the lowest SES by household income had significantly higher all-cause and CVD mortality rates in a 1-year follow-up period compared with the three other SES categories.[55]

- **National statistics.** In 1995, the median gross domestic product (GDP) converted to international dollars using purchasing power parity rates was $8341 (IQR $4737-$20048) across all ESC member countries. By 2019 it had increased to $32297 (IQR $15751-$47489) ranging from <$12000 in Republic of Kosovo, Kyrgyzstan, Tunisia, and Uzbekistan to $121293 in Luxembourg (see Supplementary material online, *Figure S8*). The GINI index (WB estimate) for 2017, providing a measure of the income divide within ESC member countries, varied between 24.2 in Slovenia and 41.4 in Turkey, with a median value across all countries of 31.0 (see Supplementary material online, *Figure S7*).
- **Stratification by national income status.** In 2019, the median GDP per capita in middle-income ESC member countries was $15 118 (IQR $12 218–$19 259) peaking at >$25000 in Kazakhstan, Turkey, and Russian Federation. This is compared with a median of $44 248 (IQR $37 571–$57 612) in high-income countries. The median values for the GINI index in 2017 were comparable in middle-income [33.2 (IQR 27.4–36.7)] and high-income [30.4 (IQR 28.7–34.4)].

Educational attainment

Socioeconomic status defined by educational attainment also associates with CVD in epidemiological studies.[56–59] 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 IHD mortality compared with males with lower educational level.[60] 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.[61]

- **National statistics.** In 1970, a median of only 2.7% (IQR 1.6–3.9%) of people aged ≥15 years living in ESC member countries received tertiary education but by 2010 this had increased to 15.6% (IQR 12.4–26.8%) ranging from <5% in Albania and Syrian Arab Republic to >20% in Greece, Cyprus, Ireland, Israel, Russian Federation, and Ukraine.
- **Education in females.** The median proportion of females with completed tertiary education in 2010 was only 12.5% (IQR 7.9–15.7%) across all ESC member countries and was lower in middle-income countries compared with high-income countries [9.0% (IQR 5.1–13.9%) vs. 13.7% (IQR 9.9–16.1%)] (see Supplementary material online, *Figure S9*).
- **Stratification by national income status.** In middle-income ESC member countries 8.9% (IQR 6.3–13.3%) of people received tertiary education compared with 14.9% (IQR 10.8–17.8%) of people living in high-income countries.

Employment

Employment as an index of SES is widely used by researchers and in a study of US adults, those who were unemployed had a >60% increase in the risk of CVD mortality during follow-up compared with those who were employed.[62] A French study found a 20% increase in the risk of CHD associated with unemployment with more than half explained by dietary and lifestyle mediators, most notably alcohol consumption and smoking.[63]

- **National statistics by sex.** In 2019, the modelled median estimate of unemployment across ESC member countries was 6.2% (IQR 4.6–10.3%) of the total labour force, ranging from <3.5% in Czech Republic, Germany, Hungary, Iceland, Malta, Netherlands, Norway, and Poland to >14% in Armenia, Bosnia, and Herzegovina, Greece, Republic of Georgia, Libya, Montenegro, North Macedonia, and Tunisia. Estimates were similar for females [6.2% (IQR 4.3–12.2%)] and males 5.8% [IQR 4.5–9.4%)].
- **Time-series data**. Unemployment estimates across ESC member countries has declined from 10.8% (IQR 6.5–13.7%) in 2000 to 6.2% (IQR 4.6–10.3%) in 2019. Unemployment during that period has been consistently higher in middle-income countries which have seen somewhat smaller declines in median rates compared with high-income countries (−17.5 vs. −29%).
- **Stratification by national income status.** In middle-income ESC member countries median unemployment in 2019 was 9.9% (IQR 5.8–14.5%) and was <5% in Belarus, Bulgaria, Kazakhstan, and Russian Federation. In high-income countries, there was less unemployment with a median rate of 4.9% (IQR 3.7–6.5%) that exceeded 9% only in Greece, Italy, and Spain (*Figure 11*).

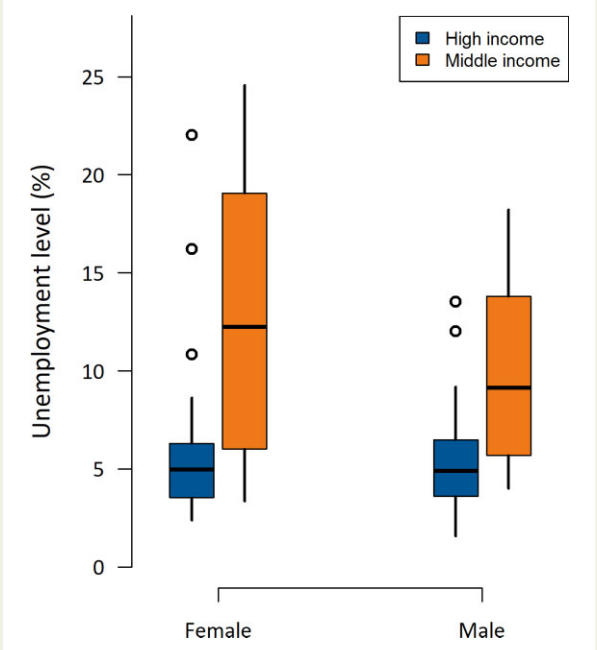


Figure 11 Unemployment levels in European Society of Cardiology member countries, stratified by sex and national income status.

Summary

- Burden of CVD is significantly influenced by the sociodemographic characteristics of the population, particularly its age structure together with ethnicity, urbanization, and SES.
- The populations of ESC member countries are ageing. Between 1970 and 2019 the proportion of individuals aged >65 years increased from a median of 9.2–17.2%, and the median age increased from 29.6 to 41.1 years. In 2019, populations in high-income countries were older than in middle-income members (median age 43.1 vs. 34.1 years), but similar trends in ageing were observed across all member countries.
- Females born in ESC member countries in 2018 are expected to live 80.8 years and males 74.8 years. Life expectancy is longer in high-income (81.6 years) compared with middle-income (74.2 years) countries.
- Between 1970 and 2018, fertility rates fell from 2.6 to 1.6, below the average of 2.1 live births per woman needed for population replacement. The decline in fertility rates has been greater in middle-income compared with high-income member countries (−59% vs. −8%).
- Infant mortality across ESC countries has declined since 1970 from 25 per 100 000 births to 3.8 in 2019, but it remains higher in middle-income compared with high-income countries (9.0 vs. 3.0 per 100 000 births).
- Ethnicity statistics are incomplete but show that in selected middle-income and high-income ESC member countries median proportions of indigenous populations were similar (83.3% and 83.1%, respectively), varying across countries from <50% to >95%.
- Urbanization is advancing across ESC member countries. In 1970, a median of 52.3% of people lived in urban environments, but by 2019 this had increased to 69.4% with middle-income populations generally less urbanized than high-income populations (62.1 vs. 75.6%).

- Socioeconomic status showed large disparities between middle-income and high-income member countries. This was reflected in differences in median income ($15118 vs. $44248) tertiary education (8.9% vs. 14.9%) and declines in unemployment (−17.5% vs. −29%).

Comment

National sociodemographic characteristics described in this report provide important context for interpreting the CVD statistics that burden ESC member countries. The ageing populations of high-income European countries where fertility rates have fallen below replacement levels, largely account for continuing high rates of CVD mortality with a declining trend most apparent in age-standardized analyses. However, ESC Atlas data confirm reports showing that life expectancy – and with it the proportion of over 65 s - is increasing in many middle-income countries at rates similar to high-income countries and this will accelerate the growing burden of CVD.[64]

The evolving age structures of ESC member countries, with ever greater proportions of their populations aged >65 years, will make sustained reductions in the prevalence of CVD difficult to achieve. The spread of urbanization across Europe during the transition from agricultural to industrial and service economies will add to the difficulty by exposing increasing numbers of people to the air pollution, noise, social deprivation, and stress that are associate with urban living (see chapter 5). ESC Atlas data show that urbanization in middle-income ESC member countries is lower compared with high-income countries but has been increasing at a similar rate and in the context of an ageing population, the consequences for the burden of CVD will doubtless be considerable. Recognition of the adverse health consequences of urbanization has prompted calls for planners to modify urban fabric to facilitate healthy choices among city dwellers.[65]

As fertility rates fall below replacement levels in ESC member countries and population ageing increases, the need for young immigrant groups to supplement the workforce and provide support for the elderly becomes more pressing. Ethnicity data in the ESC Atlas are incomplete but confirm that in many member countries 20% or more of the populations comprise minority ethnic groups. Socioeconomic deprivation is common in these groups and is compounded by a range of health inequalities many of which are an indirect consequence of discrimination and racism.[30–40] Premature CHD, for example, blights the lives of young South Asian males living in the UK, Canada, and elsewhere in the world while black African and Afro-Caribbean populations show enhanced predisposition to hypertension, heart failure and stroke.[66–68] Yet evidence shows that health outcomes for ethnic minority groups are as good as indigenous populations once the healthcare system has been accessed.[66,69] This has important implications for the policy which needs to be directed at CVD prevention by improving access to healthy life choices and facilitating navigation of healthcare systems.

Socioeconomic status is by definition lower among those living in middle-income compared with high-income ESC member countries and underpins many of the health inequalities described in this report. Lower SES in middle-income countries is reflected in differences in GDP per capita, educational attainment and employment all of which combine to reduce access to healthy life choices and high-quality healthcare. Many of the inequalities in CVD between middle-income and high-income ESC member countries, including the 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 between middle-income and high-income ESC member countries.

Healthcare expenditure and funding of cardiovascular care

Introduction

In this section. we consider the financial burden of CVD and the different types of funding across ESC member countries. Estimates of financial burden are limited to those countries that have been the subject of systematic reviews and comparative health economic studies.[70,71] Incomes and costs are quoted in USD according to WB convention, or in Euros (€), depending on the data source. We explore associations between the types of funding and volumes of CVD services.

Health expenditure across European Society of Cardiology member countries

Current health expenditure across European Society of Cardiology countries

Current health expenditure quantifies the total healthcare spend using a common currency unit adjusted to take into account the different purchasing power parity of national currencies. ESC member countries have very different healthcare systems, institutional contexts and income levels. It is not surprising, therefore, that CHE per capita in 2018 varied widely from approximately USD 260 in Kyrgyzstan to USD 8114 in Switzerland.[72] Even after adjusting for local purchasing power, high-income countries spent, on average, four times more on healthcare than those in the middle-income group. Within the high-income group, the expenditure range was considerable. Switzerland, Norway, Germany, and Luxembourg all spent more than USD 6000 per capita, followed by seven countries spending more than USD 5000 per capita. Among middle-income countries, Montenegro, Bulgaria, Russian Federation, Serbia, and Bosnia Herzegovina had the highest expenditure at more than USD 1300 per capita while Kyrgyzstan, Uzbekistan, Morocco, and Republic of Moldova were at the bottom of the list, spending between USD 260 and USD 480 per capita (*Figure 12*).

When the share of current health expenditures funded from domestic private sources is considered, further differences between high- and middle-income countries become apparent. In 2018, private sources accounted for 28% of the health spending in high-income countries, ranging from just 13% in Luxembourg and 14% in Sweden, up to 68% in Switzerland. Compare this with middle-income countries, where 47% of the health spend was from private sources, peaking at >70% in countries such as

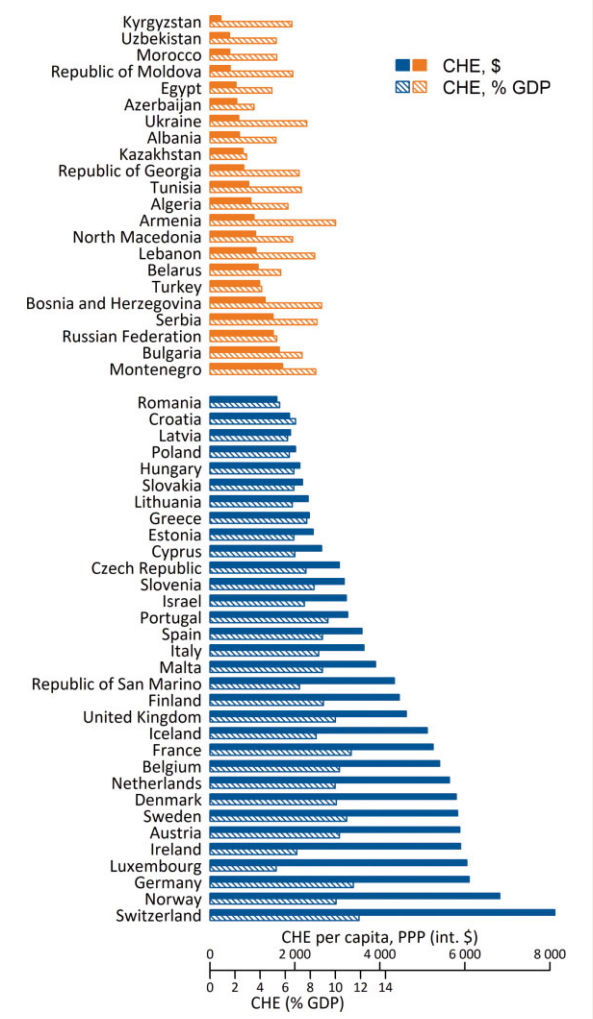


Figure 12 Current healthcare expenditure per capita by European Society of Cardiology member countries in USD and as a percentage of gross domestic product.

Armenia, Azerbaijan, and Egypt. National comparisons are difficult because the private spend includes a mixture of voluntary health insurance premiums (e.g. in Switzerland) as well as payments made directly to healthcare providers, as happens in weaker healthcare systems. However, the data shed light on the disparities that exist between countries with a likely impact on access to healthcare services and treatments.

Ratio of current health expenditure to gross domestic product

This ratio is an indicator of how much a country spends on healthcare relative to all other goods and services. Across the 52 ESC member countries, the ratio in 2018 averaged 7.6%, ranging from 6.6% in middle-income countries to 8.4% in high-income countries [median 7.3% (IQR 6.4–9%)]. Within middle-income countries, the health expenditure ranged from 2.9 to 10% of GDP [median 6.6% (IQR 5.3–7.6%)], Kazakhstan, Azerbaijan, Turkey, and Egypt each spending <5% of GDP on healthcare. Within high-income countries, the health expenditure ranged from 5.3 to 11.9% of GDP [median 8.4% (IQR 6.8–10%)], with Switzerland, France, and Germany topping the list, spending more than 11% of GDP on healthcare. In comparison, Luxembourg and Romania spent <6% of their GDP on healthcare.

Luxembourg spent 5.3% of GDP on healthcare despite its expenditure of USD 6048 per capita, but this reflects its status as one of the richest ESC countries and illustrates why both absolute and relative healthcare expenditure need consideration in international comparisons.

Encouragingly, during 2012–2016, after a long period of stagnant growth, increases in health expenditure per capita have come to exceed growth in GDP in many ESC member countries, with both middle-income and high-income countries increasing the proportion of GDP dedicated to health (*Figure 13*).

Economic and financial burden of cardiovascular disease: a significant gap in evidence

In recent years, a few international organizations have made considerable effort to refine their data collection methods and provide estimates of CVD-related health expenditures across countries. The Eurostat and the Organization for Economic Co-Operation and Development (OECD) have collaborated in developing guidelines for the distribution of health spending by disease, age, and sex. In 2016, for the first time, OECD released data on health spending by disease, age, and sex in 12 countries, reporting that CVD accounted for more than 10% of current health expenditure as well as the largest share of inpatient and pharmaceutical spending.[73]

In 2016, Eurostat commissioned the Health Expenditures by Diseases and Conditions (HEDIC) project,[74] which included Bulgaria, Czech Republic, Germany, Greece, Latvia, Lithuania, Hungary, The Netherlands, Slovenia, Finland, and Sweden. The HEDIC project confirmed the OECD findings by reporting that CVD represented the highest component of health expenditure in all countries, accounting for about 16% of the spend in 2013. Both the OECD and HEDIC studies demonstrated the feasibility of estimating CVD-related expenditures in a wide range of national settings and data contexts, but no further updates have been released by these two institutions since then.

In 2015, the European Heart Network estimated that CVD cost the EU economy €210 billion, of which 53% (€111 billion) was due to healthcare costs, 26% (€54 billion) to productivity losses, and 21% (€45 billion) to the informal care of people with CVD. As of today, this remains the most contemporary estimate of the economic burden of CVD in EU countries. From this brief overview, it is strikingly evident that there is a significant gap in understanding the CVD-related expenditure as well as overall economic burden CVD poses on societies across ESC countries.

More recent evidence is available only at the national level but is reported here for completeness. Among high-income nations, Public Health England estimated that CVD costs the economy £7.4 billion yearly [6% of the total National Health Service (NHS) budget], rising to £15.8 billion when wider economic costs were included.[75] In France, in 2018, the estimated cost of CVD based on individuals covered under the national health insurance system was €14.3 billion, representing 10% of all reimbursed

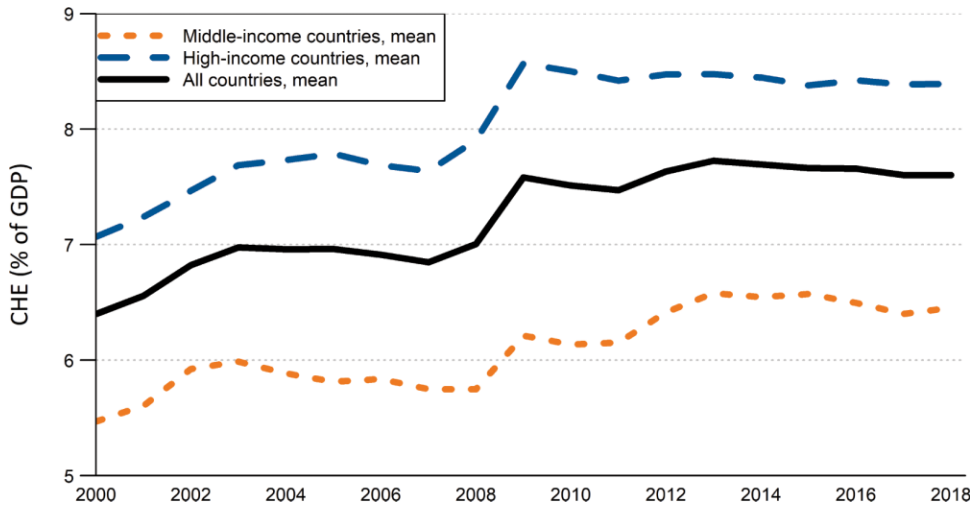


Figure 13 Proportion of gross domestic product dedicated to healthcare in middle-income and high-income European Society of Cardiology member countries (2000–18).

health expenditure.[76] In the Netherlands, the expenditure for CVD in 2017 amounted to €10.2 billion, representing 11.7% of total Dutch healthcare expenditure.[77] The data serve to illustrate the substantial CVD healthcare costs incurred by these high-income countries, although it is likely that they apply different methodological approaches to measuring these costs and cautious interpretation of international comparisons is therefore necessary.

Limited data from middle-income European countries have come from reports on the economic burden of NCDs, prepared in collaboration between the WHO and local Ministries of Health. Armenia (2018) estimated the burden of CVD to be 40.2% of total government healthcare expenditure (it does not include out-of-pocket payments, costs of private insurers, and non-healthcare costs as transport).[78]

Sources and types of funding of cardiovascular disease services

Healthcare systems across ESC member countries are heterogeneous with notable differences regarding funding sources (private, public, or mixed) and healthcare reimbursement (activity-based funding, defined annual budget or blended model).[79] Variable provider remuneration methods create different incentives, which influence provider behaviour, thereby influencing the quality, quantity, and efficiency of healthcare provision.[80]

In the 2020 survey administered as part of the ESC Atlas programme, the majority of countries (59.6%) reported that the public sector is the predominant source of funding for their hospitals, either through taxation or through compulsory social insurance. Nevertheless, in all ESC member countries, a variable mix of private sources also contribute to healthcare funding and may require out-of-pocket reimbursement with the potential for significant demands on the family purse.[81]

For hospital reimbursement, most ESC member countries (75.4%) have introduced payment systems, which are partially or totally based on diagnosis-related groups (DRGs). Diagnosis-related groups constitute clinically and financially homogeneous disease groups linked with a certain pre-defined cost which takes into account specific criteria, including primary and secondary diagnoses, patient characteristics, and treatment/procedural characteristics.[82]

As the main payment mechanism in 37 ESC member countries, DRG payment is believed to improve efficiency by incentivizing hospitals to treat more patients, while limiting the amount of resources per patient.[83] In countries that have moved from global annual budgets to DRGs, hospital activity in terms of procedure rates has often increased while waiting times have tended to diminish.[84–86] On the other hand, the potential overexpansion of activities, due to the direct link between service provision and payment, can be counterbalanced by the presence of budget limits in certain countries, aimed at keeping the hospital revenues through DRG-based systems within a pre-defined budget.[87] Over 75% of ESC member countries have a defined annual budget for their health services, the majority of which are capable of further subsidising their hospitals in the case of a budget deficit. Global budgets are effective in terms of controlling costs and achieving macro-economic efficiency, as payers can easily predict their annual spending.[88] However, since the link between individual performance and amount of payment is weak, hospitals have the incentive to reduce productivity. Indeed, the number of high-cost CV procedures tends to be lower among ESC member countries that are predominantly based on global budgets.

Collectively, different funding and reimbursement methods can serve as powerful means to signal health policy priorities and to accomplish desired objectives.[89,90] Most ESC member countries have introduced blends of payment strategies, and evidence from OECD countries suggests that the weaknesses of one payment method can be mitigated by the strengths of another in order to achieve high-quality care at an affordable cost.[91]

Summary

- In 2018, high-income countries spent, on average, four times more on healthcare than middle-income countries.
- In 2018, the ratio of current health expenditure to GDP ranged from 6.6% in middle-income countries to 8.4% in high-income countries.
- In a 2016 OECD report from 12 countries, CVD accounted for more than 10% of current health expenditure as well as the largest share of inpatient and pharmaceutical spending.
- The 2016 HEDIC project report from 11 European countries confirmed that CVD represented the highest component of health expenditure, accounting for about 16% of the spend.
- In 2015, the European Heart Network estimated that CVD cost the EU economy €210 billion. This remains the most recent estimate of the economic burden of CVD in EU countries.
- Public Health England estimated that CVD costs the economy £7.4 billion yearly (6% of the total NHS budget), rising to £ 15.8 billion when wider economic costs were included.
- The public sector is the predominant source of hospital funding in >50% of ESC member countries.
- For hospital reimbursement, >75% of ESC member countries have introduced payment systems based on DRGs.
- The number of CV procedures tends to be higher among those ESC member countries that use DRGs.
- More than 75% of ESC member countries have a defined annual budget for health services, meaning that annual hospital expenses for each hospital must remain within certain limits.

Comment

CVD has major economic consequences that affect individuals, health systems, and societies across the globe. It is estimated that total (medical and indirect) costs of CVD in the United States will double from USD 555 billion in 2015 to a staggering USD 1.1 trillion in 2035. VI.[92] Variable rises in costs of CVD are likely to occur globally, reflecting the interaction of multiple factors including:

- Completion of the epidemiological transition from infectious to NCD in many low-income countries where CVD has now become the leading cause of death,
- Population ageing,
- Technological costs of management hardware.

In order to meet the economic challenges of CVD, policymakers need access to reliable information about the direct healthcare costs of CVD and the broader impacts on national economies. As reported above, information about CVD-related health expenditures across European countries is sparse and restricted to a limited number of countries included in the OECD and HEDIC projects.[76,77] The findings, however, have been consistent in showing that CVD represents the highest component of healthcare expenditure accounting for about 16% of the national spend. As populations age and technological costs increase, CVD will further erode national economies unless policymakers act to protect their populations against the disease burden. Nowhere is this more important than in the middle-income ESC member countries where rates of CVD are highest and national economies are least able to fund its spiralling costs.

Environment, lifestyle, and clinical risk factors

Environmental, lifestyle, and clinical factors, have been identified as key determinants of CVD risk.[93,94] The extent to which these factors are amenable to modification determines their importance for risk reduction at individual and population levels.[95] The steep declines in CVD mortality seen in many high-income countries during the last 50 years have been driven largely by interventions targeted at-risk factor modification.[96] In France, for example, population CV health, based on a basket of lifestyle and risk factor metrics, has improved significantly during this period.[97] In less prosperous economies, the adoption of western lifestyles has contributed to CVD taking over from infectious disease and dietary deprivation as the major cause of death.[98] These epidemiological changes are a reminder that CVD is mainly a preventable disorder and that modifications to risk factor prevalence provide the most effective means of reducing the burden of disease in Europe and across the world.[99,100]

Environmental risk factors

Air pollution and noise are responsible for over 75% of the disease burden attributable to environmental risk factors.[94,101] Each year, an estimated 48 000 new cases of CHD* occur across Europe due to environmental noise pollution.[102] According to the WHO, about 58% of air-pollution-related mortality is caused by CVD. Migrant studies lend further support to the role of the environment as a risk factor by showing that South Asians living in the UK have a higher CVD risk than those living in South Asia[103] while Finnish twins living in Sweden have lower rates of CHD than their co-twins living in Finland,[104] confirming that environmental changes can modify risk independently of genetic factors.

Air pollution

Pollution with particulate matter and gases has various causes including residential and commercial energy use, agriculture, land traffic, and power generation. It is a major health hazard responsible for 7.6% of global DALYs[94] and linked to 6.5 million premature deaths annually,[105] rivalling the impact of smoking, hypertension, and physical inactivity on population health.[106] Premature deaths associated with exposure to fine particulate matter ($PM_{2.5}$) are usually attributed to CVD and the European Union (EU) has now set an air quality standard for $PM_{2.5}$ equal to 25 μg/m3.[107] Although the link between $PM_{2.5}$ exposure and CVD has been difficult to confirm,[108,109] the weight of evidence is supportive[110,111] and the adverse effects of air pollution on population health are not in dispute. Residential location moderates vulnerability to ambient air pollution, with individuals living close to busy roads showing heightened susceptibility to CVD risk.[112,113] It is estimated that air pollution reduces the mean life expectancy in Europe by about 2.2 years with an annual, attributable per capita mortality rate in Europe of 133/100 000 people per year.[114]

The United Nations Sustainable Development Goals developed in 2016 include air pollution as a pressing sustainability concern[115] and the WHO is now monitoring pollution indicators including air pollution-related mortality, access to clean energy in homes and air quality in cities.[116] Meanwhile European environment policy, resting on the principles of precaution, prevention, and rectifying pollution at source, provide grounds for optimism that the challenges imposed by pollution are high on the political agenda.[117]

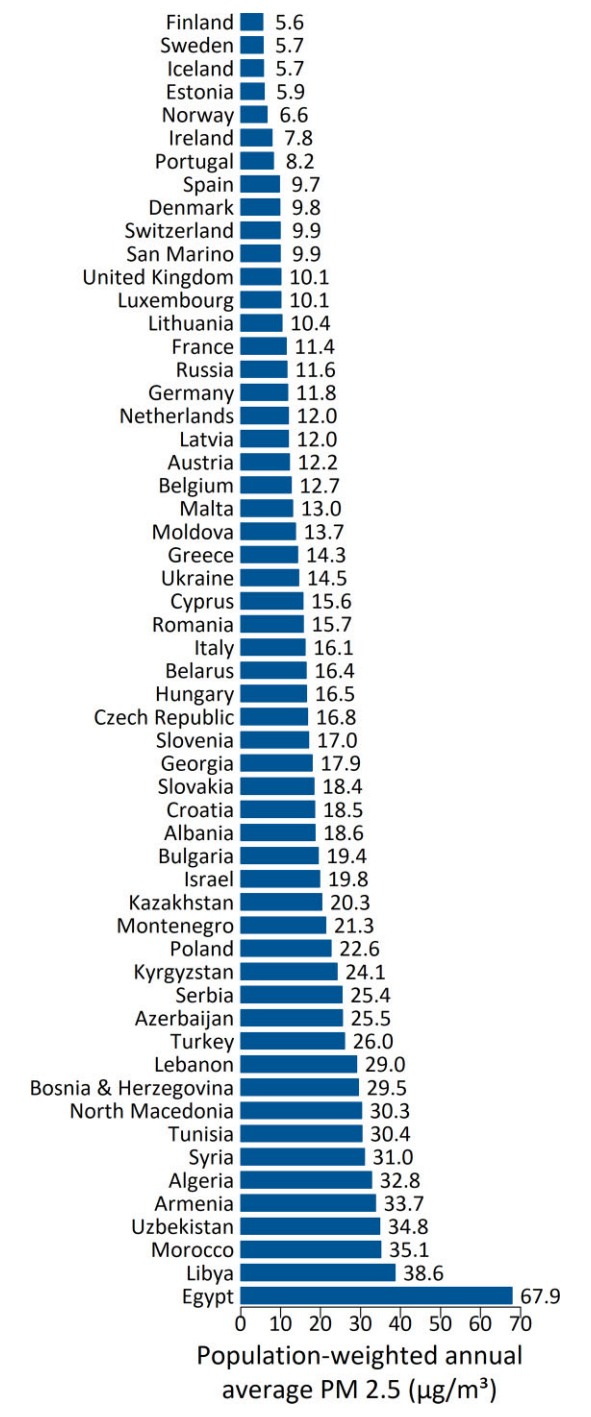


Figure 14 Annual population-weighted average concentration of PM 2.5 (µg/m³) in European Society of Cardiology member countries.

- **National statistics.** In 2019, the median annual population-weighted $PM_{2.5}$ concentration across all ESC member countries was 16.3 (IQR 11.2–24.4) µg/m^3 but exceeded the EU air quality standard (25 µg/m^3) in 14 countries: Algeria, Armenia, Azerbaijan, Bosnia and Herzegovina, Egypt, Lebanon, Libya, Morocco, North Macedonia, Serbia, Syrian Arab Republic, Tunisia, Turkey, and Uzbekistan (*Figure 14*).
- **Time-series data.** During the last 30 years, $PM_{2.5}$ air pollution has declined across ESC member countries from 22.5 (IQR 17.5–27.3) µg/m^3 in 1990 to 16.3 (IQR 11.2–24.4) µg/m^3 in 2019. Declines have been largely limited to high-income countries where the median $PM_{2.5}$ pollution has fallen by 35% compared with only 7% in middle-income countries (see Supplementary material online, *Figure S36*).
- **Stratification by national income status.** In 2019, the median $PM_{2.5}$ concentrations were over twice as high in middle-income ESC member countries [25.8 (IQR 19.2–31.5)] µg/m^3 compared with high-income countries [11.9 (IQR 9.8–15.8)] µg/m^3. All 14 countries that exceeded the EU air quality standard in 2019 were middle-income countries (*Figure 15*).
- **Disability-adjusted life years.** It is estimated that median air pollution caused by particulate matter was responsible for 805 (IQR 293–1755) age-standardized DALYs across all ESC member countries, considerably more in middle-income countries [1814 (IQR 1548–2352)] compared with high-income countries [322 (IQR 206–510)] (*Figure 16*).

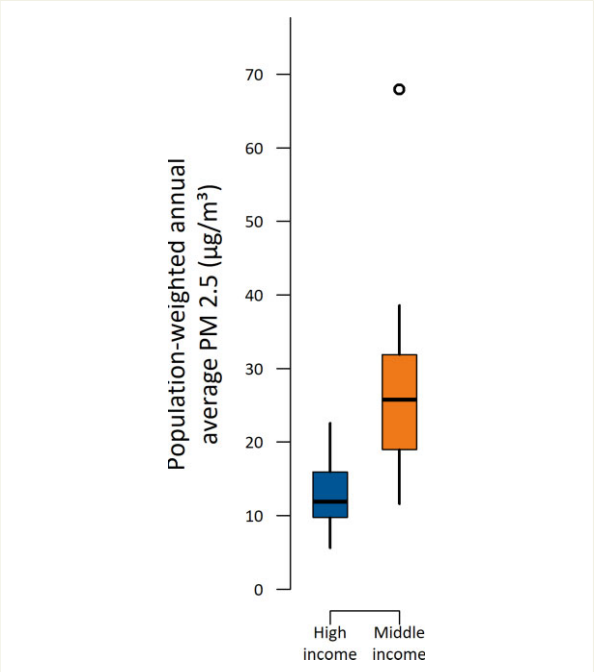


Figure 15 Annual population-weighted average concentration of PM 2.5 (µg/m³) in European Society of Cardiology member countries, stratified by national income status.

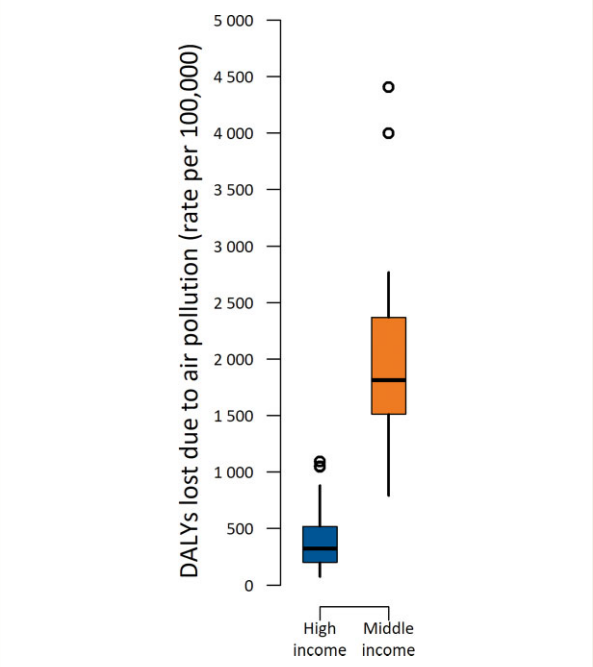


Figure 16 Age-standardized rate per 100 000 people of disability-adjusted life years lost due to particulate matter air pollution in European Society of Cardiology member countries, stratified by national income status.

Environmental gases are also polluting the air across ESC member countries and there has been particular interest in the damaging effects of ozone which has been linked to CVD in some[118,119] but not all studies.[120]

- **National statistics.** In 2019, median seasonal population-weighted ozone concentrations across all ESC member countries were 44.5 (IQR 37.8–51.3) parts per billion (ppb), ranging from <35 ppb in Finland, Ireland, Lithuania, Norway, Romania, and UK to >50 ppb in Cyprus, Israel, Italy, Malta, Republic of San Marino, Slovenia, Algeria, Armenia, Egypt, Kyrgyzstan, Libya, Morocco, Syrian Arab Republic, Tunisia, and Uzbekistan (see Supplementary material online, *Figure S10*).
- **Time-series data.** During the last 30 years, air pollution with ozone has remained stable, the median concentration having declined by just 7.5% across ESC member countries (see Supplementary material online, *Figure S11*.
- **Stratification by national income status.** In 2019, there was little difference in ozone concentrations between middle-income ESC member countries [48.9 (IQR 39.3–52.4)] ppb compared with high-income countries [42.9 (IQR 35.9–48.0)] ppb.

Environmental noise

Noise may also increase the risk of CVD, particularly among individuals living in densely populated urban environments close to busy roads or rail stations. It is estimated that noise pollution is responsible for 48 000 new cases of CHD per year as well as 12 000 premature deaths across Europe.[121] The EU has set permissible noise levels in residential areas of 55 and 50 dB during daytime and night, respectively.[122] These limits are often exceeded and noise exposure above 55 dB[A] might affect up to 40% of the population of the EU.[94] Noise induces stress and disturbs sleep, predisposing to CHD[123–125] with the risk increasing by 6% for every 10 dB[A] increase of day–night noise.[126] These adverse CV consequences of noise are, it seems, driven by small elevations of blood pressure, triglycerides, and glycated haemoglobin that occur with exposures >65 dB[A].[127] It is estimated that a 5 dB[A] reduction in environmental noise across the USA would reduce incident cases of hypertension and CVD by 1.2 million and 279 000 cases per year, respectively.[128]

- **National statistics.** 2017 data for the percentage of people exposed to urban noise levels >55 dB by country are available only for the high-income ESC member countries.
  - **Urban road noise** The median people exposure was 15.8% (IQR 11.8–23.3%) ranging from <10% in Croatia, Finland, Germany, Greece, Portugal, Slovakia, and Slovenia to >25% in Bulgaria, Cyprus, Latvia, Lithuania, and Switzerland (see Supplementary material online, *Figure S12*).
  - **Urban rail noise** The median people exposure was 1.3% (IQR 0.7–2.3%) ranging from <0.5% in Lithuania and Portugal to >3% in Austria, Cyprus, France, Germany, and Switzerland (see Supplementary material online, *Figure S13*).

Neighbourhood characteristics

Neighbourhood characteristics impact significantly on CVD risk. Several studies reported increased CVD risks and increased case fatality rates for residents living in the most disadvantaged neighbourhoods.[129,130] A Swedish follow-up study showed a 90% increase of CHD risk in females and a 50% increase in males in high- compared with low-deprivation neighbourhoods.[131] A more recent UK study reported graded associations between quintiles of small area deprivation and risk of myocardial infarction and heart failure, with excess risk peaking at 41 and 55%, respectively, for most vs. least deprived quintiles.[132]

- **National statistics.** 2019 data for proportions of people living in disadvantaged neighbourhoods characterized by crime, violence, or vandalism were available for 30 high-income ESC member countries but only five middle-income countries. Across those 35 countries with available data, a median of 8.4% (IQR 6.5–12.7%) of their populations inhabited disadvantaged neighbourhoods, ranging from <5% in Croatia, Lithuania, Norway, and Poland to >15% in Greece, The Netherlands, and Bulgaria (see Supplementary material online, *Figure S14*).

Lifestyle and cardiovascular risk

Lifestyle risk factors mainly include smoking, alcohol consumption, lack of exercise, and dietary intake of calories and trans-fats.[133] These risk factors are modifiable and have therefore major potential for reducing CVD risk through primary or secondary prevention. Low-risk lifestyle choices prevented more than 80% of

coronary events in the Nurses' Health Study[134] and provided similar protection against myocardial infarction in a cohort study of Swedish women.[135]

Smoking

There is no safe level of smoking. Light smokers, consuming only one cigarette per day have nearly half the excess risk for developing CVD compared with heavy smokers (20 cigarettes per day).[136] Passive smokers too are at risk, and when passive exposure is substantial, it is associated with a similar relative risk of CVD as light active exposure.[137,138] Smokers who quit can reduce their risk of CVD by 39% within 5 years, but it takes at least 5–10 years, and perhaps up to 25 years after quitting, for CVD risk to match that of a person who has never smoked.[139] Smoking cessation after myocardial infarction is particularly important since it can halve the risk of death during follow-up.[140] E-cigarettes have been put forward as a safer alternative or as a method for smoking cessation, but some studies have found harmful CV effects of E-cigarette use. Because of a lack of robust longitudinal data, the evidence is considered insufficient by guideline groups to support the use of e-cigarettes to reduce tobacco use.[141–143] A recent meta-analysis showed that e-cigarette use among adolescents and young adults was associated with a greater risk for subsequent cigarette smoking.[144]

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.[145] Therefore, 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 a continuous decline in the prevalence of smoking across Europe.[146]

- **National statistics.** Data for 2019, or the latest available year, showed that across ESC member countries, a median of 22.1% (IQR 17.0–26.5%) of the adult population (age ≥15 years) were regular daily smokers, ranging from <10% in Iceland and Norway to >35% in Bosnia and Herzegovina, Bulgaria, and Montenegro, North Macedonia (*Figure 17*). Data for 2019, or the latest available year, showed that across high-income ESC member countries, a median of 3% (IQR 1.75–3.95%) were regular vapers.
- **Stratification by sex.** Overall, the smoking prevalence is lower in females compared with males, with the median rates of 14.8% (IQR 9.2–18.0%) and 28.3% (IQR 22.3–38.3%), respectively.
- **Stratification by national income status.** In middle-income countries, 43.4% (IQR 36.2–46.9%) of males were regular daily smokers compared with just 8.8% (IQR 4.0–26.0%) of females although there was considerable variation among countries, with >30% of females smoking in Bosnia and Herzegovina, Bulgaria, and Montenegro. In high-income countries, 23.4% (IQR 19.0–28.7%) of males smoked compared with 15.6% (IQR 13.0–17.9%) of females (*Figure 18*).

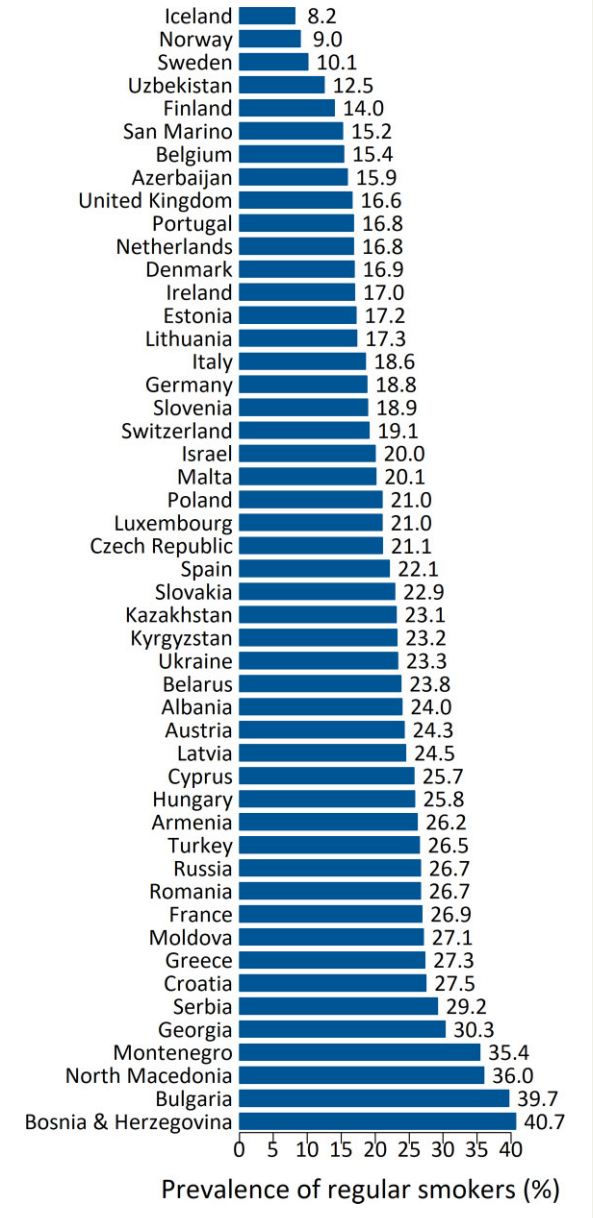


Figure 17 Prevalence (%) of regular daily smokers in the population, age 15+ in European Society of Cardiology member countries.

Alcohol consumption

Recommended upper limits for alcohol consumption vary substantially by country, reflecting a lack of consensus about precise risk thresholds.[147] There is also uncertainty about the associations of alcohol consumption with CVD. These uncertainties have been addressed in two recent studies. The first, a population-based cohort of nearly 2 million adults, found that excess drinking (>21 and 14 units a week for males and females, respectively) increased the risk of heart failure and stroke but reduced the risk of myocardial infarction.[148] These heterogenous associations were largely confirmed in a second study of over half a million current drinkers without previous CVD.[149] Alcohol consumption showed a positive curvilinear association with all-cause mortality, with the threshold for lowest risk 100 g/week (5.2 L/year). Associations with stroke and heart failure were also approximately linear but

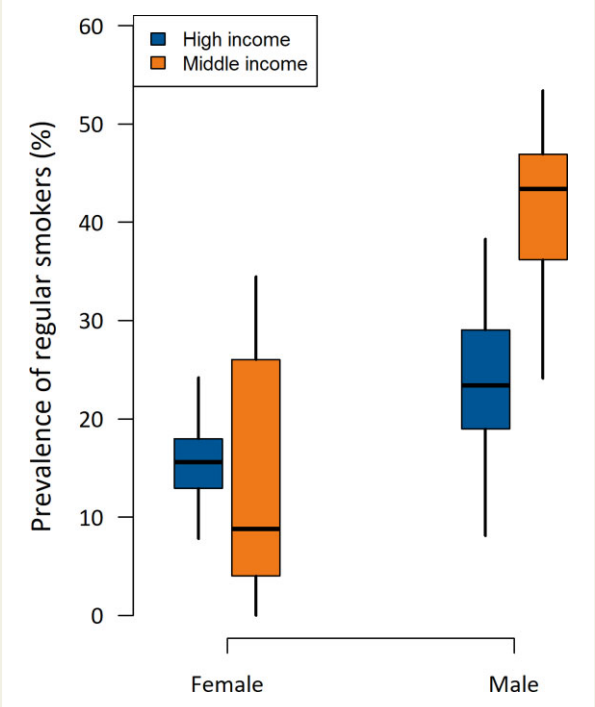


Figure 18 Prevalence (%) of regular daily smokers in the population, age 15+ in European Society of Cardiology member countries, stratified by sex and national income status.

for myocardial infarction increased alcohol consumption was log-linearly associated with a lower risk. Notwithstanding the protective effects of alcohol against myocardial infarction, it has been estimated that the life expectancy of a 40-year-old drinker could be increased by up to two years by reductions in alcohol consumption below 100 g/week.[150] Reduction to this level is much lower than the safe drinking limits set in many countries and likely to prove challenging. In the USA, for example, where excessive alcohol consumption is responsible for 1 in 10 deaths,[151] the recommended limit is 196 g/week, almost twice as high as the 100 g/week threshold for lowest all-cause mortality.

The EU is the heaviest-drinking region in the world and has the highest proportion of total ill health and premature death due to alcohol.[152] An action plan to reduce the harm caused by alcohol has been endorsed by 53 European Member States. It includes a wide range of policies and programmes that are relatively easy and cheap to implement and have the potential to reduce the harmful use of alcohol, promote health and well-being, improve productivity, and enhance human, health, and social capital across the life course from birth to old age.[152]

- **National statistics.** Latest data for 2018 showed that the median per capita pure alcohol consumption across ESC member countries was 9.6 (IQR 6.3–11.6) L/year in people aged ≥15 years ranging from <1 L/year in Algeria, Egypt, Libya, Morocco, and Syrian Arab Republic to >12 L/year in Czech Republic, France, Germany, Ireland, Latvia, Lithuania, Luxembourg, Spain, and Bulgaria (*Figure 19*).
- **Stratification by sex.** Overall, the median per capita alcohol consumption among females was lower compared with males: 4.5 (IQR 2.5–5.5) L/capita/year vs. 15.0 (IQR 10.4–18.5) L/capita/year. This was a consistent finding across nearly all ESC member countries.
- **Stratification by national income status.** The median per capita alcohol consumption for 2016–2018 in middle-income ESC member countries was 5.9 (IQR 2.0–8.4) L/year. In high-income countries, consumption was higher at 11.4 (IQR 9.4–12.2) L/year and in both middle-income and high-income countries, the median alcohol consumption was three to four times higher in males compared with females (*Figure 20*).

Exercise

Insufficient physical activity is defined 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.[153] Inactivity increases the risk of several NCDs such as IHD, Type 2 diabetes, breast and colon cancers, and accounts for nearly 10% of all deaths worldwide.[154] Exercise has consistently been shown to improve CV health through mechanisms that include blood pressure lowering, weight reduction, increased insulin sensitivity, and a more favourable plasma lipoprotein profile.[155] In a meta-analysis of 21 prospective studies including more than 650 000 adults a high level of leisure-time physical activity and a moderate level of occupational physical activity reduced the overall risk of incident CHD and stroke among males and females by 20–30% and 10–20%, respectively.[156] In particular, leisure-time physical activity has a beneficial health effect.[157] Light intensity physical activity may be sufficient[158] and its beneficial effects have been confirmed by the Prospective Urban Rural Epidemiology (PURE) investigators who reported that higher recreational and non-recreational physical activity was associated with a lower risk of mortality and CVD events in a study of 130 000 inhabitants of 17 high-, middle-, and low-income countries.[159] They concluded that measures to increase physical activity represent a simple, widely applicable, low-cost global strategy for reducing deaths and CVD in middle age. International guidelines are consistent in their recommendations for physical activity for the prevention of CVD.

Worldwide, physical inactivity is estimated to be the primary cause of ~30% of IHD. The importance of physical activity for tackling the obesity epidemic and beyond has been stressed by the WHO. 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.[160]

- **National statistics.** Data for 2016 showed that the median prevalence of insufficient physical activity across ESC member countries was 30.8% (IQR 26.0–35.8%) ranging from <20% in Finland, Belarus, Republic of Georgia, Kyrgyzstan, Republic of Moldova, Russian Federation, Ukraine, and Uzbekistan to >40% in Cyprus, Germany, Italy, Malta, and Portugal (see Supplementary material online, *Figure S15*).
- **Stratification by national income status.** The median prevalence of insufficient physical activity across middle-income ESC member countries was 26.2% (IQR 18.6–32.3%). In high-

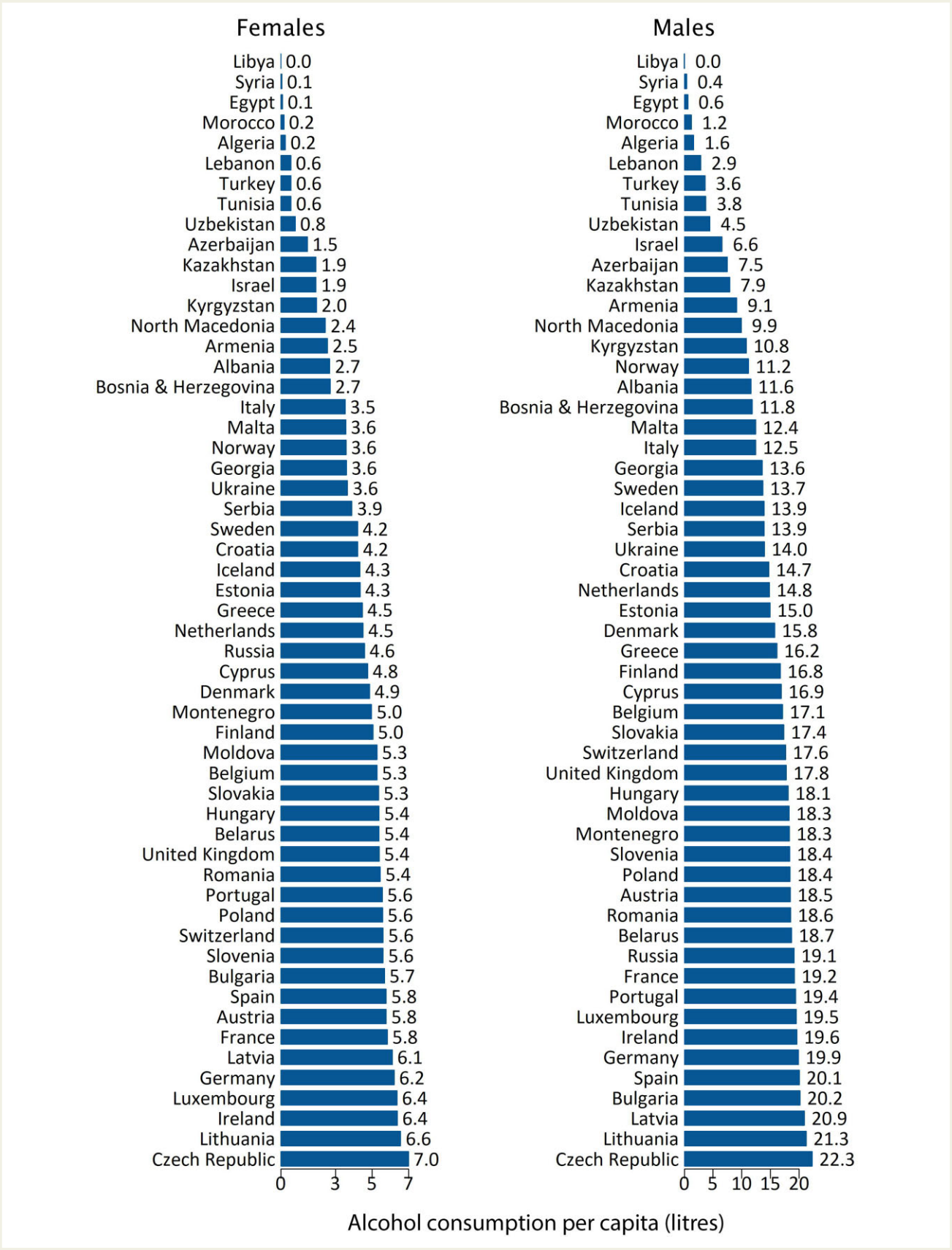


Figure 19 The sum per person of recorded and unrecorded annual alcohol consumed in females and males aged >15 years in European Society of Cardiology member countries. Data are litres of pure alcohol.

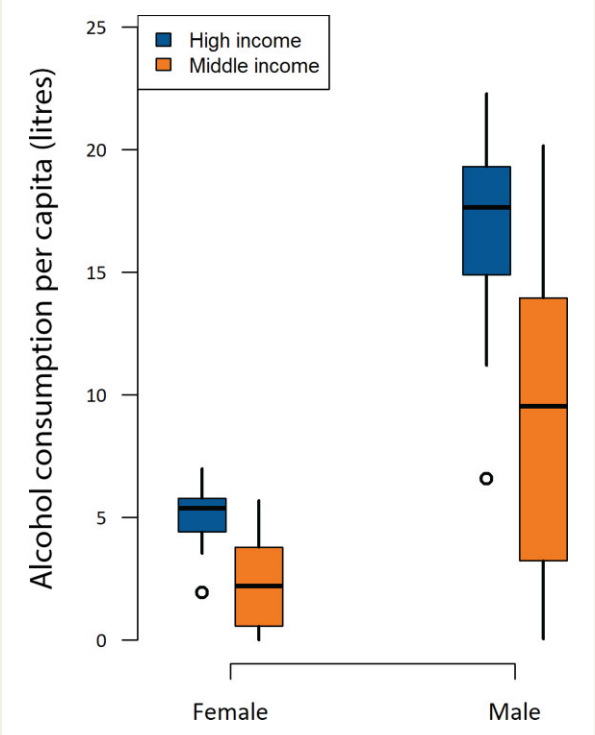


Figure 20 The sum per person of recorded and unrecorded annual alcohol consumed in females and males aged >15 years in European Society of Cardiology member countries, stratified by national income status. Data are litres of pure alcohol.

income countries, insufficient physical activity was more prevalent with a median of 32.0% (IQR 28.5–35.9%) (see Supplementary material online, *Figure S16*).

Diet

It is widely accepted that dietary factors contribute to CV risk. Dietary fats and sugar have been the major foci of interest, and both have plausible associations with CVD based on the risks posed by dyslipidaemia and dysfunctional glucose metabolism. Research is, however, hampered by variable imprecision in the dietary measurement and the difficulties of changing socially ingrained dietary habits in trial populations. When associations between dietary components and CVD risk are identified, they are often confounded by lifestyle effects, making the nutritional contribution hard to ascertain. Nevertheless, a recent study suggests that dietary risks are the primary contributor to CHD mortality worldwide.[161] It is estimated that across the European region, one in every five premature deaths could be prevented by an optimized diet.[162] 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.[163]

Dietary fats

In a systematic review of studies reporting associations between fat intake and CVD, trans-fats but not saturated fats were associated with all-cause and CHD mortality.[164] Red meat intake, in particular, increases CHD risk,[165] but replacement of saturated fats with polyunsaturated fat can reduce risk by 13%.[166] The CV benefits of a diet rich in vegetables, fruits, herbs, nuts, beans whole grains, and unsaturated fats—the Mediterranean diet— has been confirmed in the PREDIMED trial.[167]

- **National statistics.** 2019 estimates for the daily intake of dietary fats (percentage of total daily energy) are available for adults aged ≥25 years living in ESC member countries
  - ***Polyunsaturated fatty acids:*** Consumption of polyunsaturated fatty acids accounted for a median of 2.8% (IQR 2.1–3.6%) of daily energy intake, ranging from <1.5% in Albania, Azerbaijan, Kyrgyzstan, and Uzbekistan to >5.0% in Israel, Norway, Lebanon, and Libya (see Supplementary material online, *Figure S17*).
  - ***Trans-fatty acids:*** Consumption of trans-fatty acids accounted for a median of 0.43% (0.34–0.49%) of daily energy intake, ranging from <0.2% in Belarus and Ukraine to >1% in Latvia, Azerbaijan, and Egypt (see Supplementary material online, *Figure S18*).
- **Stratification by national income status.**
  - ***Polyunsaturated fatty acids:*** Consumption of polyunsaturated fatty acids accounted for a median of 2.1% (IQR 1.7–3.0%) of daily energy intake in middle-income countries and a median of 3.2% (IQR 2.5–3.7%) of daily energy intake in high-income countries (see Supplementary material online, *Figure S19*).
  - ***Trans-fatty acids:*** Consumption of trans-fatty acids accounted for a median of 0.36% (IQR 0.24–0.44%) of daily energy intake in middle-income countries and a median of 0.44% (IQR 0.38–0.57%) of daily energy intake in high-income countries (see Supplementary material online, *Figure S20*).

Sugar and sugar-sweetened beverages

Sugar consumption shows association with CVD risk and in the National Health and Nutrition Examination Survey (NHANES), consumption among US adolescents was positively associated with atherogenic lipid profiles.[168] An updated and more extended analysis of NHANES participants confirmed that most US adults consume more added sugar than is recommended for a healthy diet with a significant relationship between added sugar consumption and increased risk for CVD mortality.[169] Mechanisms driving this relationship are unclear but probably involve multiple pathways in addition to an increased propensity for weight gain and Type 2 diabetes.

- **National statistics.**
  - ***Sugar:*** In 2018, sugar consumption supplied a median of 313 (IQR 272–384) kcal/capita/day across ESC member countries, ranging from <200 kcal/capita/day in Albania, Bosnia and Herzegovina, Kyrgyzstan, Republic of Moldova, and Uzbekistan to >450 kcal/capita/day in Belgium, Croatia, Denmark, Ireland, and Switzerland (see Supplementary material online, *Figure S21*).
  - ***Sugar-sweetened beverages:*** In 2019, the estimated intake of sugar-sweetened beverages across ESC member countries for adults aged ≥25 years was 102.7 (IQR

57.7–131.9) g/day, ranging from <25 g/day in Armenia, Republic of Moldova, and Ukraine to >150 g/day in Belgium, Croatia, Ireland, Israel, Luxembourg, Malta, Netherlands, Poland, Romania, Republic of San Marino, and Spain (see Supplementary material online, *Figure S22*).

- **Stratification by national income status.**
  - ***Sugar:*** In 2018, sugar consumption supplied a median of 291 (IQR 213–343) kcal/capita/day in middle-income countries, little different from the 306 (IQR 231–358) kcal/capita/day consumed in 2014. In high-income countries, the 2018 sugar consumption was higher at 338 (IQR 282–436) kcal/capita/day, slightly less than the 355 (IQR 291–436) kcal/capita/day consumed in 2014.
  - ***Sugar-sweetened beverages:*** In 2019, middle-income countries consumed a median of 56.9 (IQR 42.6–92.9) g/day of sugar-sweetened beverages, but in high-income countries, consumption was higher at 115.6 (IQR 99.9–156.2) g/day (see Supplementary material online, *Figure S23*).

Dietary sodium

A higher intake of dietary sodium is associated with increased blood pressure levels.[170,171] The maximum daily intake of dietary sodium recommended by the WHO is 2 g for adults but currently most populations consume much more.[172] A recent systematic review and meta-analysis of randomized trials showed a dose–response relation between dietary sodium reduction and blood pressure lowering that was greater for those with higher blood pressure.[173] A large and increasing number of countries now have salt reduction strategies in place, although activity remains limited in low- and middle-income regions.[174] The WHO has adopted a global target of a 30% reduction in the mean population intake of salt/sodium by 2025.[175]

- **National statistics.** In 2019, the median sodium intake across ESC member countries in adults aged ≥25 years was 3.3 (IQR 2.9–3.8) g/day, ranging from <2.5 g/day in Estonia, Algeria, Lebanon, Libya, Morocco, Syrian Arab Republic, Tunisia, and Turkey to >5 g/day in Croatia, Czech Republic, Hungary, Romania, Slovakia, Slovenia, Albania, Bosnia and Herzegovina, Bulgaria, Montenegro, North Macedonia, and Serbia (see Supplementary material online, *Figure S24*).
- **Stratification by national income status.** The median sodium intake for middle-income countries was 3.5 (IQR 2.5–4.1) g/day, similar to high-income countries where the median intake was 3.3 (IQR 3.2–3.8) g/day (see Supplementary material online, *Figure S25*).

Dietary fruit and vegetables

Low intake of fruit and vegetables increases the risk of NCDs, such as CHD and cancer. In a systematic review and dose–response meta-analysis of 95 prospective studies, a 200 g/day increment in intake of fruit, or vegetables, or fruit and vegetables combined, was associated with an 8–13% reduction in the relative risk of CVD.[176] Progressive reductions in the risk of CVD and all-cause mortality were observed up to an intake of 800 g/day of fruit and vegetables combined.[176] These findings are consistent with those reported in the Prospective Urban Rural Epidemiology [PURE] study of 135 335 individuals from 18 low-income, middle-income, and high-income countries.[177] Follow-up 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 5 servings per day.[178]

- **National statistics.** 2019 estimates of the median fruit and vegetable consumption are available for adults aged ≥25 years living in ESC member countries.
  - ***Fruit consumption:*** An estimated median of 155.4 (IQR 112.8–195.4) g/day were consumed, ranging from <100 g/day in Latvia, Republic of Georgia, Kyrgyzstan, Republic of Moldova, and Ukraine to >250 g/day in Greece, Albania, Montenegro, and Turkey (see Supplementary material online, *Figure S26*).
  - ***Vegetable consumption:*** An estimated median of 203.2 (IQR 165.1–306.3) g/day were consumed, ranging from <150 g/day in Czech Republic, Finland, France, Iceland, The Netherlands, Norway, and Sweden to >400 g/day in Romania, Armenia, Egypt, Turkey, and Uzbekistan (see Supplementary material online, *Figure S27*).
- **Stratification by national income status.**
  - ***Fruit consumption:*** In middle-income countries, the median fruit consumption was 170.9 (IQR 108.2–212.0) g/day which was higher compared with high-income countries with a median fruit consumption of 149.9 (IQR 113.4–180.6) g/day (see Supplementary material online, *Figure S28*).
  - ***Vegetable consumption:*** In middle-income countries, the median vegetable consumption was 290.7 (IQR 196.8–383.2) g/day which was higher compared with high-income countries with a median vegetables consumption of 194.8 (IQR 153.1–223.9) g/day (see Supplementary material online, *Figure S29*).

Clinical risk factors

The Framingham Heart Study, one of the first longitudinal studies of CV epidemiology, identified major risk factors predisposing to the development of CVD.[179] More recently, the INTERHEART study confirmed that hypertension, dyslipidaemia, diabetes, and obesity, together with psychological factors and the lifestyle factors discussed above, account for >90% of the population attributable risk of acute myocardial infarction (AMI).[95] All these factors are amenable to control or elimination with the potential to make a substantial reduction in incident CVD at the population level.[180] Yet, risk factors are often poorly managed, even in high-risk patients as shown in the primary care arm of the recent EUROASPIRE V survey. A large proportion of people at high CVD risk had poorly controlled blood pressure, lipid levels, or diabetes and nearly half were obese (BMI ≥30 kg/m^2). The investigators concluded that there is considerable potential to reduce the risk of future CVD throughout Europe by delivery of improved preventive cardiology programmes.[181]

Blood pressure

Raised blood pressure is the leading global risk factor for CVD.[182] There is a continuous linear relationship between blood pressure levels and the risk of stroke or myocardial infarction.[183] Treatment to lower blood pressure provides significant protection against CV events, with incremental benefits of more intensive treatment in patients at higher risk (concomitant vascular disease, renal disease, or diabetes).[184] International surveys show that rates of raised systolic blood pressure (≥140 mm Hg) have increased substantially over the last four decades particularly in low- and middle-income countries with knock-on increases in DALYs and deaths attributable to hypertension.[185] Population-based interventions plus pharmacological treatment for people with elevated blood pressure are necessary to address the global burden of hypertension, especially in poorer countries.

- **National statistics.** In 2015, the median age-standardized prevalence of elevated blood pressure (defined as systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg) among adults >18 years of age, across the ESC member countries was 25.0% (IQR 19.9–28.5%), ranging from ≤18% in Belgium, Israel, Switzerland, and UK to >30% in Croatia, Slovenia, and Bosnia and Herzegovina (*Figure 21*).
- **Stratification by sex.** Data for 2015 showed that the prevalence of hypertension in all ESC member countries was lower in females than in males, with the median rates of 22.3% (IQR 15.5–24.0%) and 26.5% (IQR 24.2–33.6%), respectively. This was reflected in the median systolic blood pressure levels in females of 123.3 (IQR 119.0–126.1) mmHg, ranging from 115.3 mmHg in Switzerland to 129.9 mmHg in Republic of Moldova, and in males of 130.3 (IQR 127.5–134.3) mmHg ranging from 119.7 mmHg in Turkey to 137.5 mmHg in Slovenia.
- **Stratification by national income status.** The median age-standardized prevalence of elevated blood pressure in middle-income countries was 26.5% (IQR 24.9–28.4%) compared with 20.6% (IQR 19.4–28.2%) in high-income countries. Differences were consistent by sex. The prevalence of hypertension in females and males was 23.8% (IQR 22.5–25.0%) and 28.4% (IQR 25.4–33.0%) in middle-income ESC member countries and 15.9% (IQR 14.6–22.0%) and 25.2% (IQR 23.7–34.4%) in high-income countries (*Figure 22*). Systolic blood pressure levels also varied by national income status, with the median levels for females and males of 126.1 (IQR 124.8–127.5) mmHg and 133.0 (IQR 129.6–134.5) mmHg in middle-income countries and 119.6 (IQR 117.5–122.4) mmHg and 128.4 (IQR 127.0–133.3) mmHg in high-income countries.
- **Time-series data.** The median age-standardized prevalence of elevated blood pressure across all ESC member countries trended downwards between 1980 and 2015 from 35.2% (IQR 31.7–38.4%) to 25.0% (IQR 19.9–28.5%). The declines were similar in females and in males (29.4 vs. 30.8%) but were less marked in middle-income countries [32.4% (IQR 30.8–36.1%) to 26.5% (IQR 24.9–28.4%)] compared with high-income countries [36.9% (IQR 34.3–39.7%) to 20.6% (IQR 19.4–28.2%)] (*Figure 23*).

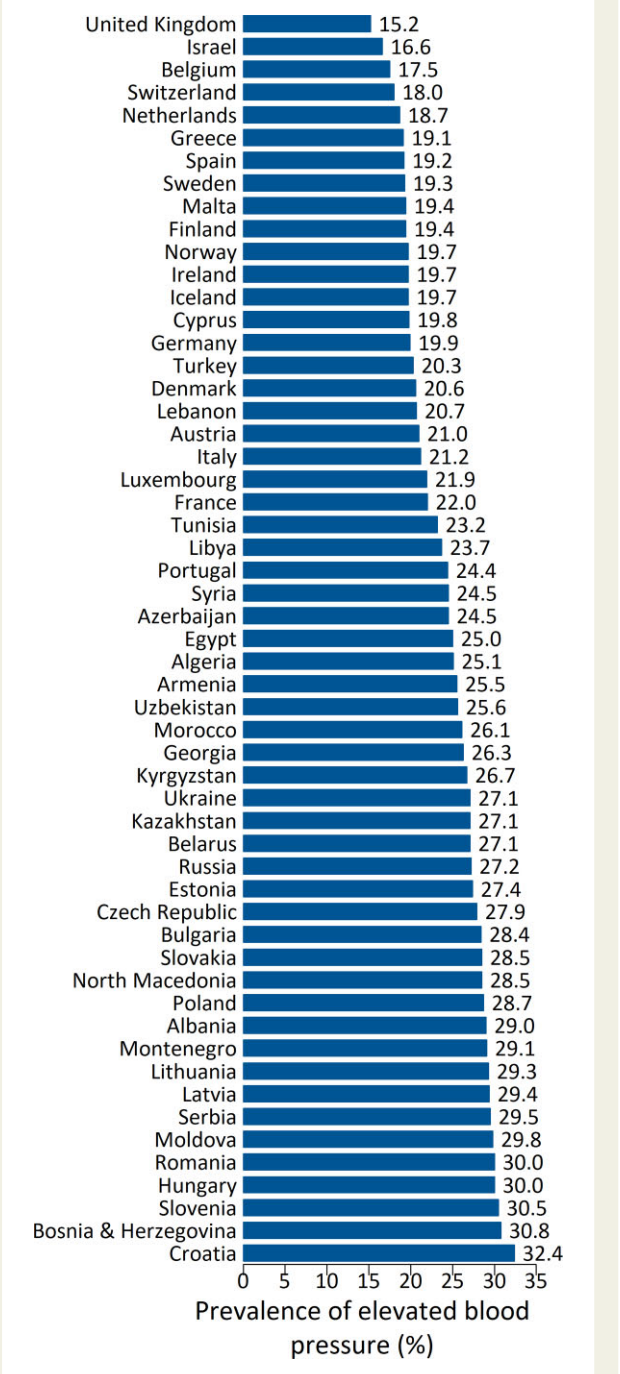


Figure 21 Age-standardized prevalence of elevated blood pressure in European Society of Cardiology member countries.

Cholesterol

Cholesterol, particularly non-HDL cholesterol—which includes LDL and very low-density lipoprotein (VLDL)—is a major determinant of CVD risk which increases with cumulative exposure to LDL during young adulthood and middle age.[186,187] Hypercholesterolaemia is commonly familial with heterozygous involvement in about 1:500 people causing considerable elevation of serum cholesterol concentrations (>8.0 mmol/L)[188] that often results in premature myocardial infarction. Familial

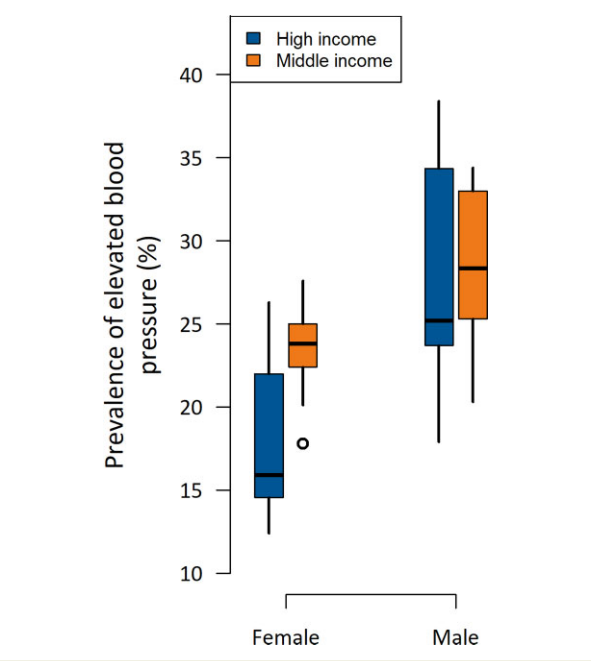


Figure 22 Age-standardized prevalence of elevated blood pressure in European Society of Cardiology member countries, stratified by sex and national income status.

hypercholesterolaemia (FH) remains a clinical diagnosis but can be confirmed by genetic testing. After diagnosis of an index case, cascade screening (lipid or genetic) of all first-degree relatives is mandatory. Hypercholesterolaemia is a major target of risk reduction programmes in which statin therapy in people with no history of CVD (primary prevention) can produce a 15% reduction in risk of vascular death for each 1 mmol/L reduction of LDL cholesterol.[189–191] More potent cholesterol lowering can be achieved with PCSK9 inhibitors which are now routinely prescribed in patients with FH when target levels are not achieved with statin therapy. HDL cholesterol associates with reduced CVD risk but is not on the causal pathway and is not, therefore, influenced by pharmacological interventions that manipulate serum concentrations. The prevalence of elevated total cholesterol exceeds 50% in high-income countries[192] and treatment often falls short—in the EUROASPIRE V survey, more than half of those with dyslipidaemia failed to achieve LDL treatment targets.[181]

- **National statistics stratified by sex.**
  - ***Total cholesterol:*** In 2018, the median age-standardized total cholesterol concentrations across all ESC member countries were 4.92 (IQR 4.71–4.99) mmol/L in females, exceeding 5 mmol/L in Croatia, Czech Republic, Estonia, France, Latvia, Lithuania, Malta, Portugal, Bulgaria, Montenegro, Russian Federation, and Serbia; and 4.82 (IQR 4.55–4.96) mmol/L in males, exceeding 5 mmol/L in Croatia, France, Latvia, Lithuania, Bulgaria, Montenegro, Russian Federation, and Serbia (see Supplementary material online, *Figure S30*).
  - ***Non-HDL cholesterol:*** In females, the median non-HDL cholesterol concentrations across all ESC member countries were 3.36 (IQR 3.20–3.49) mmol/L, exceeding 3.50 mmol/L in Croatia, Estonia, France, Latvia,

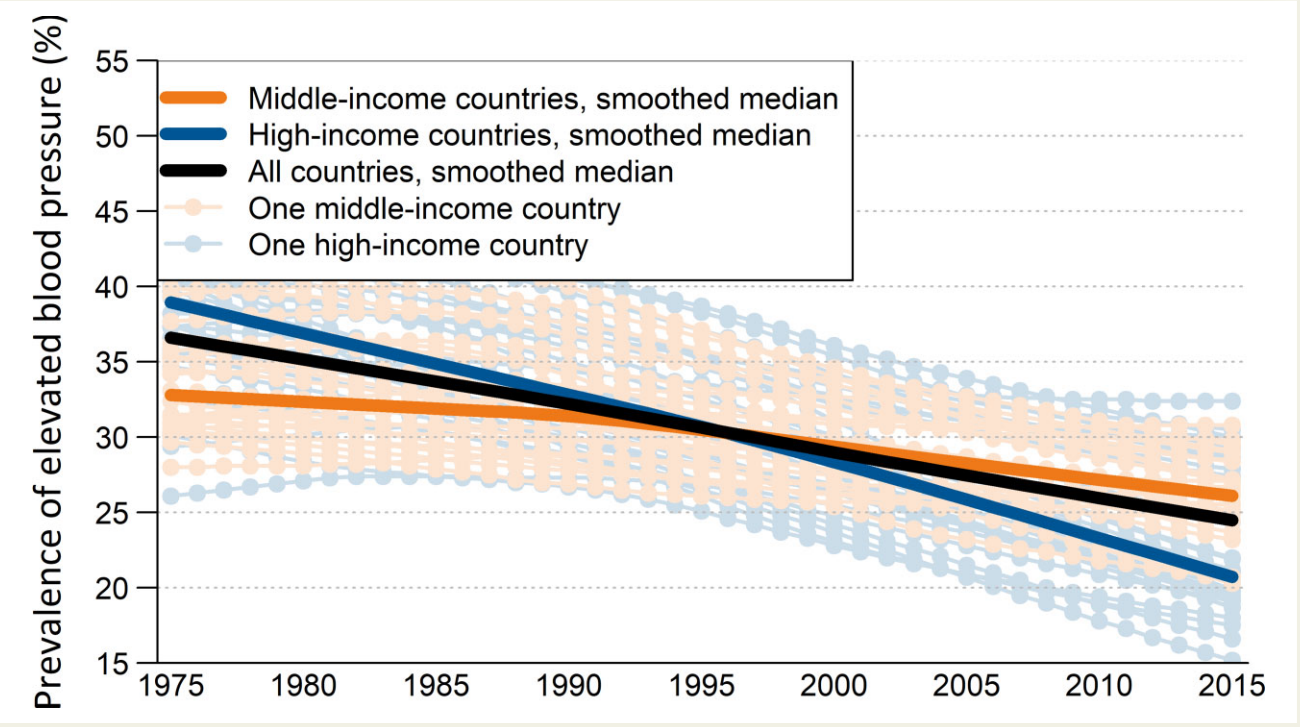


Figure 23 Time series: age-standardized prevalence of elevated blood pressure in European Society of Cardiology member countries (1975–2015).

Lithuania, Malta, Portugal, Slovenia, Lebanon, North Macedonia, Russian Federation, Serbia, and Uzbekistan. In males, the median concentrations tended to be higher at 3.53 (IQR 3.28–3.68) mmol/L, exceeding 3.75 mmol/L in Austria, Croatia, France, Latvia, Lithuania, Malta, Bulgaria, Lebanon, Montenegro, North Macedonia and Serbia (see Supplementary material online, *Figure S37*).

  - ***HDL cholesterol:*** In females, the median HDL cholesterol concentrations across all ESC member countries were 1.53 (IQR 1.39–1.61) mmol/L, falling below 1.20 mmol/L in Algeria, Egypt, and Republic of Georgia. In males the median concentrations tended to be lower at 1.27 (IQR 1.16–1.30) mmol/L, falling below 1.00 mmol/L in Egypt and Republic of Georgia (see Supplementary material online, *Figure S31*).

- **Stratification by national income status.**
  - ***Total cholesterol:*** In 2018, the median age-standardized total cholesterol concentrations across middle-income countries were 4.64 (IQR 4.48–4.97) mmol/L in females and 4.53 (IQR 4.22–4.96) mmol/L in males. In high-income countries, the median concentrations tended to be higher in females and males at 4.96 (IQR 4.85–5.01) mmol/L and 4.87 (IQR 4.74–4.96) mmol/L, respectively (see Supplementary material online, *Figure S32*).
  - ***Non-HDL cholesterol:*** In females, the median non-HDL cholesterol concentrations across middle-income countries were 3.34 (IQR 3.17–3.49) mmol/L, compared with 3.29 (IQR 3.21–3.68) mmol/L in males. In high-income countries concentrations in females and males tended to be higher at 3.43 (IQR 3.26–3.48) mmol/L and 3.60 (IQR 3.38–3.68) mmol/L, respectively (*Figure 24*).
  - ***HDL cholesterol:*** In middle-income countries, the median HDL cholesterol concentrations in females and males were 1.32 (IQR 1.22–1.50) mmol/L and 1.13 (IQR 1.07–1.27) mmol/L, respectively. In high-income countries, concentrations tended to be higher at 1.59 (IQR 1.54–1.65) and 1.28 (IQR 1.25–1.32) mmol/L in females and males, respectively (see Supplementary material online, *Figure S33*).
- **Time-series data.**
  - ***Total cholesterol:*** The median age-standardized total cholesterol concentrations across all ESC member countries reduced between 1980 and 2018 from 5.53 (IQR 5.05–5.84) mmol/L to 4.92 (IQR 4.71–4.99) mmol/L in females and from 5.51 (IQR 5.02–5.88) to 4.82 (IQR 4.55–4.96) mmol/L in males. Reductions during this period were largely confined to high-income countries where the median concentrations declined by 15.0% in females and 16.6% in males. In middle-income countries, there was little change in the median cholesterol concentrations during this period (1.8 and 1.7% in females and males, respectively) (see Supplementary material online, *Figure S34*).
  - ***Non-HDL cholesterol:*** The median non-HDL cholesterol concentrations across ESC member countries declined between 1980 and 2018 from 4.03 (IQR 3.63–4.42) mmol/L to 3.36 (IQR 3.20–3.49) mmol/L in females and from 4.20 (IQR 3.76–4.60) mmol/L to 3.53 (IQR 3.28–3.68) mmol/l in males. Again, declines were largely confined to high-income countries (20.7% in females and 21.2% in males) compared with low- income countries (4.4% in females and 4.8% in males) (*Figure 25*).
  - ***HDL cholesterol:*** In females, the median HDL cholesterol concentrations across ESC member countries increased between 1980 and 2018 from 1.43 (IQR 1.23–1.47) mmol/L to 1.53 (IQR 1.39–1.61) mmol/L. Increases were similar in middle-income and high-income countries. In males, HDL cholesterol concentrations showed little change between 1980 and 2018 going from 1.29 (IQR 1.12–1.34) to 1.27 (IQR 1.16–1.30) mmol/L. Changes were similar in middle-income and high-income countries (see Supplementary material online, *Figure S35*).

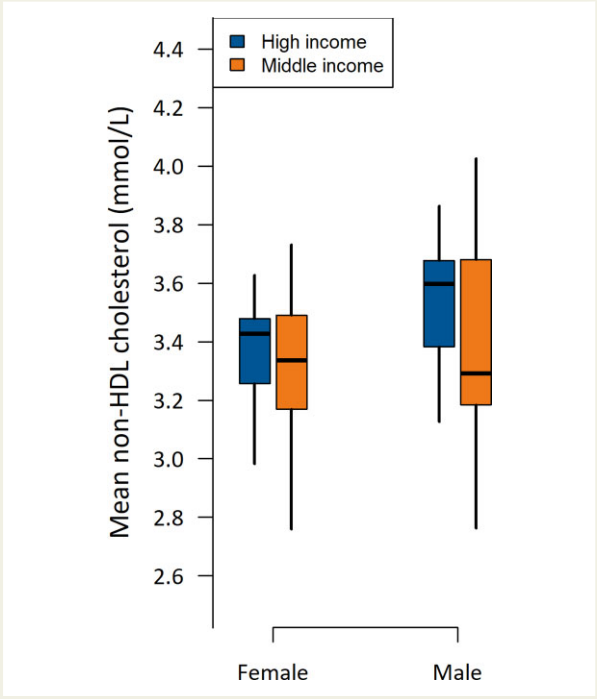


Figure 24 Mean non-HDL cholesterol (mmol/L), stratified by sex and national income status in European Society of Cardiology member countries.

Obesity

The prevalence of overweight and obesity, defined by a body mass index (BMI) of ≥25 kg/m^2 and ≥, respectively, is increasing in both developed and developing countries and is threatening to halt further reductions in CVD mortality.[193] The prevalence of obesity is now higher than that of underweight, both globally and in most regions of the world.[194] The obesity epidemic has largely been driven by global trade liberalization, economic growth, and rapid urbanization affecting lifestyle and food intake, with a trend towards a larger consumption of animal fat and added sugar.[195] In 2016, the Global BMI Mortality Collaboration meta-analysis reported that in overweight and obese people, the hazard ratio for mortality for every 5 kg/m^2 increase in BMI was 1.39 (95% confidence interval 1.34–1.43) among people living in the European region.[196]

Pharmacological treatment options are limited, although the recent demonstration of sustained weight reduction in response to

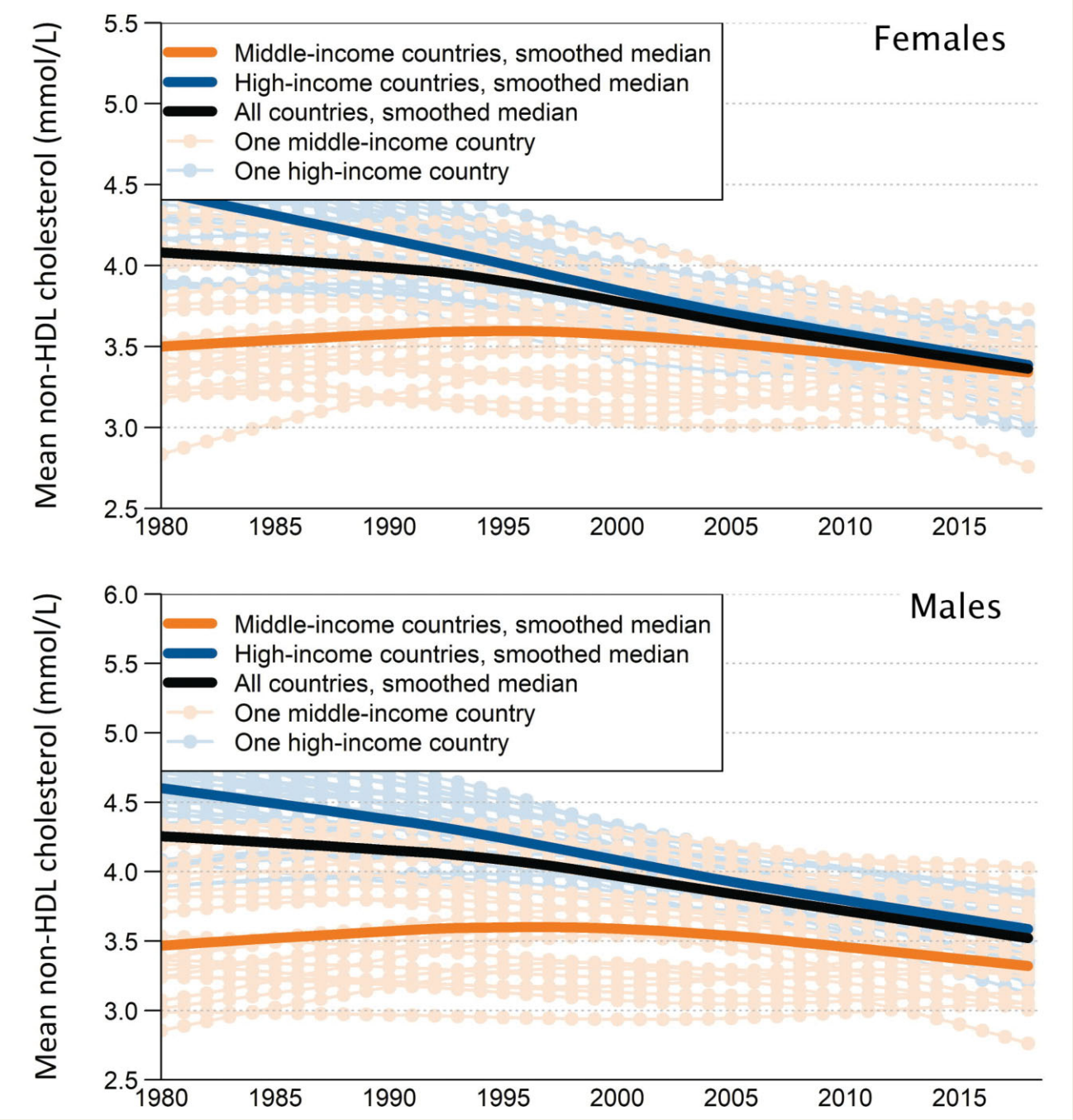


Figure 25 Time series: mean non-HDL cholesterol (mmol/L) in females and males in European Society of Cardiology member countries.

treatment with a GLP-1 receptor agonist has offered some encouragement.[197] More effective has been bariatric surgery and there is evidence that this may combine weight loss with protection against adverse CV outcomes.[198] However, population solutions to the obesity epidemic should lie in lifestyle modification and policy initiatives to encourage exercise and healthy living.

- **National statistics**. Data for 2016 showed that, across ESC member countries, 22.5% (IQR 20.7–25.7%) of adults >18 years old are obese (*Figure 26*).
- **National statistics stratified by sex**. There was little difference by sex in the prevalence of obesity, with levels as high as 22.7% (IQR 20.9–26.0%) in females and (22.2% (IQR 20.2–24.2%) in males. Obesity affected more than one in three females in Algeria, Egypt, Libya, Tunisia, Syrian Arab Republic and Turkey, and more than one in four males in Czech Republic, Malta, Hungary, Israel, Ireland, UK, Lebanon, Libya, and Bulgaria.
- **Stratification by national income status.** In 2016, the overall median prevalence of obesity in middle-income countries was

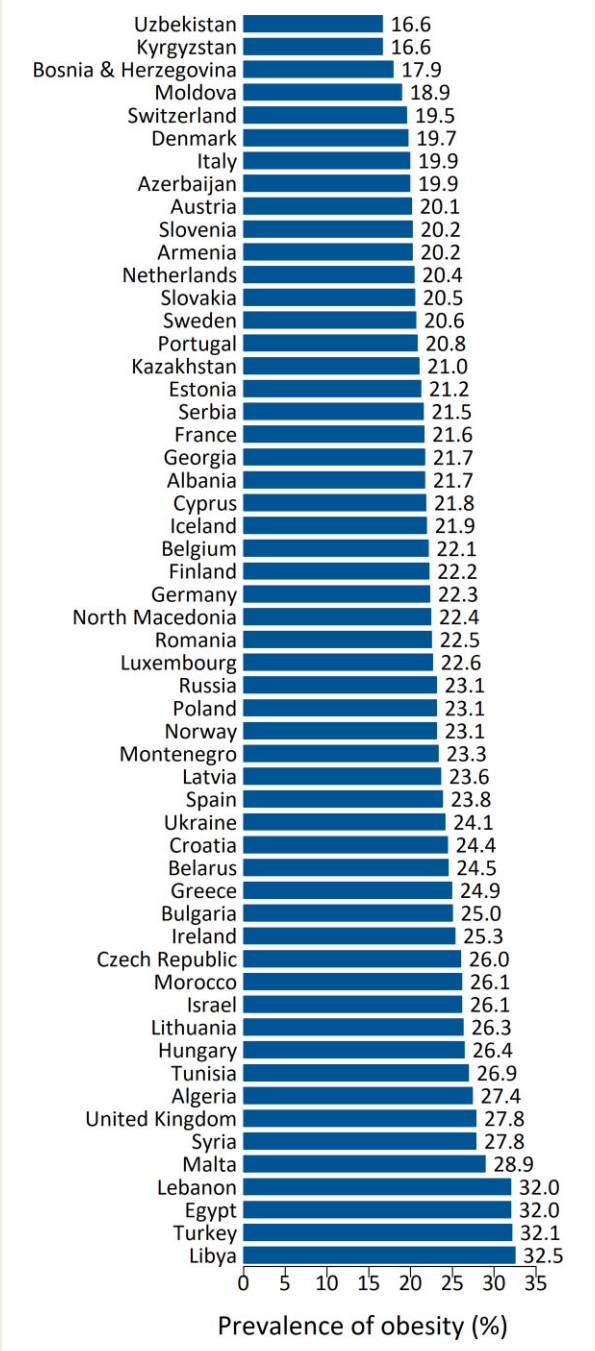


Figure 26 Prevalence of obesity (BMI ≥ 30 kg/m²) among adults in European Society of Cardiology member countries.

23.2% (IQR 20.8–27.0%) with the median prevalence of obesity in females and males being 24.1% (IQR 22.0–34.4%) and 20.4% (IQR 17.9–22.6%), respectively. In high-income countries, the median obesity prevalence was 22.3% (IQR 20.7–24.7%) with the median prevalence in females and males being 21.6% (IQR 20.2–24.9%) and 23.6% (IQR 21.9–24.4%), respectively (*Figure 27*).

- **Time-series data.** The median age-standardized prevalence of obesity across ESC member countries rose steeply between

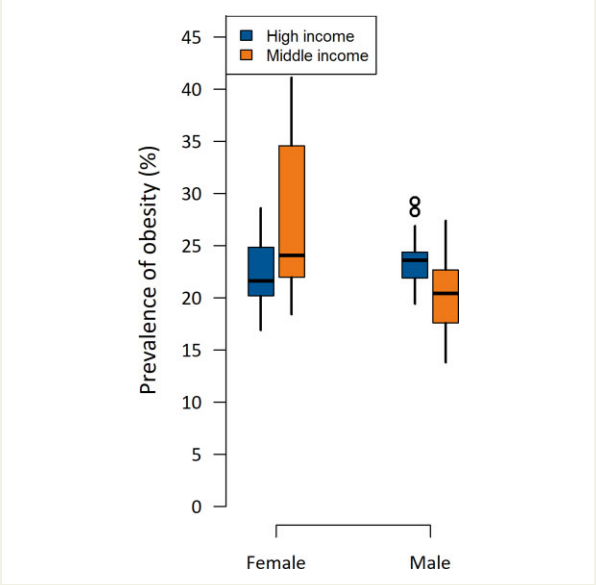


Figure 27 Prevalence of obesity (BMI ≥ 30 kg/m²) among adults, stratified by sex and national income status in European Society of Cardiology member countries.

1980 and 2016 from 9.6% (IQR 8.1–11.9%) to 22.5% (IQR 20.7–25.7%). The increase was greater in males [7.4% (IQR 5.4–8.6%) to 22.2% (IQR 20.2–24.2%)] compared with females [11.8% (IQR 9.5–15.2%) to 22.7% (IQR 20.9–26.0%)]. Increases in population obesity were similar in middle-income and high-income countries (*Figure 28*).

Diabetes

Obesity is an independent driver of CV risk, but its major impact is in its contribution to the epidemic of type II diabetes that now affects an estimated 422 million people globally of whom over 60 million live in the European region. The prevalence of diabetes is increasing among all ages in the European Region, mostly due to increases in overweight and obesity, unhealthy diet and physical inactivity.[199] Having diabetes doubles the risk of death compared with people without diabetes. At least half of these deaths are caused by CVD, usually IHD or stroke.[199] For this reason, the Director General of the WHO described obesity and diabetes as one of the biggest global health crises of the 21st century. She described the crisis as the product of a world in which food is plentiful and exercise is optional, driven less by population failure to resist the temptations of fats and sweeten foods, but more by government failure to take on the powerful food industry and to promote leisure-time exercise and healthy lifestyle.[200]

Diabetes is amenable to treatment through glycaemic control; however, the knock-on benefits for reducing the risk of CVD are small. The recently available GLP-1 receptor agonists and SGLT2 inhibitors look promising in this regard[201] and bariatric surgery is yet more effective in delivering substantial weight reduction and control of metabolic risk factors.[202] Even so, these novel pharmacological and surgical interventions cannot match disease prevention strategies for CV risk reduction at a population level.[203]

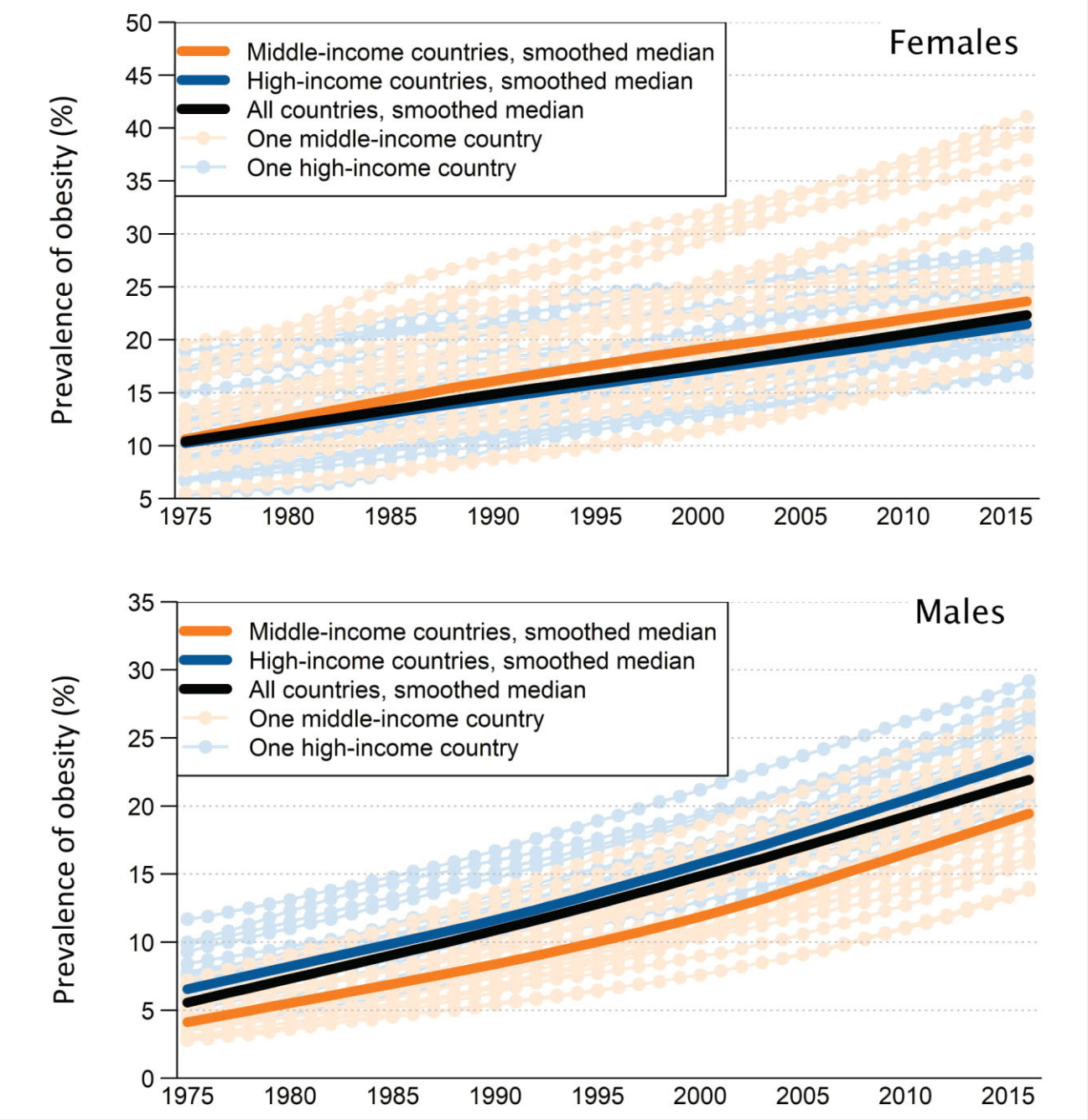


Figure 28 Time series: prevalence of obesity (BMI ≥ 30 kg/m²) among females and males in European Society of Cardiology member countries (1975–2016).

Prevention requires policy initiatives that create an environment in which people are empowered to make healthy lifestyle choices to protect against obesity and its damaging effects on glucose metabolism. Initiatives of proven benefit include sugar taxes and traffic light labelling on food and drink.[204–206]

- **National statistics.** In 2019, the median prevalence of diabetes in adults aged 20–79 years living in ESC member countries was 6.1% (IQR 5.4–8.6%), ranging from ≤4% in Ireland, Lithuania, and UK to ≥10% in Germany, Egypt, Lebanon, Libya, Syrian Arab Republic, and Turkey (*Figure 29*).
- **Stratification by national income status.** The median prevalence of diabetes was greater in middle-income countries [6.9% (IQR 6.1–9.1%)] compared with high-income countries [5.8% (IQR 5.0–6.9%)] (*Figure 30*).

Summary

- The median $PM_{2.5}$ concentrations in 2019 were over twice as high in middle-income ESC member countries compared with

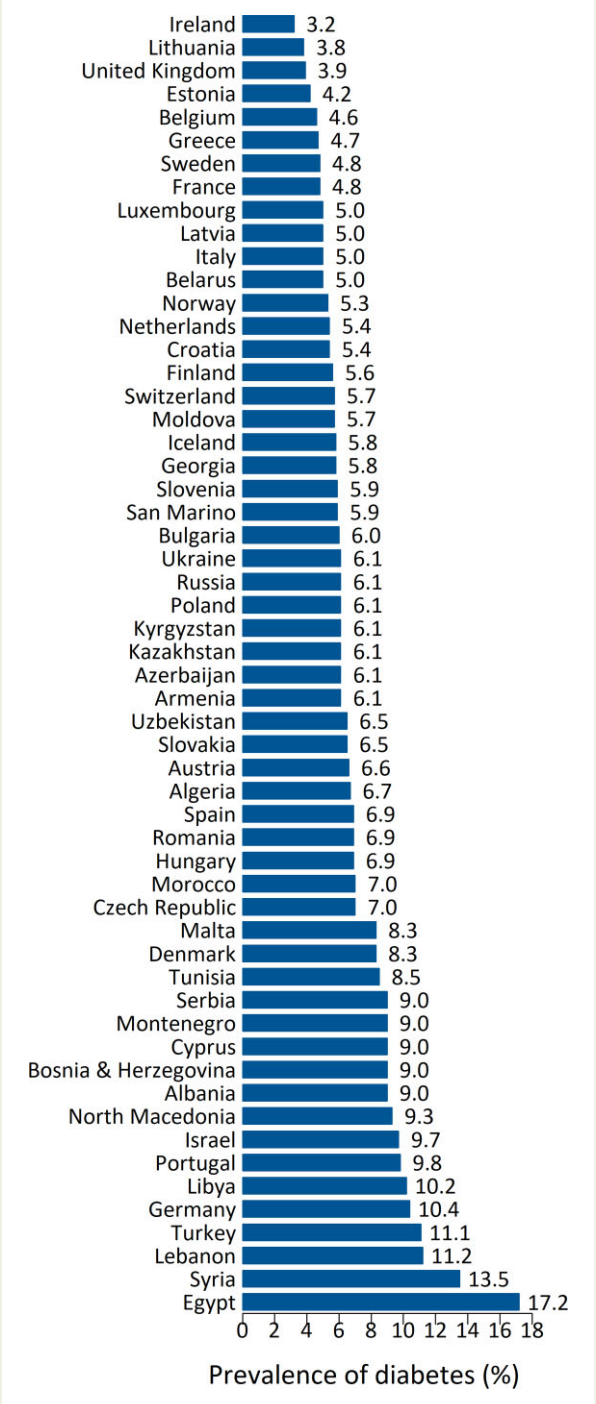


Figure 29 Age-standardized prevalence (%) of Type 1 or Type 2 diabetes among adults aged 20–79 in European Society of Cardiology member countries.

high-income countries and exceeded the EU air quality standard in 14 countries, all middle income.

- During the last 30 years, the median $PM_{2.5}$ concentrations have decreased, but these declines were mainly limited to high-income countries. Ozone concentrations, on the other hand, have shown little differences across ESC member countries and have remained stable during the last 30 years.

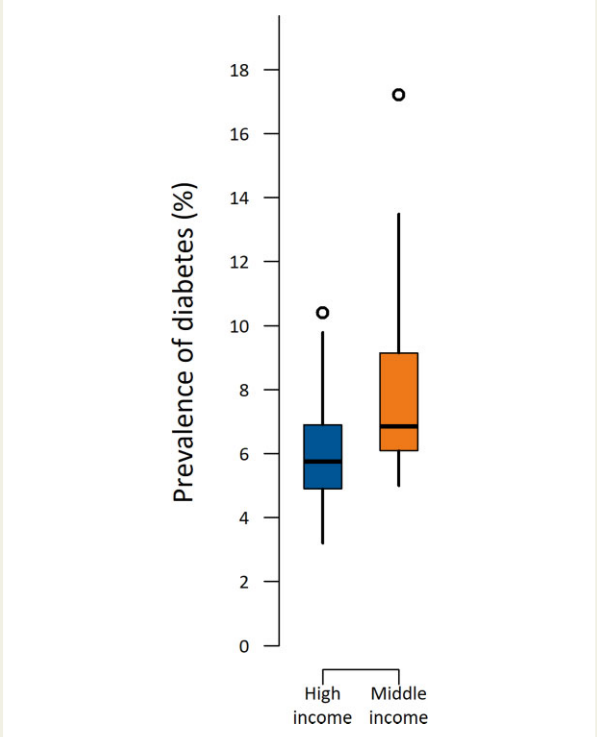


Figure 30 Age-standardized prevalence (%) of Type 1 or Type 2 diabetes, stratified by national income status among adults aged 20–79 in European Society of Cardiology member countries.

- More than one out of five adults across the ESC member countries were regular daily smokers in 2019. Smoking was more common among males than females, particularly in middle-income countries with over 4 out of 10 males being regular daily smokers compared with <1 out of 10 females.
- In 2018, alcohol consumption in males was three times as high as in females, both in middle-income and high-income countries.
- In 2016, 3 out of 10 adults across the ESC member countries were insufficiently active. High-income country inhabitants were more likely to be insufficiently active compared with low-income country inhabitants.
- In 2019, consumption of polyunsaturated fatty acids and trans-fatty acids was highest in high-income countries. High-income countries also consumed larger amounts of sugar-sweetened beverages and lower amounts of vegetables and fruits.
- Age-standardized data for 2015 showed that almost one in four people in ESC member countries had elevated blood pressure. Systolic blood pressure was higher in males compared with females and in middle-income countries compared with high-income countries. Across nearly all countries, the prevalence of elevated blood pressure has been trending downwards the last 35 years; however, this downwards trend was less marked in middle-income countries.
- Age-standardized data for 2018 showed that total blood cholesterol concentrations were similar in females and males but tended to be higher in high-income compared with

middle-income countries. Blood cholesterol concentrations across all of the ESC member countries have shown a small downward trend the last 40 years, more marked in high-income compared with middle-income countries.
- In 2016, more than one in five adults across the ESC member countries were obese with similar prevalence rates in high-income and low-income countries. The prevalence of obesity has more than doubled over the past 35 years.
- Across all of the ESC member countries, ~1 in 15 adults had diabetes in 2019. The prevalence of diabetes was lower in high-income compared with middle-income countries where it often exceeded 10%.

Comment

Previous ESC Atlas reports have focused on lifestyle and the prevalence of clinical risk factors across member countries.[4,5] We have now included statistics relating to key environmental risk factors, particularly air pollution, noise, and neighbourhood characteristics which make important independent contributions to CVD risk. The data show that for many ESC member countries, exposures to air and noise pollution have exceeded the standards set by European agencies and while noise pollution showed no relation to national income status, excessive $PM_{2.5}$ concentrations occurred exclusively in middle-income countries where age-standardized DALYs caused by particulate matter were over five times those of high-income countries. This is important since these middle-income ESC member countries bear the greatest CVD burden. While air pollution cannot be modified by CV healthcare, ESC Atlas data have identified it as a major target for policymakers.

Inequalities in CVD risk factors between middle-income and high-income ESC member countries were not restricted to air pollution. Lifestyle contributes importantly to the heightened CVD risk in middle-income countries, particularly smoking which, among males, was five times more prevalent compared with high-income countries. Hypertension and diabetes too were more prevalent in middle-income countries. These lifestyle and clinical factors can be targeted by a range of preventive and curative treatments that provide a means of reducing the CVD burden. However, if population benefits are to be realized, management must go beyond the treatment of prevalent cases and include policy initiatives to discourage smoking and facilitate case-finding among those large groups of asymptomatic persons with raised blood pressure and glycaemia.

Previous ESC Atlas reports have focused on the inequalities between middle-income and high-income member countries, and these remain as important as ever.[4,5] Attention also needs to be given to sex differences exemplified in the lifestyle and risk factor statistics presented in the present report. Historically, CVD has been inappropriately characterized as a disease of males. Nowadays, it has become clear that despite higher age-adjusted mortality in males, CVD is causing more deaths in females. Nevertheless, looking at the general population, males still have worse risk factor profiles compared with females. The data show that smoking rates in ESC member countries were twice as high in males compared with females and five times as high in males living in middle-income compared with high-income member countries. Rates of hypertension were also higher in males who were more commonly dyslipidaemic with higher non-HDL and lower HDL cholesterol concentrations. Sex-stratified data for diabetes were unavailable, but its tendency to be more prevalent in males is well established.[207] The important inequalities by sex in CVD risk factors documented in this report provide policymakers and clinicians with further options to tailor preventative and therapeutic interventions in order to reduce the CVD disease burden across ESC member countries.

Cardiovascular disease morbidity

Morbid manifestations of CVD include a range of disorders that vary epidemiologically in terms of their incidence and prevalence. They include IHD, stroke, peripheral artery disease, atrial fibrillation, and valvular heart disease all of which are discussed in this section of our report with reference to the 57 ESC member countries.

The incidence is the number of newly diagnosed cases per unit of time. The prevalence is the proportion of people in a population who have disease at a given time, including those who have ever experienced an acute CV event. Herein, we report the annual incidence and prevalence estimates of CVDs. In order to better capture health impact, we also present DALYs due to CVDs which combine information regarding premature death (years of life lost) and disability caused by the CVD (years lived with CVD) to provide a summary measure of health lost due to that condition.[208] In the 2021 ESC Cardiovascular Statistics, we now provide additional summary data for RHD, calcific aortic valve disease, degenerative mitral valve disease, and out-of-hospital cardiac arrest.

Few countries are able to provide accurate epidemiological data across the spectrum of CVDs. Other sources of disease incidence and prevalence are, therefore, required. Throughout this section, we present data from the Global Burden of Disease Study, which models national morbidity estimates for CVD using data from health surveys, prospective cohorts, health system administrative data, and registries.[209,210] The strength of the original data source is key to the accuracy of the final modelled estimates. Although the statistics from the Global Burden of Disease Study are the best available, caution is necessary in their interpretation, recognizing that as new source material becomes available, the modelled estimates of disease incidence and prevalence will change.[211,212] Additional caution is required in making international comparisons for which distortions are caused by differences in methodologies applied to the calculation of disease estimates and also by differences in national age structures which require mitigation by age-standardizing incidence and prevalence statistics.

Cardiovascular disease

Cardiovascular disease is a collective term for a range of disorders. It is defined by IHME as incorporating death and disability resulting from 11 CV causes, led by IHD, stroke, and hypertensive heart disease, as well as disability due to heart failure. Both atherosclerotic and non-atherosclerotic CVD are included.[213] The term is useful because many CV disorders, particularly IHD and stroke, share

common risk factors and treatments allowing clinicians and policy-makers to develop preventive and therapeutic strategies directed at a broad CV target. Assimilated data by the WHO provide contextual information about the global burden of CVD which causes more than half of all deaths across Europe and 46 times the combined number of deaths from acquired immune deficiency syndrome, tuberculosis, and malaria.[214]

Cardiovascular disease: National statistics

Incidence In 2019, there were an estimated 12.7 million new cases of CVD across ESC member countries. National population size was an important determinant of incident caseload with Germany contributing more than a million new cases and Russian Federation more than 2 million new cases. The median, age-standardized annual incidence estimate for CVD was 747.6 (IQR 558.2–971.9) per 100 000 inhabitants of each member country, ranging from <500 in Cyprus, France and Portugal to >1000 in Azerbaijan, Belarus, Egypt, Estonia, Republic of Georgia, Kyrgyzstan, Morocco, Syrian Arab Republic, Ukraine, and Uzbekistan (*Figure 31*).

Prevalence In 2019, there were an estimated 113 million people living with CVD in the 57 ESC member countries. The median age-standardized annual prevalence estimate per 100 000 inhabitants of each member country was 6963 (IQR 5719–7509), ranging from <5000 in Israel, Portugal, and Switzerland to >8000 in Egypt, Republic of Georgia, Lebanon, Libya, Morocco, Syrian Arab Republic, and Uzbekistan (*Figure 31*).

Cardiovascular disease: stratification by sex

Incidence In 2019, females accounted for more new cases of CVD across ESC member countries compared with males (6.5 million vs. 6.1 million), but after age standardization, median estimates per 100 000 people were lower in females than in males [668.3 (IQR 483.5–857.9) vs. 824.5 (IQR 663.0–1050.2)] (see Supplementary material online, *Figure S38*).

Prevalence In 2019, there were more females than males living with CVD across ESC member countries (60 million vs. 53 million). The median age-standardized prevalence estimates per 100 000 people were lower for females compared with males [6369 (IQR 5385–7139) vs. 7586 (IQR 5963–8143)], ranging from 4642 in Israel to 8903 in Egypt for females and from 5150 in Portugal to 9614 in Egypt for males (see Supplementary material online, *Figure S38*).

Cardiovascular disease: stratification by national income status

Incidence The median age-standardized incidence estimate for CVD per 100 000 people was higher in middle-income countries compared with high-income countries [975.0 (IQR 888.6–1028 vs. 601.5 (IQR 526.2–681.9)] for both females and males (see Supplementary material online, *Figure S38*). In middle-income countries, incidence estimates peaked at >1200 per 100 000 people in Azerbaijan, Egypt, and Uzbekistan, but in high-income countries, incidence estimates were lower and peaked at 1021 per 100 000 people in Estonia.

Prevalence The median age-standardized prevalence estimates for CVD per 100 000 inhabitants were higher in middle-income countries compared with high-income countries [7469 (IQR 7094–8016) vs. 5819 (IQR 5347–6845)] (see Supplementary material online, *Figure S38*). The age-standardized prevalence per 100 000 people in middle-income countries ranged from 6241 in Turkey to 9281 in Egypt, and in high-income countries from 4871 in Portugal to 7882 in Estonia.

Cardiovascular disease: time-series data

Incidence Between 1990 and 2019, estimates for the median age-standardized incidence of CVD per 100 000 inhabitants showed a small decline from 897.9 (IQR 765.5–1033.4) in 1990 to 747.6 (IQR 558.2–971.9) in 2019 (see Supplementary material online, *Figure S39*). Declines in incidence rates per 100 000 inhabitants were generally small and in seven middle-income countries (Azerbaijan, Bosnia and Herzegovina, Egypt, Libya, Tunisia, Ukraine, and Uzbekistan), small increases were recorded.

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for CVD per 100 000 people remained stable at 7150 (IQR 6864–7623) in 1990 vs. 6963 (IQR 5719–7510) in 2019 (see Supplementary material online, *Figure S39*). Modest increases in prevalence were recorded in just two high-income countries (Estonia and Latvia) and in 15 middle-income countries (Azerbaijan, Belarus, Bosnia and Herzegovina, Egypt, Republic of Georgia, Lebanon, Libya, Republic of Moldova, Morocco, Russian Federation, Serbia, Syrian Arab Republic, Tunisia, Ukraine, and Uzbekistan).

Cardiovascular disease: disability-adjusted life years

In 2019, CVD accounted for an estimated 85 million DALYs across ESC member countries. There was a median estimate of 4893 (IQR 2295–7346) age-standardized DALYs due to CVD per 100 000 inhabitants, ranging from <2000 in Denmark, France, Iceland, Israel, Luxembourg, The Netherlands, Norway, Spain, and Switzerland to >10 000 in Azerbaijan, Uzbekistan, Ukraine, and Egypt (see Supplementary material online, *Figure S40*). Ischaemic heart disease and stroke were the major contributors to DALYs due to CVD, accounting for >80% of the total burden. Disability-adjusted life years for males were nearly twice as high compared with females [6393 (IQR 2900–9238) vs. 3628 (IQR 1733–5892)] and nearly four times as high in middle-income compared with high-income countries [8485 (IQR 6152–8987) vs. 2385 (IQR 1977–3978)] (*Figure 32*). In high-income countries, DALYs due to CVD have declined by more than half since 1990 but in middle-income countries, the decline has been much smaller (see Supplementary material online, *Figure S41*).

Ischaemic heart disease

Ischaemic heart disease is defined by IHME as the disease of the coronary arteries, usually from atherosclerosis, leading to myocardial infarction or ischaemia, following the Fourth Universal

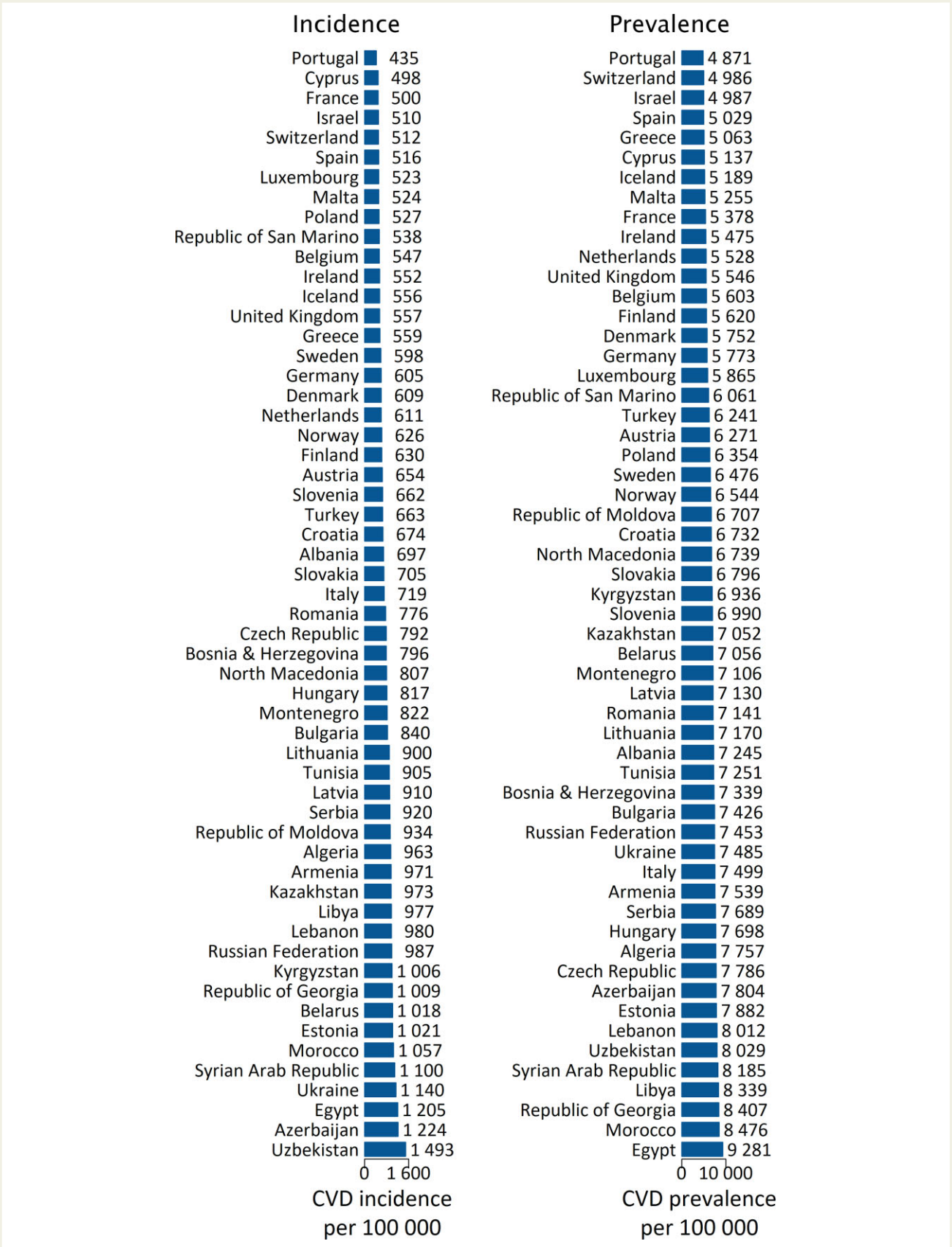


Figure 31 Age-standardized incidence and prevalence of cardiovascular disease across European Society of Cardiology member countries.

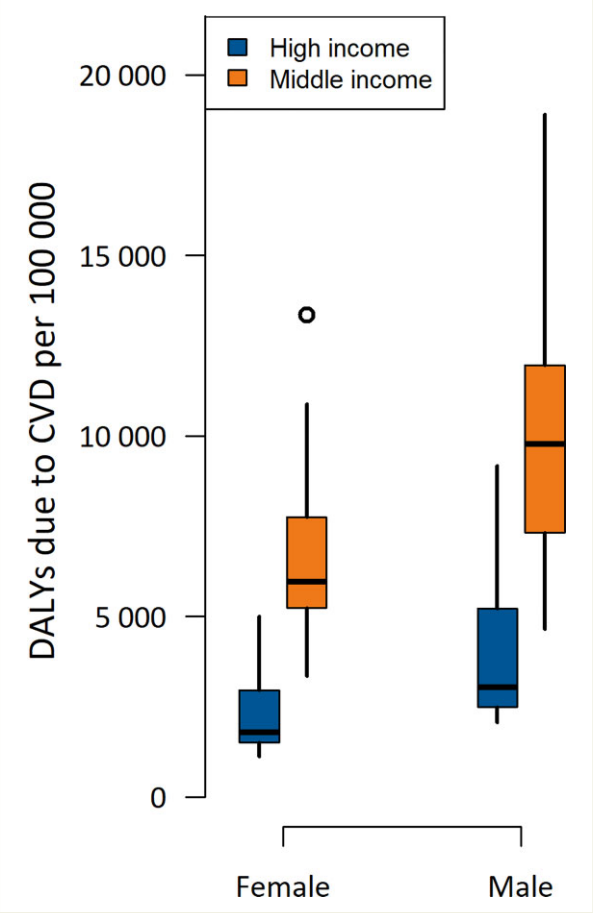


Figure 32 Age-standardized disability-adjusted life years due to cardiovascular diseases in inhabitants of European Society of Cardiology member countries.

Definition of MI and, for stable angina, physician diagnosis.[215] Ischaemic heart disease is usually caused by obstructive coronary atherosclerosis and is the most common manifestation of CVD. It is also the manifestation that has seen the most profound reductions in mortality across ESC member countries in recent years. This has been achieved through a combination of preventive and therapeutic strategies but is now threatened by the epidemic of obesity and Type 2 diabetes affecting ESC member countries. Meanwhile, in low- and lower middle-income countries across the world, the increasing adoption of western lifestyles is seeing IHD emerge as a growing health hazard[159] that has led to calls for policy and legislative interventions for health promotion and primary prevention, similar to those that have been effective in many high-income countries.[216]

Ischaemic heart disease: National statistics

Incidence In 2019, IHD was the most common manifestation of incident CVD with an estimated 5.8 million new cases in the 57 ESC member countries. The median age-standardized incidence estimate per 100 000 people was 293.3 (IQR 195.8–529.5) ranging from <150 in Cyprus, Luxembourg, Portugal, and Poland to >1000 Uzbekistan (*Figure 33*).

Prevalence In 2019, there were an estimated 47.6 million people living with IHD in the 57 ESC member countries. The median age-standardized prevalence estimate per 100 000 inhabitants of each member country was 2895 (IQR 1811–3737) ranging from <1600 in Cyprus, Luxembourg, and Portugal to >5000 in Egypt, Morocco, and Syrian Arab Republic (*Figure 33*).

Ischaemic heart disease: stratification by sex

Incidence In 2019, females accounted for fewer new cases of IHD compared with males (2.6 million vs. 3.2 million), and after age standardization, the median estimates for incident IHD per 100 000 people were substantially lower in females than males [226.2 (IQR 116.3–420.6) vs. 363.0 (IQR 283.7–659.7)] (*Figure 34*).

Prevalence There were fewer females than males living with IHD in ESC member countries (21.1 million vs. 26.5 million). The median age-standardized prevalence estimates per 100 000 people were lower for females compared with males [2194 (IQR 1133–3062) vs. 3793 (IQR 2526–4774)] with Portugal recording the lowest and Egypt the highest estimates for both sexes (see Supplementary material online, *Figure S42*).

Ischaemic heart disease: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for IHD per 100 000 people were more than twice as high in middle-income countries compared with high-income countries [552.1 (IQR 387.5–626.0) vs. 203.2 (IQR 177.4–260.0)]. In middle-income countries, the incidence estimates per 100 000 people varied between 246.3 and 1011.6 in Albania and Uzbekistan while in high-income countries, it varied between 82.6 and 594.6 in Portugal and Estonia (*Figure 34*).

Prevalence The median age-standardized prevalence estimates for IHD per 100 000 people were higher in middle-income countries compared with high-income countries [3935 (IQR 3425–4597) vs. 1856 (IQR 1645–2787)] in both females and males (see Supplementary material online, *Figure S42*). In middle-income countries, age-standardized prevalence estimates per 100 000 inhabitants ranged from 2529 in Albania to 5624 in Egypt, and in high-income countries from 1325 in Portugal to 4320 in Estonia.

Ischaemic heart disease: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for IHD per 100 000 people declined from 404.5 (IQR 282.3–554.7) to 293.3 (IQR 195.8–529.5) (*Figure 35*). Incidence estimates declined consistently in all high-income countries, yet in middle-income countries, declines were small and in seven countries (Azerbaijan, Belarus, Kyrgyzstan, Libya, Syrian Arab Republic, Ukraine, and Uzbekistan), incidence estimates for IHD increased.

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for IHD per 100 000 people showed a small decline from 3357 (IQR 2140–4139) in 1990

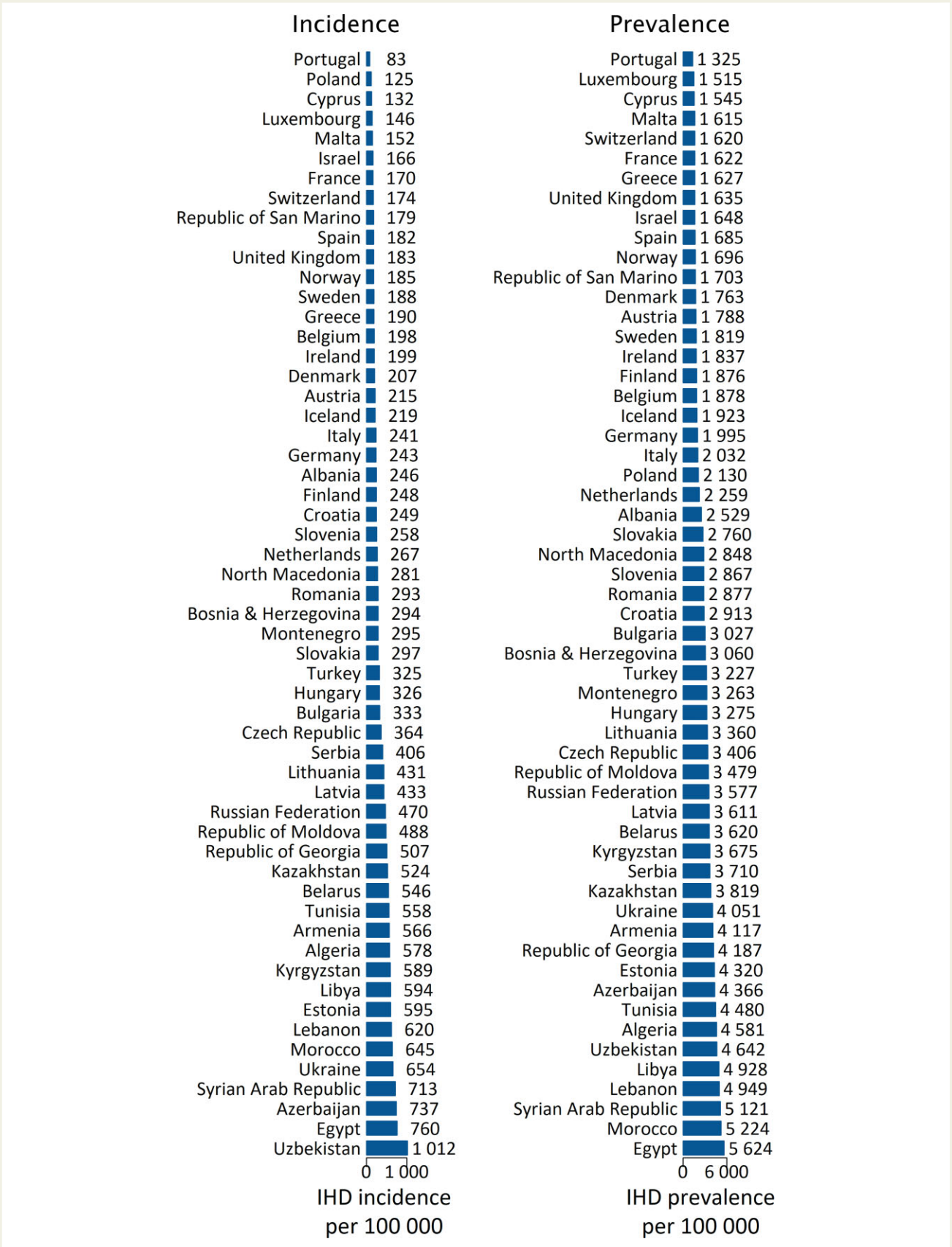


Figure 33 Age-standardized incidence and prevalence of ischaemic heart disease in European Society of Cardiology member countries.

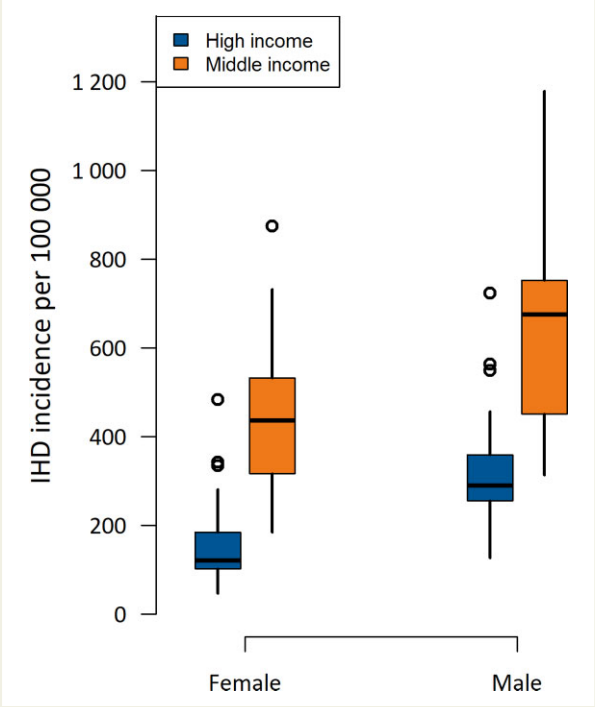


Figure 34 Age-standardized incidence of ischaemic heart disease in European Society of Cardiology member countries, stratified by sex and national income status.

to 2895 (IQR 1811–3737) in 2019 (see Supplementary material online, *Figure S43*). Variable, usually small, declines in age-standardized prevalence estimates for IHD per 100 000 people were recorded in most ESC member countries, but in two high-income countries (Estonia and Latvia) and 10 middle-income countries (Azerbaijan, Belarus, Egypt, Libya, Lebanon, Russian Federation, Syrian Arab Republic, Tunisia, Ukraine, and Uzbekistan), rates of IHD remained stable or increased. In Uzbekistan, the estimated rate increase was substantial, from 3639 to 4642 per 100 000 people.

Ischaemic heart disease: disability-adjusted life years

In 2019, IHD accounted for an estimated 45.8 million DALYs across ESC member countries, accounting for approximately half of all DALYs due to CVD. The median number of age-standardized DALYs due to IHD was estimated at 2342 (IQR 1107–3922) per 100 000 inhabitants, ranging from <800 in France, Israel, The Netherlands, Portugal, Republic of San Marino, and Spain to >7000 in Azerbaijan, Uzbekistan, and Ukraine (see Supplementary material online, *Figure S44*). Disability-adjusted life years for males were twice as high compared with females [3262 (IQR 1645–5538) vs. 1616 (IQR 645.0–2741)] and over three times as high in middle-income compared with high-income countries [4036 (IQR 3352–5280) vs. 1158 (IQR 853.4–2098)] (see Supplementary material online, *Figure S45*). In high-income countries, DALYs due to IHD have declined by more than half since 1990, but in middle-income countries, the decline has been smaller (see Supplementary material online, *Figure S46*).

Stroke

Stroke by WHO criteria is defined as rapidly developing clinical signs of (usually focal) disturbance of cerebral function lasting >24 h or leading to death.[217] It is often the result of atherosclerotic cerebrovascular disease-causing cerebral haemorrhage or

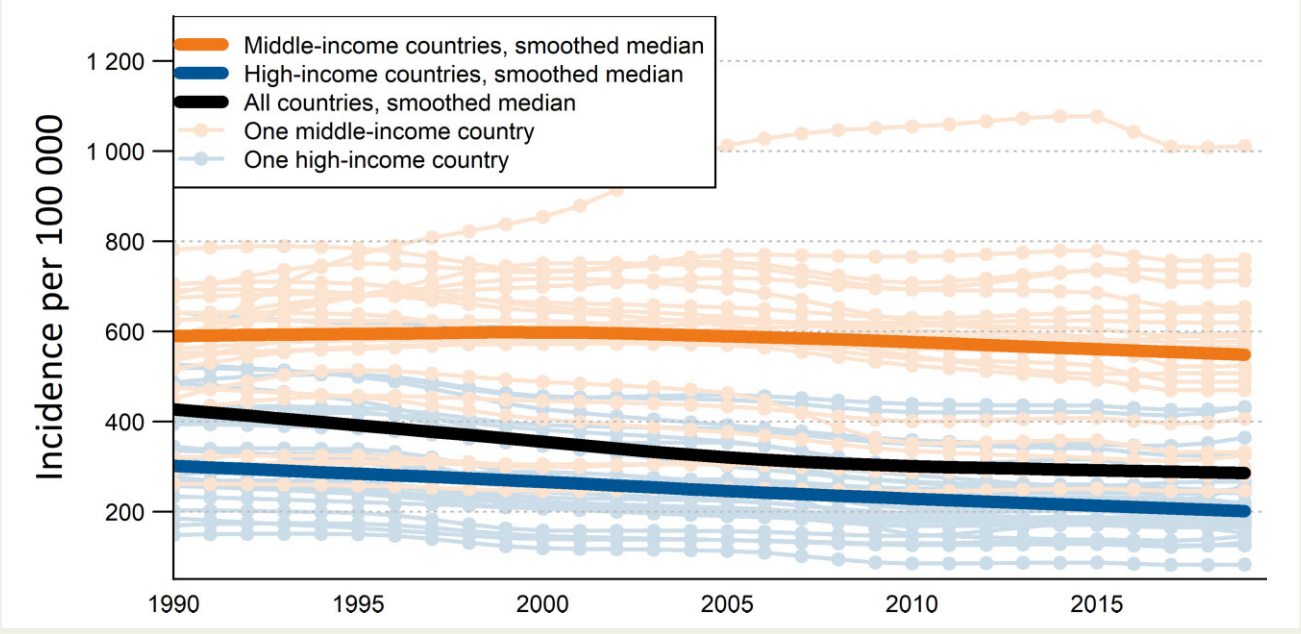


Figure 35 Time series: age-standardized incidence of ischaemic heart disease in European Society of Cardiology member countries (1990–2019).

thrombotic obstruction to cerebral blood flow with ischaemic brain injury. Embolic obstruction is also a common cause of stroke, particularly in people with atrial fibrillation. Healthcare costs related to stroke are substantial and in 2015, were estimated at €45 billion a year in the EU.[218] The number of people living with stroke in Europe has been fairly stable in recent years but is estimated to increase by almost one-third by 2047, mainly because of population ageing and improved survival rates.[219] This has led to 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.[220] Here, we present GBD statistics for combined haemorrhagic and ischaemic stroke.

Stroke: national statistics

Incidence In 2019, there were 2.1 million new cases of stroke in the 57 ESC member countries with a median age-standardized incidence estimate per 100 000 people of 135.2 (IQR 73.4–183.6) (see Supplementary material online, *Figure S47*). Estimates ranged from <65 in five high-income countries (France, Ireland, Luxembourg, Switzerland, and UK) to >200 in nine middle-income countries (Azerbaijan, Bosnia and Herzegovina, Bulgaria, Egypt, Kazakhstan, Macedonia, Montenegro, Serbia, and Uzbekistan).

Prevalence In 2019, there were an estimated 17.1 million people with a history of stroke living in the 57 ESC member countries (see Supplementary material online, *Figure S47*). The median age-standardized prevalence estimate for stroke per 100 000 people was 1046 (IQR 728–1311), ranging from 608 in Switzerland to 1806 in Egypt. In both females and males, prevalence was higher in middle-income countries compared with high-income countries.

Stroke: stratification by sex

Incidence In 2019, numbers of new strokes were similar in females and males (1.2 million and 922 000) with similar median age-standardized estimates across ESC member countries [130.0 (IQR 75.2–180.2) and 129.4 (IQR 72.8–188.4)] (*Figure 36*).

Prevalence In 2019, more females than males were estimated to be living with stroke (10.0 million vs. 7.1 million) in ESC member countries (see Supplementary material online, *Figure S48*). The Median age-standardized prevalence estimates per 100 000 people were 1111 (787.6–1387) for females and 993.3 (671.8–1214) for males. Prevalence estimates for females and for males were lowest in Switzerland (655.4 and 556.8) and highest in Egypt (2110 and 1561).

Stroke: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for stroke per 100 000 people were over twice as high in middle-income countries compared with high-income countries [185.5 (IQR 167.2–208.5)] vs. 76.5 [IQR 68.7–103.8)].

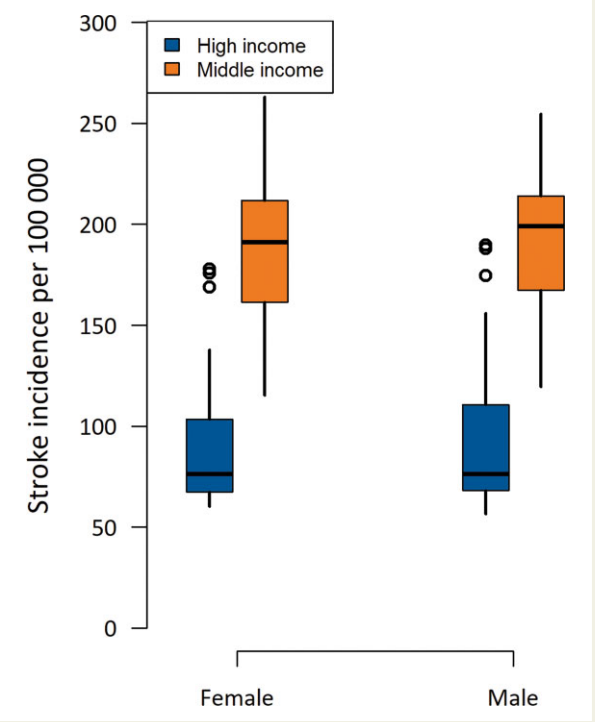


Figure 36 Age-standardized incidence of stroke in European Society of Cardiology member countries, stratified by sex and national income status.

The differences in estimated incidence rates were similar for females and for males (*Figure 36*). In middle-income countries, incidence estimates per 100 000 people ranged from 117.6 in Armenia to 259.3 in Macedonia, while in high-income countries, they ranged from 58.9 in Switzerland to 184.4 in Romania.

Prevalence The median age-standardized prevalence estimates for stroke per 100 000 people were nearly twice as high in middle-income countries compared with high-income countries [1354 (IQR 1222–1524) vs. 781.1 (IQR 668.7–1026)] (see Supplementary material online, *Figure S48*). In middle-income countries, age-standardized prevalence per 100 000 inhabitants ranged from 910.5 in Armenia to 1806 in Egypt, and in high-income countries from 608.3 in Switzerland to 1328 in Romania.

Stroke: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for stroke per 100 000 people declined from 190.2 (IQR 128.0–225.5) to 135.2 (IQR 73.4–183.6). Incidence estimates declined in all high-income countries, but in five middle-income countries (Azerbaijan, Bosnia and Herzegovina, Egypt, Tunisia, and Libya), estimates were stable or showed variable increases during this period (see Supplementary material online, *Figure S49*).

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for stroke per 100 000 people declined

slightly from 1283 (IQR 1055–1523) to 1046 (IQR 728–1311). Declines in prevalence estimates occurred in all high-income countries, but in seven middle-income countries (Azerbaijan, Bosnia and Herzegovina, Egypt, Lebanon, Libya, Morocco, and Tunisia) estimates showed a variable increase (see Supplementary material online, *Figure S49*).

Stroke: disability-adjusted life years

In 2019, stroke accounted for an estimated 23.4 million DALYs across ESC member countries, representing approximately one-quarter of all DALYs due to CVD. The median number of age-standardized DALYs due to stroke was estimated at 1231 (IQR 571.3–2218) per 100 000 inhabitants, ranging from <500 in Austria, France, Israel, Iceland, Ireland, and Switzerland to >3000 in Bulgaria, Republic of Georgia, Kazakhstan, Macedonia, Montenegro, and Uzbekistan (see Supplementary material online, *Figure S50*). Age-standardized DALYs for males were higher compared with females [1402 (IQR 616.8–2463) vs. 1096 (IQR 540.2–1991)] and nearly four times as high in middle-income compared with high-income countries [2276 (IQR 1946–2992) vs. 578.9 (IQR 533.6–946.5)] (see Supplementary material online, *Figure S51*). In high-income countries age-standardized DALYs due to stroke have declined by more than half since 1990, but in middle-income countries, the decline has been smaller (see Supplementary material online, *Figure S52*).

Peripheral arterial disease

Institute for Health Metrics and Evaluation defines PAD as having an ankle–brachial index (ABI) of <0.90, with intermittent claudication defined as leg pain on exertion among those with an ABI below that threshold.[221] After CHD and stroke, PAD is the third most prevalent form of atherosclerotic CVD. The risk of PAD increases sharply with age and with exposure to major CV risk factors. It is estimated that PAD, whether or not it is symptomatic, increases CV morbidity and mortality risks by 80–90%.[222] Reports suggest that within 5 years of diagnosis, 10–15% of patients who have intermittent claudication will die from CVD.[223] This highlights the importance of the identification and modification of risk factors associated with PAD, heart disease, and stroke.

Peripheral arterial disease: national statistics

Incidence In 2019, there were an estimated 2.5 million new cases of PAD in the 57 ESC member countries. The median age-standardized incidence estimate for new cases of PAD per 100 000 people was 136.8 (IQR 118.8–166.8), ranging from 107.3 in Syrian Arab Republic to 224.9 in Denmark (see Supplementary material online, *Figure S53*).

Prevalence In 2019, there were an estimated 29.5 million people living with PAD in the 57 ESC member countries. The median age-standardized prevalence estimate for PAD per 100 000 people was 1459.5 (IQR 1254–1942), ranging from 1045 in Syrian Arab Republic to 2702 in Denmark (see Supplementary material online, *Figure S53*).

Peripheral arterial disease: stratification by sex

Incidence In 2019, incident case estimates for PAD were higher for females living in the 57 ESC member countries compared with males (1.6 million vs. 915 619). Age-standardized incidence estimates per 100 000 people were also higher in females compared with males [157.1 (IQR 130.5–183.0) vs. 114.1 (IQR 100.9–148.8)] (see Supplementary material online, *Figure S54*).

Prevalence In 2019, there were more than twice as many females as males estimated to be living with PAD (19.8 million vs. 9.6 million) in ESC member countries. The median age-standardized prevalence estimates for PAD per 100 000 people were also higher for females than males [1675 (IQR 1387–2230) vs. 1168 (IQR 1005–1602)] (see Supplementary material online, *Figure S54*). Estimates per 100 000 people for females ranged from 1192 in Syrian Arab Republic to 3036 in Denmark and for males from 771.2 in Russian Federation to 2327 in Denmark.

Peripheral arterial disease: stratification by national income status

Incidence Estimates for median age-standardized incidence of PAD per 100 000 people were lower in middle-income compared with high-income countries [123.3 (IQR 111.2–135.1) vs. 165.5 (IQR 134.2–174.8)] (see Supplementary material online, *Figure S54*). In middle-income countries, incidence estimates per 100 000 people ranged from 107.3 in Syrian Arab Republic to 157.5 in Ukraine while in high-income countries, they ranged from 112.0 in Slovakia to 224.9 in Denmark.

Prevalence Median age-standardized prevalence estimates for PAD per 100 000 people were lower in middle-income compared with high-income countries [1280 (IQR 1117–1392) vs. 1915 (IQR 1447–2049)] (see Supplementary material online, *Figure S54*). In middle-income countries, age-standardized prevalence estimates ranged from 1045 in Syrian Arab Republic to 1726 in Russian Federation and in high-income countries from 1185 in Slovakia to 2702 in Denmark.

Peripheral arterial disease: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for PAD per 100 000 people remained relatively stable, changing from 144.3 (IQR 128.0–239.8) in 1990 to 136.8 (IQR 118.8–166.8) in 2019. In high-income countries, a decline in incidence estimates occurred from 238.0 (IQR 148.9–246.7) in 1990 to 165.5 (IQR 134.2–174.8) in 2019 (see Supplementary material online, *Figure S55*).

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for PVD per 100 000 people showed just minor change from 1552 (IQR 1314–2832) to 1460 (IQR 1254–1942) in 2019. Small declines in prevalence estimates occurred in all but one (Latvia) high-income countries; however, small increases occurred in nine middle-income countries (Bosnia and Herzegovina, Egypt, Republic of Georgia, Libya, Lebanon, Republic of Moldova, Serbia, Tunisia, Uzbekistan) (see Supplementary material online, *Figure S55*).

Peripheral arterial disease: disability-adjusted life years

In 2019, PAD accounted for only about 1% of DALYs due to CVD. The median age-standardized number of DALYs across ESC member countries was estimated to be 20.8 (IQR 10.6–32.4) per 100 000 people. Disability-adjusted life years due to PAD were somewhat lower in females compared with males [16.7 (IQR 9.6–24.1) vs. 23.1 (IQR 10.8–41.4)] and in middle-income compared with high-income countries [9.9 (IQR 8.3–15.4) vs. 25.3 (IQR 21.0–39.2)] (see Supplementary material online, *Figure S56*). Time-series analysis showed almost no change in age-standardized DALYs due to PAD between 1990 and 2019 [20.3 (IQR 10.4–32.9) vs. 20.8 (IQR 10.6–32.4)].

Atrial fibrillation

Atrial fibrillation, persistent or paroxysmal, is defined by IHME as a supraventricular arrhythmia due to progressive atriopathy, defined by surface ECG diagnosis based on irregular RR intervals [in the absence of complete atrioventricular (AV) block] and no distinct P waves.[224] Atrial fibrillation is prevalent across all high-income countries and increasingly across many middle- and low-income countries.[225] It worsens quality of life,[226] increases mortality, and is associated with significant morbidity, including an increased risk of stroke.[227] The prevalence of AF across Europe is expected to rise substantially as the population ages[228] and this will increase rates of AF-related strokes and hospitalizations with knock on effects for healthcare costs. In 2020, AF is predicted to directly cost the UK between 0.9 and 1.6% of National Health Service expenditure.[229]

Atrial fibrillation: national statistics

Incidence In 2019, there were an estimated one million new cases of AF in the 57 ESC member countries with the median age-standardized incidence per 100 000 people estimated at 63.0 (IQR 56.4–71.2) (see Supplementary material online, *Figure S57*). Incidence rates exceeded 80 per 100 000 people in Austria and Sweden.

Prevalence In 2019, there were an estimated 15.7 million people living with AF across ESC member countries. The estimated age-standardized prevalence rate per 100 000 was 893.7 (IQR 790.8–1007) ranging from <500 in Algeria, Egypt, Syrian Arab Republic, and Tunisia to >1000 in Austria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Poland, Slovakia, Sweden, UK, Belarus, Republic of Moldova, Russian Federation, and Ukraine (see Supplementary material online, *Figure S57*).

Atrial fibrillation: stratification by sex

Incidence In 2019, there were estimated to be fewer cases of AF in females compared with males (498 000 vs. 539 000) across ESC member countries. The estimated median age-standardized incidence per 100 000 inhabitants was also lower in females [51.0 (IQR 45.1–58.0) vs. 76.3 (IQR 69.8–83.7)] (see Supplementary material online, *Figure S58*).

Prevalence In 2019, fewer females than males were estimated to be living with AF (7.5 million vs. 8.3 million) across ESC member countries. The median age-standardized prevalence estimates for AF per 100 000 people were lower for females than males [696.6 (IQR 554.6–781.3) vs. 1146 (IQR 1051–1265)] (see Supplementary material online, *Figure S58*). Rates for females ranged from 493.8 in Switzerland to 958.5 in Ukraine and for males from 469.0 in Algeria to 1725 in Sweden.

Atrial fibrillation: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for AF per 100 000 people were similar in middle-income countries compared with high-income countries [64.0 (IQR 42.5–68.2) vs. 61.7 (IQR 58.7–73.8)] (see Supplementary material online, *Figure S58*). In middle-income countries, incidence estimates per 100 000 people ranged from 40.5 in Algeria and Tunisia to 76.8 in Ukraine and in high-income countries from 50.9 in Switzerland to 88.44 in Sweden.

Prevalence The median age-standardized prevalence estimates for AF per 100 000 people were similar in middle-income countries compared with high-income countries [898.6 (IQR 515.7–956.8) vs. 871.3 (IQR 831.4–1048)] (see Supplementary material online, *Figure S58*). Estimates remained similar in females compared with males.

Atrial fibrillation: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for AF per 100 000 people remained relatively stable at 66.9 (IQR 62.2–71.0) in 1990 and 63.0 (IQR 56.4–71.2) in 2019 (see Supplementary material online, *Figure S59*). Stable estimates were also recorded by sex and national income status.

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for AF per 100 000 people were stable at 926.3 (IQR 856.9–989.8) in 1990 and 893.7 (IQR 790.8–1007) in 2019 (see Supplementary material online, *Figure S59*).

Atrial fibrillation: disability-adjusted life years

In 2019, AF accounted for 2.4 million DALYs, <3% of all DALYs due to CVD. The median age-standardized DALYs due to AF were estimated at 128.9 (IQR 116.1–145.8) per 100 000 inhabitants of ESC member countries (see Supplementary material online, *Figure S60*), with little difference by sex or national income status. Time-series analysis showed little change in age-standardized DALYs due to AF between 1990 and 2019.

Rheumatic heart disease

Rheumatic heart disease, a chronic autoimmune valvulitis due to rheumatic fever, is defined by IHME as a clinical diagnosis by a physician.[230] It is a disease of poverty driven by poor housing and overcrowding which in 2015 affected 33.4 million people globally and caused 319 400 deaths most of which occurred in low- and

lower-middle-income countries.[13] In a recent meta-analysis[231] that included 1 090 792 participants from 82 studies, the overall prevalence estimates for RHD using WHO criteria were 11.3% (IQR 7.2–16.2%), varying inversely with national income status. In response to the continuing high prevalence of RHD in developing countries, the WHO has endorsed a strategy that includes improving living conditions of at-risk populations, treating all patients with streptococcal pharyngitis with penicillin and using antibiotic prophylaxis in persons with a history of RHD to prevent recurrence.[232]

Rheumatic heart disease: national statistics

Incidence In 2019, there were an estimated 152 700 new cases of RHD in the 57 ESC member countries, with a median age-standardized incidence per 100 000 inhabitants of 4.7 (IQR 3.0–8.1) (see Supplementary material online, *Figure S61*). Incidence estimates exceeded 40 per 100 000 people in Albania, Armenia, Azerbaijan, Republic of Georgia, Kyrgyzstan, and Uzbekistan.

Prevalence In 2019, there were an estimated 2.3 million people living with RHD across ESC member countries. The estimated age-standardized prevalence rate per 100 000 was 58.2 (IQR 33.0–139.9), ranging from <25 in Denmark, Finland, Greece, Iceland, Malta, Norway, and Sweden to >700 in Albania, Armenia, Azerbaijan, Republic of Georgia, Kyrgyzstan, and Uzbekistan (see Supplementary material online, *Figure S61*).

Rheumatic heart disease: stratification by sex

Incidence There was a small excess of new cases of RHD in females living in ESC member countries compared with males (84 700 vs. 67 900) and this was reflected in the estimated median age-standardized incidence rate per 100 000 inhabitants which was also higher in females [5.3 (IQR 3.2–9.3) vs. 4.3 (IQR 2.9–6.9)] (see Supplementary material online, *Figure S62*.

Prevalence In 2019, more females than males were estimated to be living with RHD (1.3 million vs. 1.0 million) across ESC member countries. The median age-standardized prevalence estimates for RHD per 100 000 people were higher for females than males [63.4 (IQR 36.1–158.1) vs. 54.0 (IQR 30.0–112.7)]. Rates for females and males were lowest in Finland (20.2 and 15.4) and highest in Armenia (872.6 and 715.9) (see Supplementary material online, *Figure S62*).

Rheumatic heart disease: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for RHD per 100 000 people were twice as high in middle-income countries compared with high-income countries [8.0 (IQR 4.5–37.0) vs. 4.2 (IQR 2.6–5.7)] (see Supplementary material online, *Figure S62*). In middle-income countries, incidence estimates per 100 000 people ranged from 2.2 in Turkey to 45.9 in Uzbekistan and in high-income countries from 1.5 in Finland to 9.0 in Lithuania.

Prevalence The median age-standardized prevalence estimates for RHD per 100 000 people were more than three times as high in middle-income countries compared with high-income countries [134.7 (IQR 59.7–642.3) vs. 39.8 (IQR 28.4–67.6)] (see Supplementary material online, *Figure S62*). The increased prevalence of RHD in middle-income countries was similar for females and males.

Rheumatic heart disease: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for RHD per 100 000 people living in the 57 ESC member countries declined from 7.8 (IQR 4.6–14.6) to 4.7 (IQR 3.0–8.1) (*Figure 37*). Incidence estimates declined in all but three high-income countries (Belgium, Netherlands, Slovakia) and in all but five middle-income countries (Republic of Georgia, Kyrgyzstan, Libya, Syrian Arab Republic, and Uzbekistan).

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for RHD per 100 000 people declined from 82.7 (IQR 44.5–218.4) to 58.2 (IQR 33.0–139.9) (see Supplementary material online, *Figure S63*). Declines of about 30% were seen in both middle-income and high-income countries.

Rheumatic heart disease: disability-adjusted life years

In 2019, RHD accounted for an estimated 693 000 DALYs across ESC member countries, <1% of all DALYs due to CVD. The median age-standardized DALYs due to RHD were 33.3 (IQR 20.4–53.4) per 100 000 inhabitants of ESC member countries, with little difference by sex (see Supplementary material online, *Figure S64*). More than twice as many DALYs due to RHD were recorded in middle-income countries compared with high-income countries [58.4 (IQR 34.4–84.2) vs. 24.3 (IQR 15.4–33.3)]. Time-series analysis showed steep declines in age-standardized DALYs due to RHD between 1990 and 2019 from 90.5 (IQR 56.1–412.0) to 33.3 (IQR 20.4–240.3) (see Supplementary material online, *Figure S65*).

Calcific aortic valve disease

Calcific aortic valve disease (AVD) is defined by IHME as 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.[233] It is a degenerative disorder that is relatively uncommon before the age of 65 years except when the valve is bicuspid when it may develop earlier. Presentation is usually with aortic stenosis which is now one of the most common types of valvular heart disease in Europe and North America, although in low and middle-income countries RHD remains more common. Calcific aortic stenosis affects about 5% of the population at age 65 years with increasing prevalence as age advances.[234,235] Increasing life expectancy, particularly in low and middle-income countries, is likely to result in a substantial future burden of calcific AVD.

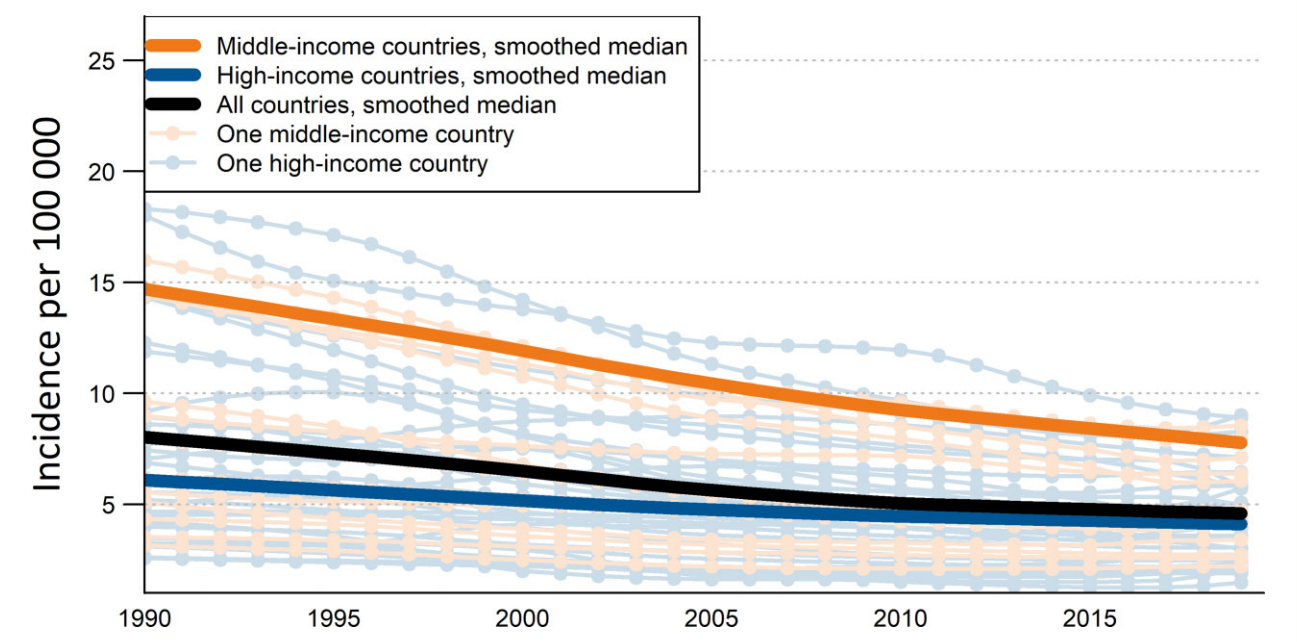


Figure 37 Time series: age-standardized incidence of rheumatic heart disease in European Society of Cardiology member countries (1990–2019).

Aortic valve disease: national statistics

Incidence In 2019, there were an estimated 248 300 new cases of calcific AVD in the 57 ESC member countries, with a median age-standardized incidence per 100 000 people of 12.6 (IQR 3.4–22.7) (*Figure 38*). Incidence rates were <2 per 100 000 people in Algeria, Kyrgyzstan, Lebanon, Libya, Syrian Arab Republic, Morocco, Tunisia, and Turkey and >40 per 100 000 people in Austria, Croatia, Estonia, Hungary, Romania, and Slovenia.

Prevalence In 2019, an estimated 4.5 million people were living with calcific AVD across ESC member countries. The estimated age-standardized prevalence per 100 000 was 181.1 (IQR 46.2–389.1), ranging from <15 in Algeria, Egypt, Kyrgyzstan, Lebanon, Libya, Morocco, Syrian Arab Republic, Tunisia, and Turkey to >500 in Austria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Romania, and Slovenia (*Figure 38*).

Aortic valve disease: stratification by sex

Incidence In 2019, there were fewer new cases of calcific AVD in females living in ESC member countries compared with males (107 400 vs. 140 900), but with age standardization, the estimated median incidence rate per 100 000 people was higher in females than males [12.2 (IQR 3.3–21.4) vs. 9.1 (IQR 3.5–25.5)] (*Figure 39*).

Prevalence In 2019, more males than females were estimated to be living with calcific AVD (2.6 million vs. 2.0 million) across ESC member countries. However, the median age-standardized prevalence estimates per 100 000 people were higher for females than males [173.8 (IQR 43.3–322.6) vs. 137.6 (IQR 47.7–477.0)] (see Supplementary material online, *66*). Estimated prevalence rates for females were lowest in Morocco (1.7) and highest in Romania (1023) and for males were lowest in Morocco (4.7) and highest in Estonia (1384).

Aortic valve disease: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for calcific AVD per 100 000 people were four times as high in high-income countries compared with middle-income countries [18.4 (IQR 9.0–30.7) vs. 4.3 (IQR 1.5–15.7)] (*Figure 39*). In high-income countries, incidence rates per 100 000 people ranged from 3.0 in The Netherlands to 62.2 in Slovenia and in middle-income countries from 0.7 in Morocco to 28.3 in Serbia.

Prevalence The median age-standardized prevalence estimates for calcific AVD per 100 000 people were more than three times as high in high-income countries compared with middle-income countries [256.4 (IQR 119.6–455.7) vs. 73.6 (IQR 11.9–279.3)] (see Supplementary material online, *Figure S66*). The increased prevalence of calcific AVD in high-income compared with middle-income countries was particularly marked in females [256.1 (IQR 148.1–379.8) and 38.2 (IQR 6.4–144.8)].

Aortic valve disease: time-series data

Incidence Between 1990 and 2019, the median age-standardized incidence estimates for calcific AVD per 100 000 people increased from 1.6 (IQR 0.7–3.5) to 12.6 (IQR 3.4–22.7)

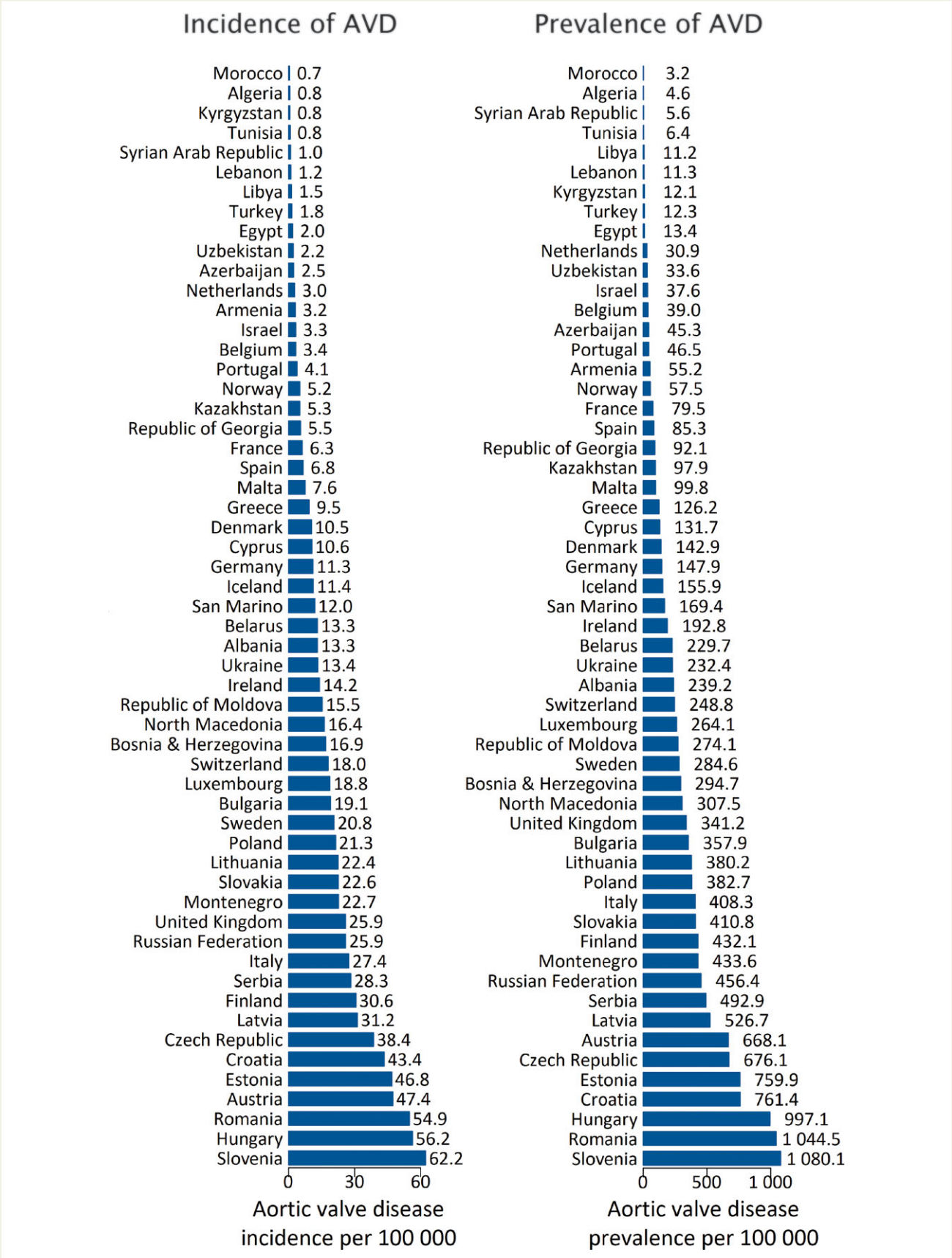


Figure 38 Age-standardized incidence and prevalence of aortic valve disease in European Society of Cardiology member countries.

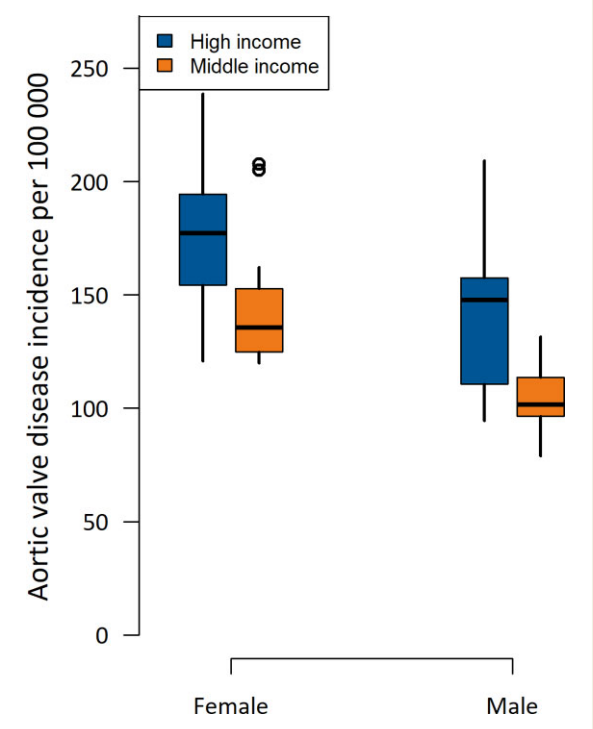


Figure 39 Age-standardized incidence of aortic valve disease in European Society of Cardiology member countries, stratified by sex and national income status.

(*Figure 40*). Incidence estimates increased in all high-income countries but in middle-income countries, increases were less marked and in Algeria, Libya, Morocco, Tunisia, and Syrian Arab Republic incidence estimates remained stable or showed a small decline.

Prevalence Between 1990 and 2019, the median age-standardized prevalence estimates for calcific AVD per 100 000 people increased 15-fold from 12.0 (IQR 5.0–49.7) to 181.1 (IQR 46.2–389.1) (*Figure 40*). Increases in prevalence rates during this period were similar for females and for males but were steeper in high-income countries compared with middle-income countries.

Aortic valve disease: disability-adjusted life years

In 2019, calcific AVD accounted for an estimated 740 000 DALYs, <1% of all DALYs due to CVD. The median age-standardized DALYs due to AVD were 32.9 (IQR 17.9–51.2) per 100 000 people, with estimates lower in females compared with males [29.4 (IQR 13.5–44.9)] vs. [37.4 (IQR 19.0–60.8)]. More than three times as many DALYs due to calcific AVD were recorded in high-income countries compared with middle-income countries [48.6 (IQR 38.0–59.6) vs. 15.1 (IQR 8.1–21.3)] (see Supplementary material online, *Figure S67*). In the period 1990–2019, DALYs due to calcific AVD showed little change in high-income countries, but in middle-income countries increased from 7.9 (IQR 4.2–21.4) to 15.1 (IQR 8.1–21.3) (see Supplementary material online, *Figure S68*).

Degenerative mitral valve disease

Degenerative MVD is defined by IHME as myxomatous degeneration of the mitral valve leading to at least moderate mitral regurgitation, excluding disease due to congenital, rheumatic, or infectious causes.[236] Also excluded is 'functional' mitral regurgitation consequent to left ventricular dilatation. The frequency and severity of degenerative MVD increase with age. Reliable incidence estimates have been hard to generate with a Swedish registry study identifying aortic stenosis[237] and the Euro Heart Survey mitral regurgitation as the most common left-sided valve disorders. There has been more consistency about aetiology with degenerative disease accounting for about two-thirds of cases of mitral regurgitation.[238,239] Like calcific AVD, degenerative MVD is primarily a disease of the elderly and if severe reduces the median survival substantially.[240] Surgical valve repair or replacement can improve the quality of life with evidence that it may also be associated with a survival benefit.[241] Variable symptomatic improvement and mortality reduction has also been reported for percutaneous mitral valve repair.[242,243]

Mitral valve disease: national statistics

Incidence In 2019, there were an estimated 284 200 new cases of degenerative MVD in the 57 ESC member countries, with a median age-standardized incidence per 100 000 people of 16.7 (IQR 2.5–26.9) (see Supplementary material online, *Figure S69*). Incidence rate estimates per 100 000 people varied widely, ranging from <1.0 in Belgium, Cyprus, Iceland, and Portugal to >30 in Croatia, Czech Republic, Hungary, Italy, Norway, Poland, Slovenia, Bosnia and Herzegovina, Republic of Georgia, and Serbia.

Prevalence In 2019, an estimated 7.1 million people were living with degenerative MVD across ESC member countries. The estimated age-standardized prevalence rate per 100 000 people was 360.6 (IQR 47.5–573.2), ranging from <20 in Belgium, Cyprus, Denmark, Iceland, Malta, and Portugal to >1000 in Italy, Norway, and Serbia (see Supplementary material online, *Figure S69*).

Mitral valve disease: stratification by sex

Incidence In 2019, there were more new cases of degenerative MVD in females living in ESC member countries compared with males (173 200 vs. 111 000), but with age standardization, the estimated median incidence rate per 100 000 inhabitants was similar in females and males [17.6 (IQR 2.8–30.0) vs. 14.9 (IQR 2.1–23.7)] (see Supplementary material online, *Figure S70*).

Prevalence In 2019, more females than males were estimated to be living with degenerative MVD (4.4 million vs. 2.7 million) across ESC member countries. Nevertheless, the median age-standardized prevalence estimates per 100 000 people were similar in females and males [363.3 (IQR 53.8–634.6) vs. 337.0 (IQR 38.2–525.6)] (see Supplementary material online, *Figure S70*). Estimated rates per 100 000 for females and for males were lowest in Cyprus (9.6 and 8.9) and highest in Italy (2725 and 1976).

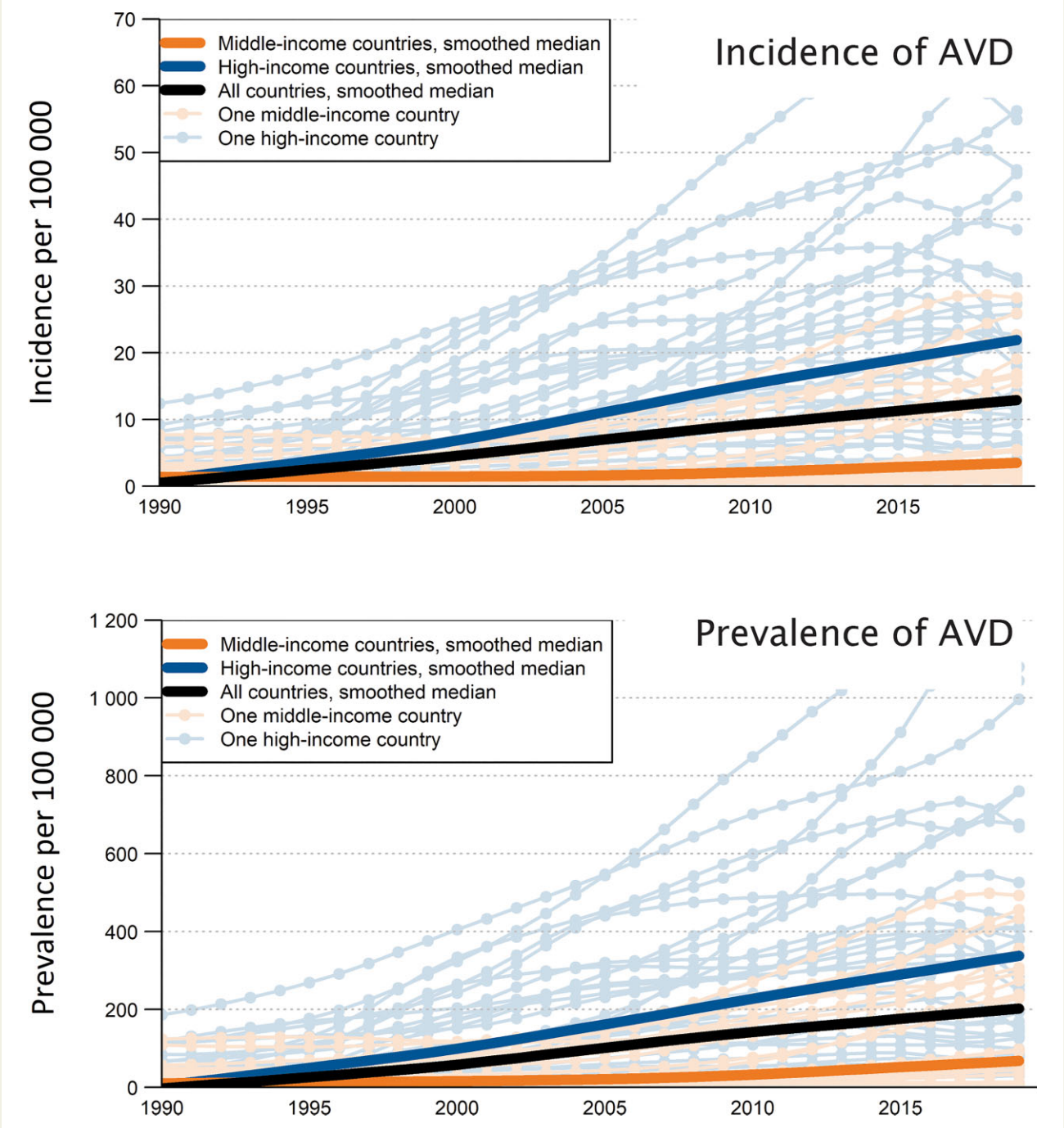


Figure 40 Time series: age-standardized incidence and prevalence of aortic valve disease in European Society of Cardiology member countries (1990–2019).

Mitral valve disease: stratification by national income status

Incidence In 2019, the median age-standardized incidence estimates for degenerative MVD per 100 000 people were four times as high in middle-income countries compared with high-income countries [19.2 (IQR 2.7–25.4) vs. 4.8 (IQR 1.5–28.3)] (see Supplementary material online, *Figure S70*). In middle-income countries, incidence rates per 100 000 people ranged from 2.5 in Morocco to 52.9 in Serbia and in high-income countries from 0.7 in Cyprus to 120.2 in Italy.

Prevalence The median age-standardized prevalence estimates for degenerative MVD per 100 000 people were nearly five times as high in middle-income countries compared with high-income countries [429.4 (IQR 54.2–536.0) vs. 87.6 (IQR 28.2–622.4)] (see Supplementary material online, *Figure S70*). The increased prevalence of MVD in high-income compared with middle-income countries was similar in females and males.

Mitral valve disease: time-series data

Incidence Between 1990 and 2019, there was no change in the median age-standardized incidence of degenerative MVD per 100 000 people living in ESC member countries. In 1990, the median incidence estimate was 16.7 (IQR 2.4–23.2) and in 2019, it was essentially the same at 16.7 (IQR 2.5–26.9).

Prevalence Median age-standardized prevalence estimates for degenerative MVD per 100 000 people showed little change between 1990 and 2019 [357.3 (IQR 44.9–498.1) vs. 360.6 (IQR 47.5–573.2)].

Mitral valve disease: disability-adjusted life years

In 2019, degenerative MVD accounted for an estimated 269 000 DALYs, <0.5% of all DALYs due to CVD. The median age-standardized DALYs due to degenerative MVD were 11.9 (IQR 8.5–17.3) per 100 000 inhabitants of ESC member countries, with estimates similar in females compared with males [12.6 (IQR 8.1–19.2) vs. (11.0 (IQR 8.0–15.4)]. DALYs due to degenerative MVD were similar in middle-income countries compared with high-income countries [12.0 (IQR 7.3–16.9) vs 11.8 (IQR 9.8–17.3)]. In the period 1990– 2019, DALYs due to degenerative MVD showed little change in middle-income countries, but in high-income countries declined from 18.3 (IQR 12.9–23.4) to 11.8 (IQR 9.8–17.3).

Out-of-hospital cardiac arrest

Out-of-hospital cardiac arrest (OHCA) is defined as the cessation of cardiac mechanical activity that is confirmed by the absence of signs of circulation and that occurs outside of a hospital setting. It is a leading cause of death in Europe.[244] The median survival-to-discharge rates of OHCA range from 3 to 10% worldwide, although survival rates of 20–40% in certain areas have been reported.[245–249] Acute myocardial infarction is the leading cause of OHCA (approximately 50% of cases) and ventricular tachycardia in ischaemic cardiomyopathy second (40% of cases).[250] Non-cardiac causes include pulmonary embolism, severe electrolyte disturbances, tension pneumothorax, and toxins. Data on incidence, management, and outcomes in Europe mainly come from the European Registry of Cardiac Arrest (EuReCa), covering 29 countries of which 20 provide data on OHCA, as summarized below.[244,251]

Out-of-hospital cardiac arrest: incidence

The EuReCa registry reports an incidence of OHCA of 89 per 100 000 people per year (range 53–166) across participating countries. Patients had a median age of 67 years (IQR 56–75 years) and 66% (IQR 53–73%) were male. The majority of OHCAs (70%) occurred at home and 67% were witnessed. Of all registered OHCAs, 20% had an initial shockable rhythm. In total, 91% had an identified medical cause, predominantly myocardial infarction.

Out-of-hospital cardiac arrest: management

Differences in the management of OHCA across participating EuReCa countries likely contribute to differences in outcomes. Response time by emergency personnel, bystander rate, and availability of an automated external defibrillator were important predictors of outcome. In 32% of countries, a response time of <10 min was achieved in urban areas; but in rural areas, response times were longer. The bystander rate was on average 58% in EuReCa countries (range 13–83%) and had increased significantly over the last 3 years from 30 to 53%. The use of AEDs ranged from 4 to 59%.

Out-of-hospital cardiac arrest: outcomes

The median EuReCa registry survival to discharge was 8% (range 0–18%). Recovery of spontaneous circulation (ROSC) before transportation was achieved in 58% of cases with an initial shockable rhythm and in 26% of patients with an initial non-shockable rhythm. In total, 64% of patients were pronounced dead on scene. Of patients transported to the hospital, survival-to-discharge was 26%. In countries that practised withdrawal of life-sustaining treatment, good neurological outcomes was achieved in 90% of survivors compared with 50% in non-practising countries.

Summary

- Declines in the incidence of CVD across ESC member countries have been small during the last 30 years and in some middle-income countries, modest increases have been recorded.
- Incidence rates of IHD and stroke have also shown variable declines during the last 30 years but continue to exact a considerable toll on population health, accounting for an estimated 70 million DALYs across ESC member countries in 2019.
- The burden of CVD falls hardest on middle-income ESC member countries where estimated incidence rates are ~30% higher compared with high-income countries. This is reflected in DALYs due to CVD which are nearly four times as high in middle-income compared with high-income countries.
- During the last 30 years, incidence rates for RHD across ESC member countries have declined by 40%. Rates remain twice as high in middle-income compared with high-income countries.
- The incidence of calcific AVD has increased seven-fold during the last 30 years, with age-standardized rates four times as high in high-income compared with middle-income countries.
- Out-of-hospital cardiac arrest is a leading cause of death in Europe, caused by acute myocardial infarction in about 50% of cases.
- Median EuReCa registry survival to discharge in patients with OHCA was 8%.

Comment

In the current 2021 iteration of CVD statistics, the granularity of disease burden has been further enhanced by the inclusion of new data on RHD, calcific AVD degenerative MVD, and OHCA. The importance of RHD is often overlooked in the high-income countries of Western Europe where incidence rates are now very low. Although the incidence is also declining elsewhere, the ESC Atlas data show that RHD remains a significant health problem in middle-income countries where it accounts for twice as many DALYs compared with high-income countries. Degenerative MVD too is found more commonly in middle-income compared with high-income countries, particularly

in females, but rate estimates vary widely between countries perhaps reflecting misclassification of functional mitral regurgitation or trivial mitral regurgitation identified during echocardiography. Although rates have been stable the last 30 years, the risk of left-sided valve disease increases with age[252] and the expectation is that degenerative MVD will become an increasing health issue among the ageing populations of ESC member countries. Calcific AVD also affects older people[252] and is already more common in high-income countries with incidence rates increasing eight-fold in the last 30 years. As life expectancy increases in middle-income countries, there is likely to be a substantial future burden of calcific AVD that will bring with it the need to expand interventional capacity to provide the necessary treatment.

At present, IHD and stroke remain the most prevalent manifestations of CVD affecting ESC member countries. The ESC Atlas data show substantial declines in the age-standardized incidence of both disorders have occurred in the last 30 years with smaller declines in disease prevalence. These changes no doubt reflect a variety of factors including lifestyle adjustments, risk factor modification, treatment effects, and national policy initiatives, and for AF-related stroke, for example, this is born out in other large-scale analyses.[253] Welcome though these changes are, the impact of IHD and stroke on population health remains devastating with these disorders accounting for an estimated 70 million DALYs across ESC member countries. The human costs in terms of sickness and disability are amplified by the economic consequences of absenteeism from work, lost productivity, and reduced life expectancy. The ESC Atlas data remind us that these costs continue to fall most heavily on middle-income countries where national action is now needed to reduce modifiable drivers of CVD such as smoking and hypertension to levels achieved in many high-income countries. PAD, although as prevalent as stroke in ESC member countries, is commonly asymptomatic and under-diagnosed, possibly accounting for it being reported more commonly in high-income countries where diagnostic technology is more readily available. Peripheral arterial disease like AF accounts for $<1\%$ of all DALYs due to CVD, but the association of AF with stroke has made it one of the most important disorders in contemporary cardiological practice because of the benefits of treatment for protecting against cerebral embolism.

Cardiovascular disease mortality

Mortality data are commonly used in disease surveillance. Death from a disease can provide an indication of its burden within a population. In addition, death is one of the most accurately ascertained outcomes. In most countries, the registration of death is a legal requirement, such that death and cause of death are regularly and reliably recorded. The cause of death is documented in a standardized manner globally, according to the WHO International Classification of Diseases. These data can be used to compile mortality measures for the population, including the absolute number of deaths and rates that adjust for differences in population size and age structure. Thus, mortality data may be used to both assess disease burden and plan health provision within an individual population and to compare CV health between different populations.

Complete coverage, accuracy, and timeliness are key for quality mortality data and essential for reliable assessment and tracking of health indicators. Although death registration systems are universal, they can vary in quality and completeness. In most developed countries, this system is relatively complete, and the mortality rates calculated from the data are reasonably accurate. However, in less-developed countries, health record systems can be incomplete such that many deaths may go unreported, particularly if they occur outside of the health system.[254,255]

The WHO considers that most of the ESC member countries have high-quality death records with relatively high levels of usability, accompanied by low levels of garbage coding.[256] This makes mortality data an informative way to describe the burden of CVD throughout the region.

In this section, CVD mortality data are presented for a maximum of 54 contributing ESC member countries, or fewer depending on the completeness of the mortality statistics of interest. There are no data for Algeria, Libya, or the Republic of Kosovo.

Number of deaths

The number of deaths from a disease demonstrates the absolute burden of that disease within a population. Although presenting just the total number of deaths of a disease limits our ability to compare between populations, it does allow us to compare between diseases in the same population.

Despite sustained declines in CVD mortality in many countries across Europe, CVDs have remained the most common cause of death within the region.[257–259] In some countries, however, improvements in CVD prevention and treatment have led to cancer becoming the leading cause of death.[259]

- **National statistics stratified by sex.** Cardiovascular diseases remain the most common cause of death within ESC member countries, accounting for just under 2.2 million deaths in females and just over 1.9 million deaths in males, in the most recent year of available data (*Figure 41*). These equate to 45 and 39% of all deaths in females and males, respectively. Ischaemic heart disease is the most common cause of CVD death accounting for 38% of all CVD deaths in females and 44% in males. Stroke is the second most common cause of CVD deaths, accounting for 26% of all CVD deaths in females and 21% in males.
- **CVDs vs. cancer.** Although the total number of CVD deaths across ESC member countries far exceeds the number of cancer deaths for both sexes (just over 900 000 and 1.1 million in females and males), numbers of cancer deaths are now greater than CVD deaths in several countries, more commonly for males ($n = 15$ countries) than females ($n = 5$ countries). These countries include Denmark, Israel, the Netherlands, Republic of Republic of San Marino, and the UK for both males and females and, additionally, Belgium, France, Ireland, Italy, Luxembourg, Norway, Portugal, Slovenia, Spain, and Switzerland for males only.
- **National income status.** For both males and females, a greater proportion of deaths are caused by CVD in middle-income countries compared with high-income countries (*Figure 42*). All countries where cancer has become the most common cause of death are high-income countries, as reflected in the

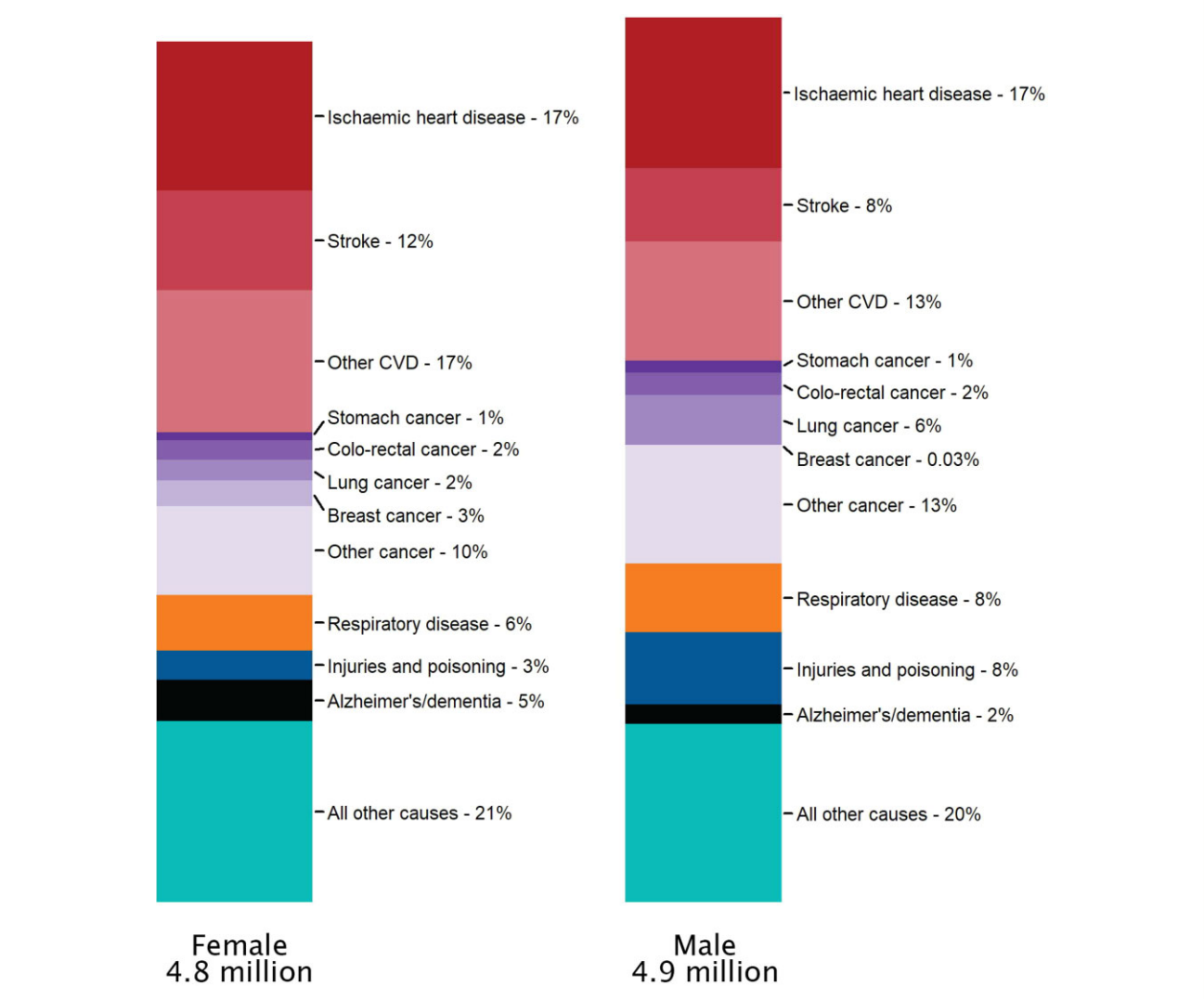


Figure 41 National causes of death in females and males in European Society of Cardiology member countries.

higher median proportion of all deaths caused by CVD in middle-income countries (males 47%, females 56%) than high-income countries (males 33%, females 35%).

Premature cardiovascular disease mortality

The risk of occurrence and death from CVDs is greater with increasing age. Epidemiologic trends towards an ageing global population are expected to result in greater burden from age-related illnesses, such as CVDs.[260] Individuals dying prematurely from CVD are of greater concern, as we know that there are effective strategies for the prevention of CVDs at younger ages. Premature CVD mortality is, therefore, an important metric of unfulfilled life expectancy that identifies an opportunity for increased prevention efforts.[261]

Although there is no standard definition of premature death, it is usually applied to deaths occurring in people younger than 65 or 75 years.[262] Here, we define it as death occurring before the age of 70 years, to align with WHO targets presented later in this publication.[263]

- **National statistics stratified by sex.** In both females and males, CVDs account for a smaller proportion of premature deaths than deaths across all ages (*Figure 43*). In individuals aged <70 years old, CVD accounts for 29 and 33% of all deaths in females and males, respectively. This equates to 335 941 deaths among females and 718 932 deaths among males.
- **CVD vs. cancer.** Cardiovascular disease remains the most common cause of premature death for males in ESC member countries, but this is not the case for females in whom cancer now causes more premature deaths ($n = 368\,856$) than any other disease. However, the number of males dying from cancer before the age of 70 ($n = 511\,457$) is higher than for females, reflecting the lower risk of overall and CVD-specific premature mortality among females.
- **National income status.** A greater proportion of all premature deaths were attributed to CVD in middle-income countries

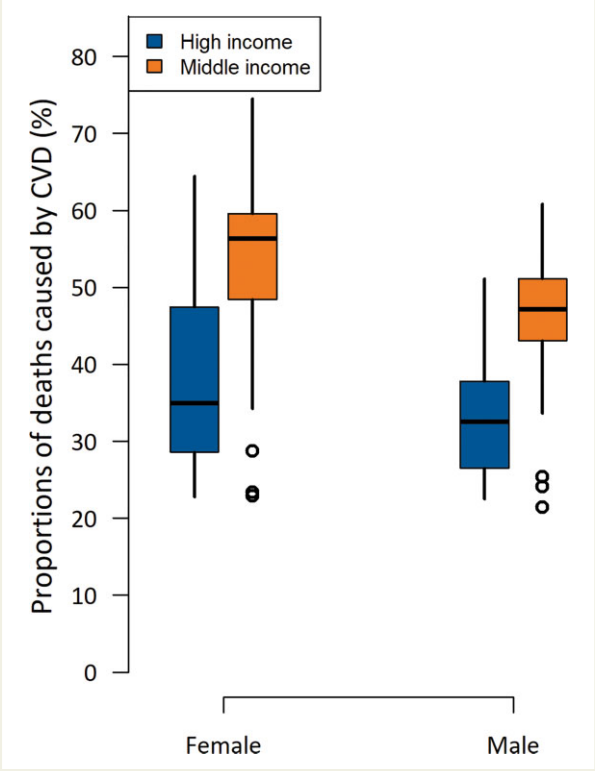


Figure 42 Proportion of deaths caused by cardiovascular disease in European Society of Cardiology member countries, stratified by sex and national income status.

compared with high-income countries, for both males and females. This disparity is greater for females, with a median of 36% of all premature deaths caused by CVD in middle-income countries compared with 16% in high-income countries. For males, the corresponding figures are 36 and 24% in middle- and high-income countries, respectively (*Figure 44*).

Potential years of life lost due to cardiovascular disease

Potential years of life lost (PYLL) is a summary measure of premature mortality. Potential years of life lost estimates the years of potential life lost due to premature death, giving greater weight to deaths at a younger age and lower weight to deaths at older age.[11] Potential years of life lost 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 the total PYLL in a population caused by a specific disease.[11]

- **National statistics stratified by sex.** Cardiovascular diseases accounted for 33 million and 41 million PYLLs, within ESC member countries, among females and males, respectively, totalling 40% of all years lost for females and 35% for males. In comparison, cancer accounted for 25% of PYLLs in females and 24% of PYLLs in males, equivalent to 21 million and 28 million PYLLs, respectively.
- **Stratification by national income status.** Cardiovascular diseases accounted for a greater proportion of PYLLs averaged across middle-income compared with high-income countries for both females (45 vs. 31%) and males (40 vs. 29%). The reverse is true for cancer, where the median proportion of PYLLs was lower in middle-income compared with high-income countries in females (21 vs. 34%) and males (20 vs. 34%). Large variations are seen between the different countries, with the lowest proportion of country-specific CVD PYLLs similar between high- and middle-income countries. In 9 (45%) of the 20 middle-income countries for which data were available, more than 40% of total PYLLs in males were attributed to CVDs. This was the case for only two high-income countries, Latvia and Romania in which more than 40% of total PYLLs were attributable to CVD. For females, seven middle-income countries and three high-income countries (Lithuania = 50%, Latvia = 52%, Romania = 52%) had ≥50% of their total PYLLs attributable to CVDs (*Figure 45*).

Cardiovascular disease crude mortality rates

Absolute mortality measures, such as the number of deaths or total PYLLs, may be misleading as they do not account for population size. Comparisons between countries and over time can use a crude rate which considers differences in population size. Crude rates are calculated by dividing the total number of deaths (or PYLLs) by population size, and commonly expressed as per 100 000 individuals within the population.[264]

- **National statistics stratified by sex.** The median crude mortality rates for CVD per 100 000 people were higher for females than males in both high-income (328 vs. 311) and middle-income countries (449 vs. 458) (*Figure 46*, see Supplementary material online, *Figure S71*). In general, country-level crude death rates decreased with increasing GDP and relative CHE. However, this relationship was affected by greater variation at lower GDP and CHE values, with some countries demonstrating low crude rates despite lower values for both (see Supplementary material online, *Figures S72 and S73*).
- **Stratification by national income status.** In general, the median crude CVD mortality tended to be higher in middle-income compared with high-income countries, but there was considerable heterogeneity between countries. For instance, three of the five countries with the lowest crude mortality CVD rates in males were middle-income (Tunisia, Lebanon, Syrian Arab Republic) whereas three of the five countries with the highest crude mortality rates were also middle income (Belarus, Ukraine, and Bulgaria). For females, four of the five countries with the lowest crude rates were middle income (Tunisia, Lebanon, Kazakhstan, Syrian Arab Republic), whereas three of the five countries with the highest rates were (Serbia, Ukraine, Bulgaria). Israel was the one high-income country that had among the five lowest crude rates for males and females, whilst Latvia, a high-income country, was among the five countries with the highest crude rates for both sexes.
- **Premature crude mortality.** The disparities between high- and middle-income countries became more apparent when

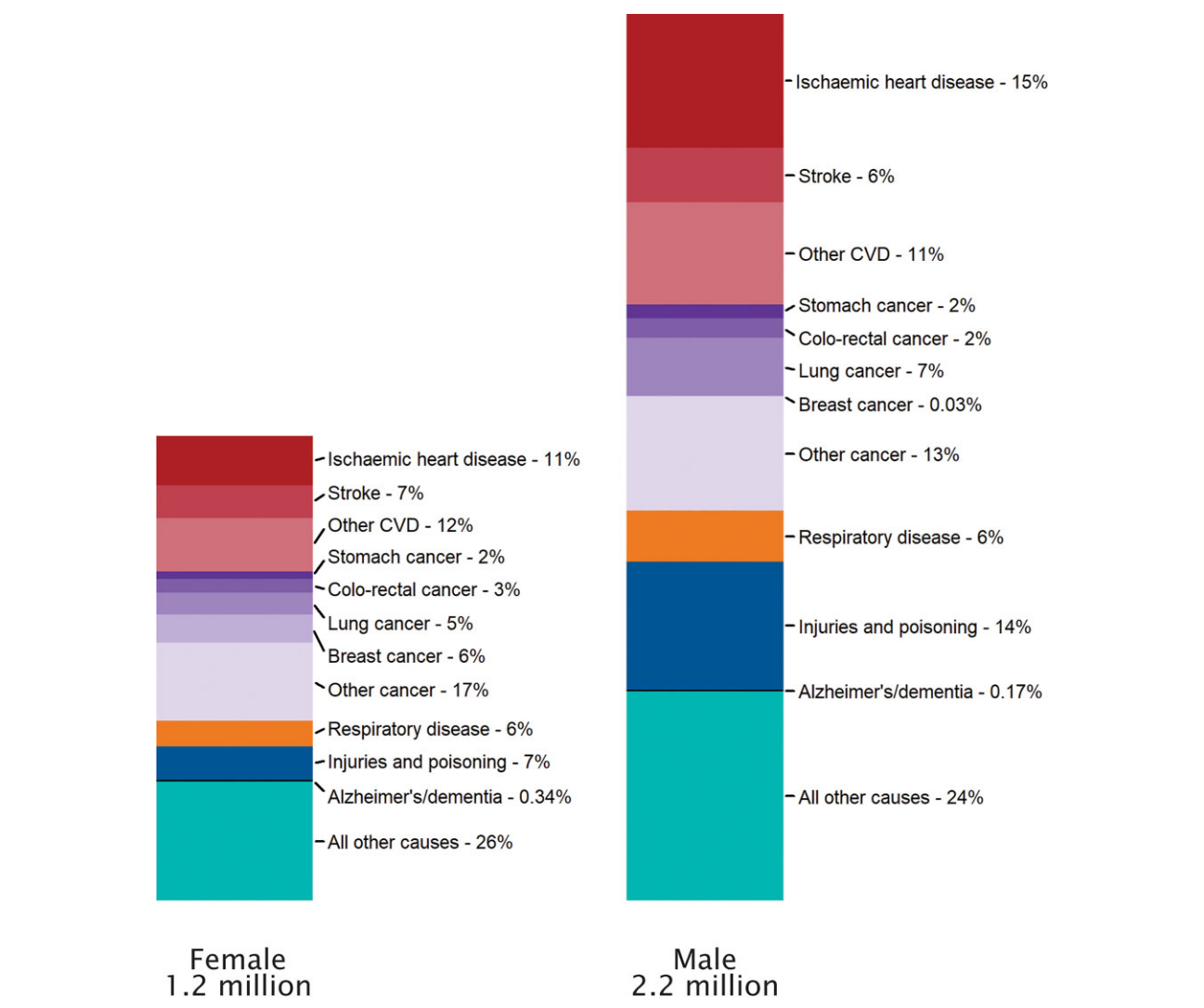


Figure 43 Premature deaths by cause in females and males in European Society of Cardiology member countries.

crude rates for premature mortality (<70 years) were considered (*Figure 47*). There were only two (Lebanon, Tunisia) of the 19 middle-income countries for which data were available, with a crude premature mortality rate for males below the median of 67/100 000 found in high-income countries. Among the 32 high-income countries, Latvia, Lithuania, Romania, and Hungary reported crude rates greater than the middle-income country median of 192/100 000. Among females, Tunisia was the only middle-income country with a crude premature mortality rate lower than the high-income median of 28/100 000. Conversely, Latvia, Hungary and Romania were the only high-income countries with crude premature CVD mortality rates for females higher than the middle-income median of 92/100 000. A similar relationship was found between premature CVD crude mortality rates (<70 years) and both GDP and CHE in both sexes, as to that found for crude mortality rates for all ages (see Supplementary material online, *Figures S76 and S77*).

- **Time-series data—crude mortality (all ages).** Although the median crude mortality rates in ESC member countries declined in both males (relative decrease of 15%) and females (relative decrease of 12%) between 1990 (or closest year of data) and the most recent year of data, differences by national income status were apparent (see Supplementary material online, *Figure S74*). During this period, increases in crude CVD mortality rates among females and males were recorded in 16 and 18 of the 20 middle-income countries with data available, respectively. Egypt, Kazakhstan, Kyrgyzstan, and the Russian Federation were the only middle-income countries showing a decrease in crude rates for females and Kazakhstan and Serbia were the only middle-income countries showing decreases for males. Of the 32 high-income countries, with data available, only Latvia and Lithuania showed increases in crude CVD mortality rates for both females and males; increases for females were also recorded within Croatia. Although high-income countries had a median relative decrease in crude rates of 31% in males and females, compared with a median relative increase of 15% in females and 27% in males in middle-income countries, those countries with a net increase in crude CVD mortality

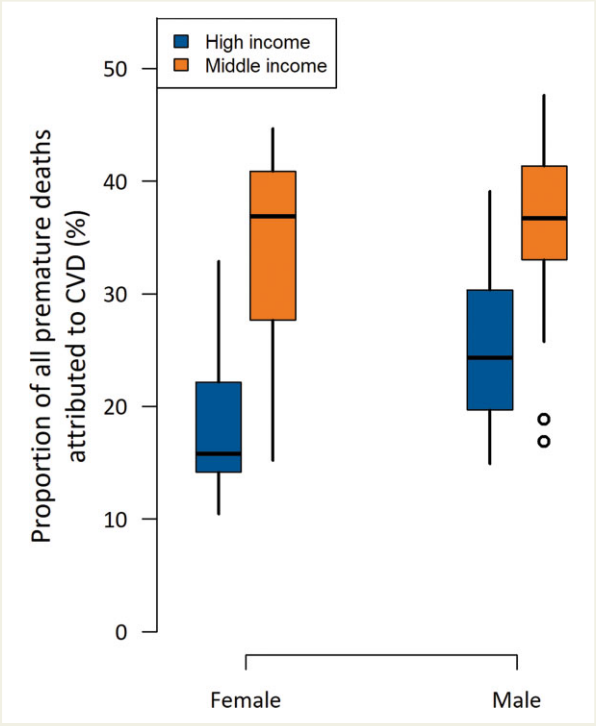


Figure 44 Proportion of all premature deaths attributed to cardiovascular disease in European Society of Cardiology member countries, stratified by sex and national income status.

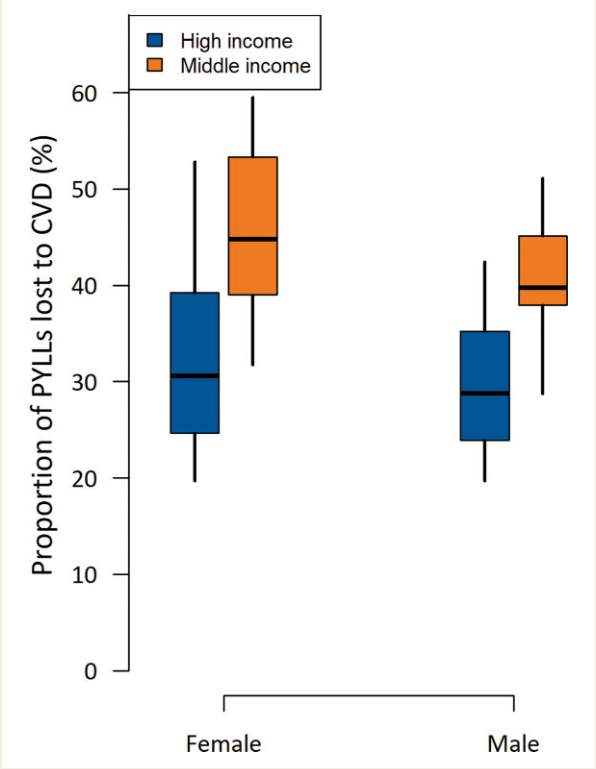


Figure 45 Proportion of potential years of life lost to cardiovascular disease in European Society of Cardiology member countries, stratified by sex and national income status.

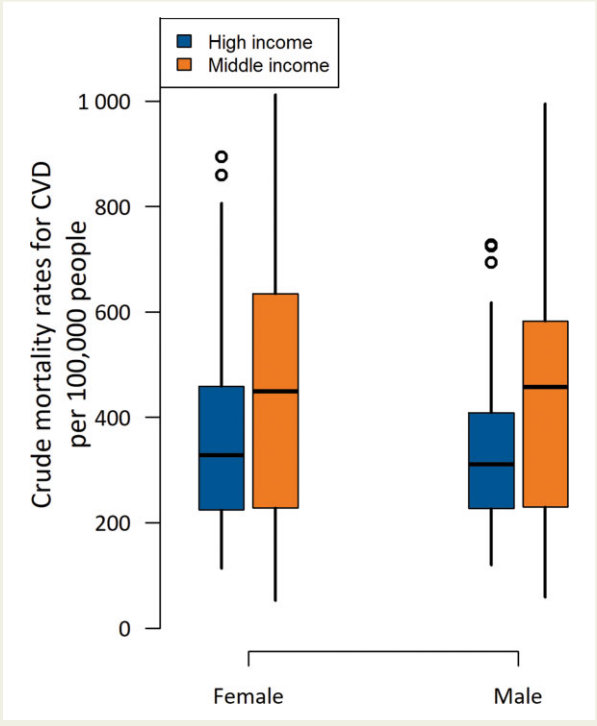


Figure 46 Crude mortality rates for cardiovascular disease per 100 000 people in European Society of Cardiology member countries stratified by sex and national income status.

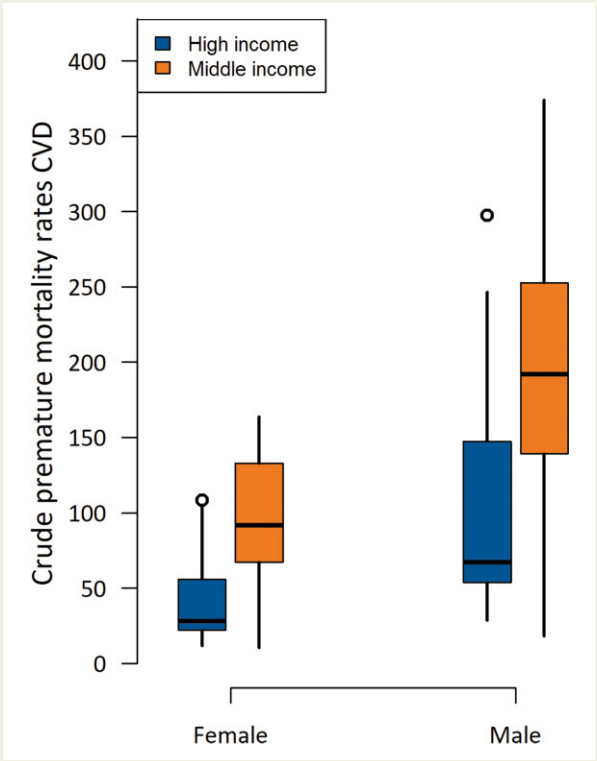


Figure 47 Crude premature mortality rate from cardiovascular disease in European Society of Cardiology member countries, stratified by sex and national income status.

between 1990 (or closest year of data) and the latest available data demonstrated large fluctuations in values, with no consistent trend over time.

- **Time-series data—premature mortality (<70 years).** Large disparities were found between the sexes in long-term trends in crude premature mortality (see Supplementary material online, *Figure S75*). Although in both males and females, Republic of San Marino was the only country not to record meaningful decreases, between 1990 and the most recent year of data, there were few data points for the country and large fluctuations from year to year. Only 2 of 19 middle-income countries, for which data were available, observed increases in crude premature mortality rates in females, compared with 11 for males. The median decreases in premature mortality were greater in high-income countries for females (56%) than middle-income countries (17%). In males, the decreases in the median values in high-income countries (−50%) compared with increases in middle-income countries (+4.4%).

Cardiovascular disease age-standardized mortality rates

For ageing-associated diseases such as CVD, the number of deaths per 100 000 population is influenced by the age distribution of that population. A population with a greater distribution of older individuals would be expected to experience a greater number of CVD deaths. Although we can make comparisons between populations of different sizes by calculating crude rates, it is often necessary to calculate age-standardized rates which adjust for population age distribution as well.[265]

Age-standardized mortality rates adjust for differences in the age distribution of populations by applying the observed age-specific mortality rates for each population to a standard population. A comparison of ASMRs for different countries will be unaffected by any differences in the age distributions of their populations. This can be useful for comparing between countries in Europe, as life expectancy can vary widely.[266]

Age-standardized mortality rates calculated for each country can be thought of as the rate that the countries would have if they had the same population distribution as the standard population. The recommended standard population used for calculating ASMRs within Europe is the 2013 European Standard Population (ESP13).[267]

- **National statistics stratified by sex.** In contrast to crude rates, ASMRs per 100 000 people that adjust for both population size and distribution are lower for females than males in both high-income (266 vs. 372) and middle-income countries (791 vs. 1033) with the median ASMRs just under three times as large in middle-income countries (*Figure 48*).
- **Stratification by national income status.** The median ASMRs for IHD among males are higher than those for stroke in both high-income (IHD ASMR = 153/100 000; stroke ASMR = 72/100 000) and middle-income countries (IHD ASMR = 250/100 000; stroke ASMR = 197/100 000), although the relative difference is much greater in high-income countries. Among females in high-income countries, these differences are lower than for males (IHD ASMR = 75100 000; stroke ASMR = 62/100 000) while in middle-income countries, the median stroke ASMRs are greater than the median IHD ASMRs among females (IHD ASMR = 160/100 000; stroke ASMR = 178.7/100 000). Age-standardized mortality rates are closely correlated with GDP and CHE, with those countries with low GBD or low CHE demonstrating higher ASMR. There is some suggestion of plateauing of ASMRs with increasing GDP and CHE, with those countries above the median values of both measures demonstrating much less variation in ASMRs than those countries below the median.

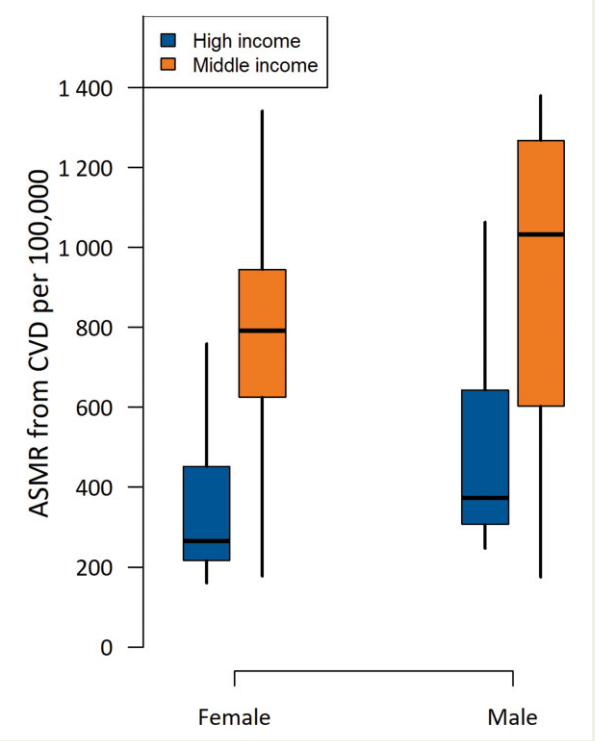


Figure 48 Age-standardized mortality rate from cardiovascular disease per 100 000 people in European Society of Cardiology member countries, stratified by sex and national income status.

- **Time-series data.** Decreases in ASMRs were seen between 1990 (or the closest year of data) and the most recent year of data in both females and males for countries with suitable data available. The median absolute rate decreases were lower in females (decrease of 293/100 000) than males (decrease of 400/100 000) over this period. Relative decreases (*Figure 49*) were also slightly greater in males (47%) than females (42%), although these differences were not so great. High-income countries demonstrated a relative decrease of more than 50% for both males (56%) and females (54%) over this time, with no high-income country experiencing an increase in ASMRs. The median relative decreases were much lower for middle-income countries (females = −10%, males = −14%), with Kyrgyzstan, FYR Macedonia, Turkey, and Uzbekistan demonstrating increases in ASMRs for both sexes; Ukraine and Belarus experiencing increases in males only; and Azerbaijan, Egypt, and Syrian Arab Republic in females only. In all of these countries,

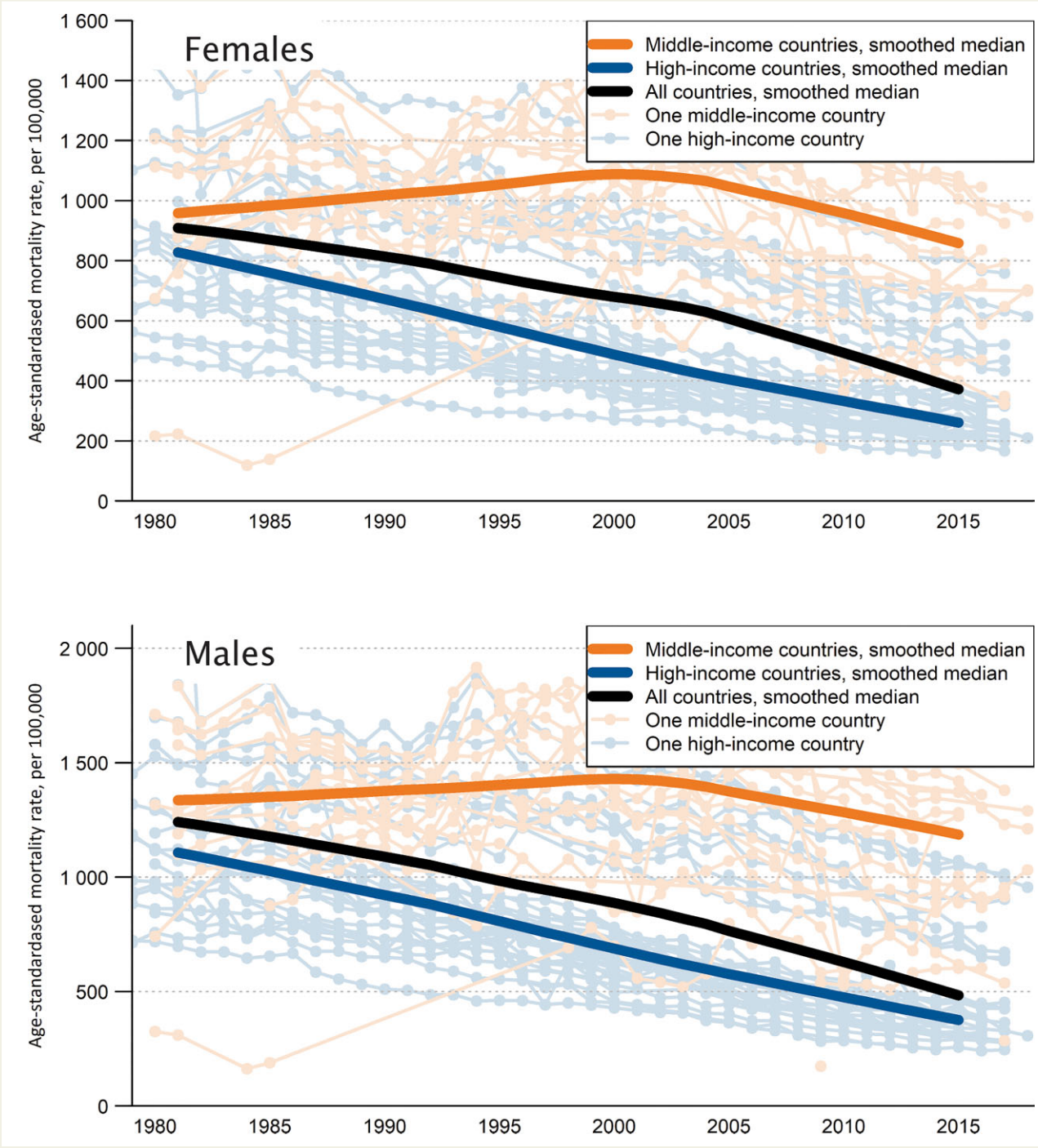


Figure 49 Time series: age-standardized mortality rate from cardiovascular disease per 100 000 people in females and males in European Society of Cardiology member countries (1980–2017).

fluctuating trends after 1990 meant that these countries experienced some decreases in recent years.

Summary

- Cardiovascular disease remains the most common cause of death in the region, accounting for more deaths among females than males, with IHD accounting for 39% of these CVD deaths in females and 45% of those in males.
- Although the total number of CVD deaths across all countries far exceeds the number of cancer deaths for both sexes, there are 15 ESC member countries in which cancer kills more males than CVD and five-member countries in which this is the case for females. All of these countries were classified as high income.

- Cardiovascular diseases remain the most common cause of premature death for males in ESC member countries, but this is not the case for females among whom cancer now causes more premature deaths than any other disease.
- There are large disparities between high- and middle-income countries in the proportion of premature deaths caused by CVD.
- Lebanon and Tunisia were the only two middle-income countries with a crude premature mortality rate for males below the median of 67/100 000 found in high-income countries.
- Latvia Hungary and Romania were the only high-income countries with crude premature CVD mortality rates for females higher than the middle-income median of 92/100 000
- Cardiovascular diseases accounted for 33 million and 41 million PYLLs, within ESC member countries, among females and males, respectively, making up 40% of all years lost for females and 35% for males. In comparison, cancer accounted for 25% of PYLLs in females and 24% of PYLLs in males, equivalent to 21 million and 28 million PYLLs, respectively.

Comment

Cardiovascular disease remains the most common cause of death within the ESC member countries and continues to be a major concern for health, social, and economic services. Although more females than males die from CVD, higher ASMRs and premature mortality measures among males suggest that females are dying from CVD at older ages. Although females may experience some physiological protection from CVD, particularly up until menopause,[268] risk factor differences between the sexes may explain some of this inequality.

The transition towards cancer as the most common cause of death in a number of high-income countries, comes as a result of substantial decreases in CVD mortality in the preceding 30–40 years, most likely due to improved prevention and treatment.[269] However, inequalities in mortality outcomes between countries give cause for concern. Further investigation into these disparities is required. In particular, a review as to how in certain countries, CVD is no longer the most common cause of death, along with a contextual analysis of risk factor prevalence, treatment, and policy approaches in those countries in which it remains the greatest burden, may help to target approaches and narrow these inequalities.

The description of trends as presented in this publication is a first step in identifying disparities between middle-income and high-income countries and this should be supported by further research incorporating more in-depth time-series analyses, that may help us map recent changes in CVD outcomes within ESC member states. Previous studies have identified recent plateauing of trends in both IHD and stroke mortality in European countries, that may not have been identified through a simple description of trends over a longer period of time.[257,258] This would be an obvious first step in analysing these data, allowing more complex follow-up work to investigate the reasons for these trends.

Such work undertaken to understand why these inequalities exist should include improved and standardized surveillance on mortality and other epidemiological measures related to CVD within countries. An investigation into population-level prevention and treatment strategies adopted by member countries, along with the country-level experience in their implementation, could help in the scale up of evidence-based strategies throughout the region.

Finally, the mortality data presented here were collected before Coronavirus disease 2019 (COVID-19) was first reported and the global pandemic ensued. Studies have reported an association between COVID-19 and CVD, with data demonstrating that COVID-19 can induce CVD and that pre-existing CVD is linked with an increased risk of death in patients with COVID-19.[270] The impact of COVID-19 on CVD mortality within ESC member states may not be known for some time, as there is a lag between death data collection, process, and release. This is a key focus for future years, especially due to concerns of a decrease in the ability of health systems to diagnose and treat CVD patients, in the light of the burden of COVID-19 on resources. An initial focus could be to work with hospitals and CV staff to determine how they have been impacted and to identify what steps would be beneficial in helping them restore CVD treatment services, as the pressure from COVID-19 recedes.

Cardiovascular healthcare delivery

The development and implementation of novel pharmacological and technological treatments, combined with policy initiatives to deliver reductions in CV mortality during the past 50 years, have been a standout achievement of contemporary medicine. The evidence base for these treatments has been meticulously developed through landmark randomized trials that have confirmed the efficacy of nearly all the commonly used pharmacotherapeutic agents and also many of the surgical and percutaneous interventional technologies. Increasingly, it has been these interventional technologies that have come to dominate cardiology practice, and this has brought with it a financial burden that many countries can ill afford. Already the healthcare budget exceeds 10% of GDP in many Western countries,[271] and recent predictions indicate that novel medical technologies will be a more significant factor than population ageing in driving up healthcare costs during the next 35 years.[272]

In this section, human and capital resource statistics are presented, as they affect CV healthcare delivery in 57 ESC member countries. These are 2019 statistics compiled in a 2020 survey of the member countries undertaken as part of the ESC Atlas programme. These data highlight areas of shortfall in CV healthcare delivery and provide policymakers with an indication of where corrective action is needed.

Cardiological specialists

There is no internationally recognized definition of what constitutes a cardiologist. While some countries require specialist training over several years, others are more permissive and allow the use of the title ‘cardiologist’ on a more arbitrary basis. This can make international workforce comparisons hard to interpret. Also unclear is what constitutes optimal specialist provision. Nevertheless, specialist involvement in CV care undoubtedly improves outcomes,[273] and this is reflected in contemporary quality

indicators.[274–276] A more diversified cardiological workforce might also improve outcomes in countries where cardiology remains a male-dominated speciality.[277,278]

- **Human resource.** Across all ESC member countries in 2019, there was a median of 85.1 (IQR 60.3–111.0) cardiologists per million people, with numbers ranging from <30 per million in the UK and Ireland to >250 per million in Greece and Republic of Georgia (*Figure 50*).
- **Females in cardiology.** Females comprised fewer than a third of all cardiologists working in ESC member countries. Under-representation of females was greatest in the Republic of Kosovo, Greece, UK, and Ireland where they comprised <15% of cardiologists. Exceptions to this trend were Estonia, Lithuania, Republic of Moldova, and Kyrgyzstan where >70% of cardiologists were females.
- **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 61.1 (IQR 51.0–86.4) vs. 99.0 (IQR 79.0–111.0) (*Figure 51*). Female cardiologists comprised 51.0% of the cardiological workforce in middle-income countries compared with 30.5% in high-income countries. These averaged data, however, conceal considerable variation across ESC member countries.

Diagnostic coronary angiography

Cardiac catheterization with coronary angiography is one of the most frequently performed diagnostic tests in patients with suspected coronary artery disease. The more recent availability of computed tomography coronary angiography (CTCA) has provided a non-invasive means of examining the coronary arteries and is particularly useful for ruling out disease in low-risk populations.[279] Functional tests, such as myocardial perfusion imaging, are also widely used to diagnose regional ischaemia caused by obstructive coronary plaque. Although there are clear guideline recommendations for the use of these non-invasive diagnostic tests rates of invasive coronary angiography show no signs of diminishing and there is now increasing evidence that this may reflect inappropriate use.[280]

- **Infrastructure.** A median of 2.6 (IQR 2.1–3.8) hospitals per million inhabitants of ESC member countries reported having facilities for cardiac catheterization in the 2020 survey (see Supplementary material online, *Figure S78*). Provision ranged from <1.5 hospitals per million in Slovakia, Kyrgyzstan, Ukraine, and Uzbekistan to >4.5 in Greece, Cyprus, and Bulgaria.
- **Service delivery.** A median of 4084 (IQR 2563–5007) diagnostic coronary angiograms per million people were performed across ESC member countries in 2019, or the most recent year that data were available, ranging from <1000 in Kyrgyzstan, Uzbekistan, and Egypt to nearly 7000 in Belgium and Switzerland (*Figure 50*).
- **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 [2.4 (IQR 1.6–3.4) vs. 2.8 (IQR 2.2–3.9)]. Despite similar facilities in terms of catheter laboratories, the median numbers of diagnostic catheter procedures per million people were lower in middle-income compared with high-income countries 2231 (IQR 1168–3860) vs. 4553 (IQR 3507–5962), although these averaged data concealed important differences with Armenia, Serbia, and Montenegro among middle-income countries performing >4000 procedures per million people, comparable to rates in many high-income countries (*Figure 51*).

Interventional cardiology

Percutaneous coronary intervention

Percutaneous coronary intervention (PCI) utilizes cardiac catheters for revascularization of obstructed coronary arteries. In stable coronary artery disease, the procedure provides effective relief of angina but does not necessarily protect against myocardial infarction or death.[281] However, there is a clear outcome benefit from PCI in the acute setting. In patients with acute myocardial infarction, primary PCI involving timely reperfusion of the culprit coronary artery reduces eventual infarct size and mortality.[282]

- **Human resource.** The 2020 survey showed a median of 12.1 (IQR 9.2–17.4) interventional cardiologists per million inhabitants of ESC member countries, with numbers ranging from <5 per million in Republic of Kosovo, Kyrgyzstan, Republic of Moldova, Montenegro, Ukraine, and Uzbekistan to >20 per million in Austria, Belgium, Bulgaria, Greece, Italy, Latvia, Malta, North Macedonia, Poland, and Slovenia (*Figure 52*).
- **Infrastructure.** The median number of hospitals per million inhabitants of ESC member countries that offered a 24 h/7 day facility for cardiac catheterization was 1.8 (IQR 1.1–2.7), ranging from <1 hospital per million people in Denmark, Egypt, Slovenia, Tunisia, and UK to >4 in Belgium, Cyprus, Poland, and Bulgaria.
- **Service delivery**
  (a) **Percutaneous coronary intervention.** A median of 1879 (IQR 1313–2550) PCI procedures per million inhabitants of ESC member countries were reported in the 2020 survey (*Figure 52*). Numbers ranged from <1000 procedures per million people in Azerbaijan, Egypt, Republic of Kosovo, Kyrgyzstan, Republic of Moldova, Tunisia, Ukraine, and Uzbekistan to >3000 in France, Germany, Latvia, Lithuania, Switzerland, and Armenia.
  (b) **Primary PCI.** A median of 522.8 (IQR 369.4–658.9) primary PCI procedures per million inhabitants of ESC member countries were reported in the 2020 survey (*Figure 52*). Numbers ranged from <50 procedures per million people in Kyrgyzstan and Uzbekistan to >900 in Lithuania.
- **Stratification by national income status.** The median number of interventional cardiologists per million inhabitants of the ESC member countries in the 2020 survey was lower in middle-income countries compared with high-income countries [8.6 (IQR 4.5–13.8) vs. 14.6 (IQR 10.5–20.3)] (*Figure 53*) and there was further inequality in 24 h/7 day catheter laboratory availability [1.7 (IQR 1.1–2.1) vs. 2.1 (IQR 1.2–2.7)]. The median numbers of PCI procedures per million inhabitants of ESC member countries reported in the 2020 survey were also lower in

Figure 50 Cardiologists and diagnostic coronary angiograms (diagnostic coronary angiograms data for the UK pertain England only) per million people in European Society of Cardiology member countries.

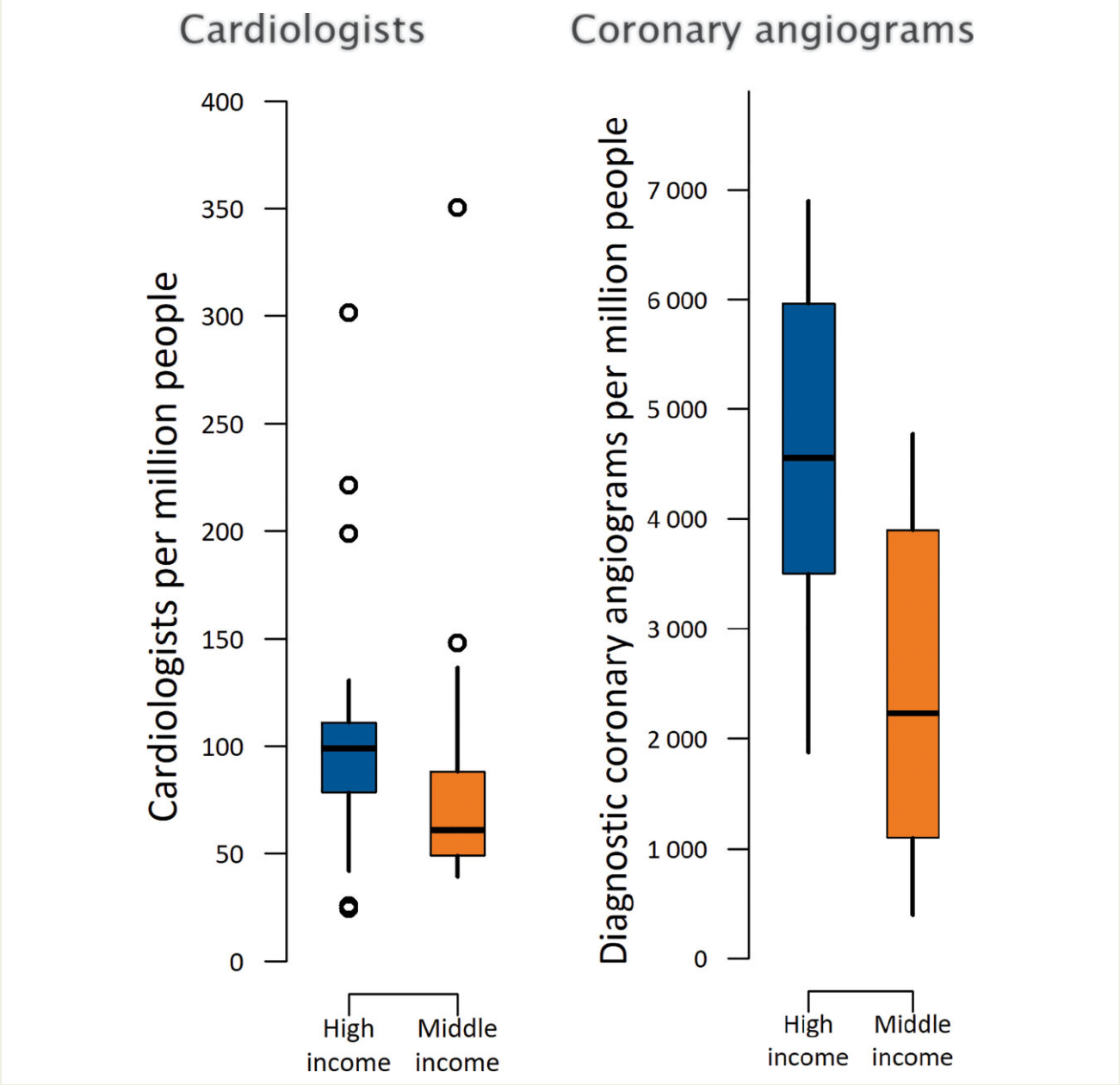


Figure 51 Cardiologists and diagnostic coronary angiograms per million people in European Society of Cardiology member countries, stratified by national income status.

middle-income compared with high-income countries [1.148 (IQR 693.7–1658) vs. 2333 (IQR 1820–2654)] (*Figure 53*). There was even greater disparity in numbers of primary PCI procedures per million inhabitants of middle-income compared with high-income countries [311.8 (IQR 37.0–650.1) vs. 533.7 (IQR 429.8–661.0)] (*Figure 53*).

Interventional heart valve procedures

Transcatheter aortic valve implantation (TAVI) has found indication in patients with severe aortic stenosis for whom the risks of surgical valve replacement are deemed excessive. Indications have now extended to include lower risk patients based on evidence of symptomatic improvement with mortality outcomes comparable to those achieved by surgery.[283,284] Percutaneous mitral valve repair is also available in selected patients with heart failure caused by, or exacerbated by, severe mitral regurgitation. The most widely used repair device, positioned across the mitral valve, draws the valve leaflets closer together and reduces regurgitant flow producing variable symptomatic improvement and mortality reduction.[242,243]

- **Infrastructure.** In the 2020 survey, a median of 1.1 (IQR 0.6–1.6) hospitals per million inhabitants of ESC member countries

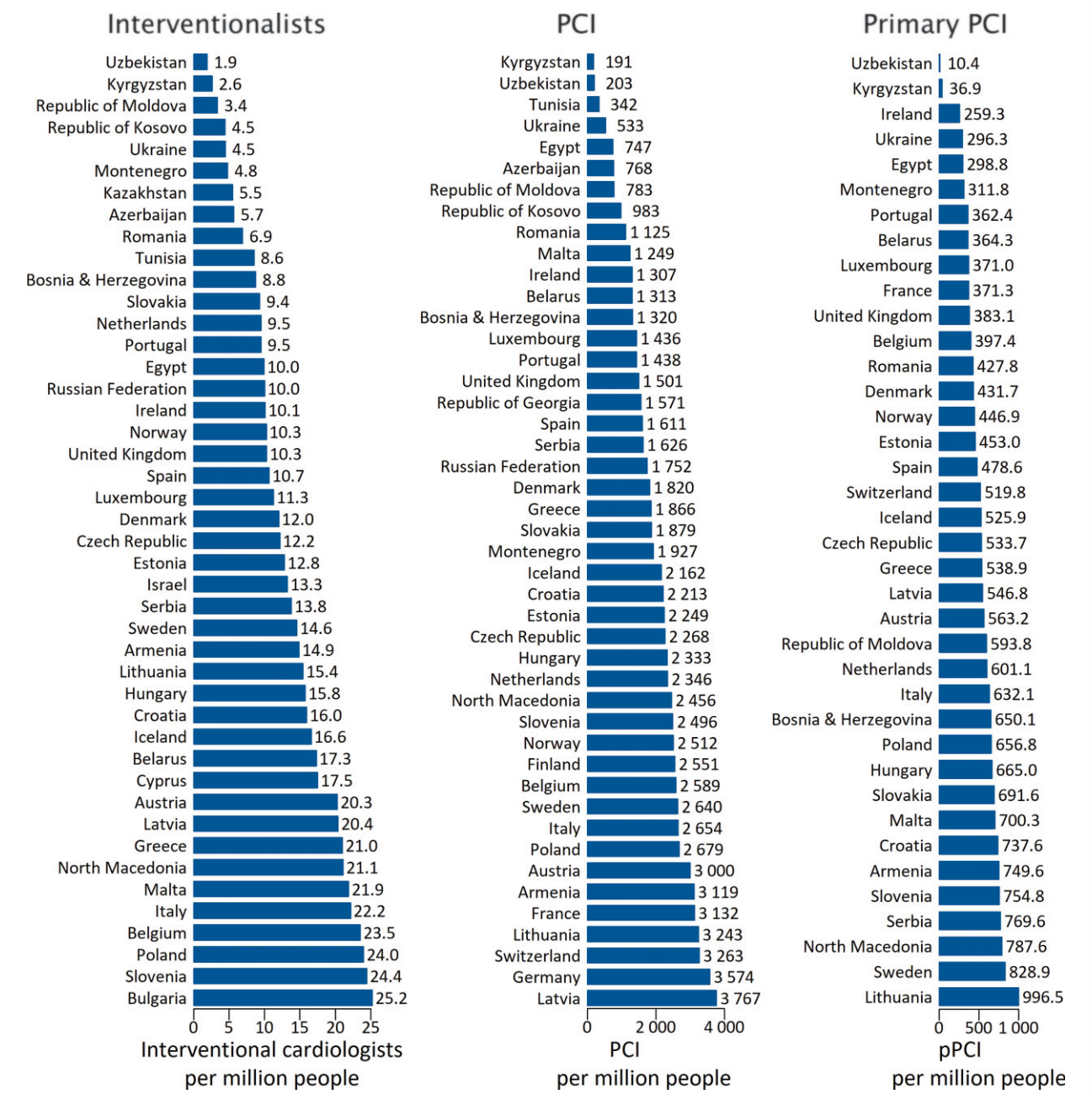


Figure 52 Interventional cardiologists, percutaneous coronary interventions, and primary percutaneous coronary interventions per million people in European Society of Cardiology member countries.

reported catheter laboratories equipped for structural heart interventions. Numbers ranged from <0.5 hospitals per million people in Azerbaijan, Belarus, Bulgaria, Egypt Republic of Georgia, and Uzbekistan to >3.0 in Cyprus and Italy. In Republic of Kosovo, there were no hospitals equipped for interventional heart valve procedures.

- **Service delivery**
  - (a) **Transcatheter aortic valve implantation.** A median of 60.0 (IQR 3.7–124.6) TAVI procedures per million inhabitants of ESC member countries were performed in 2019, ranging from <1 procedure per million people in Azerbaijan, Bosnia, and Herzegovina and Uzbekistan to >200 in France, Germany, and Switzerland (*Figure 54*).
  - (b) **Percutaneous mitral valve repair.** A median of 5.4 (IQR 1.6–13.1) procedures per million people per year were performed across ESC member countries in 2019 with Switzerland and Germany reporting 47.2 and 78.4 procedures per million people, respectively.
  - (c) **Percutaneous tricuspid valve repair.** Procedure rates in the 17 countries that reported in the 2020 survey were very low and exceeded 1 per million people only in Austria, Denmark, Germany, Lithuania, Spain, and Switzerland.

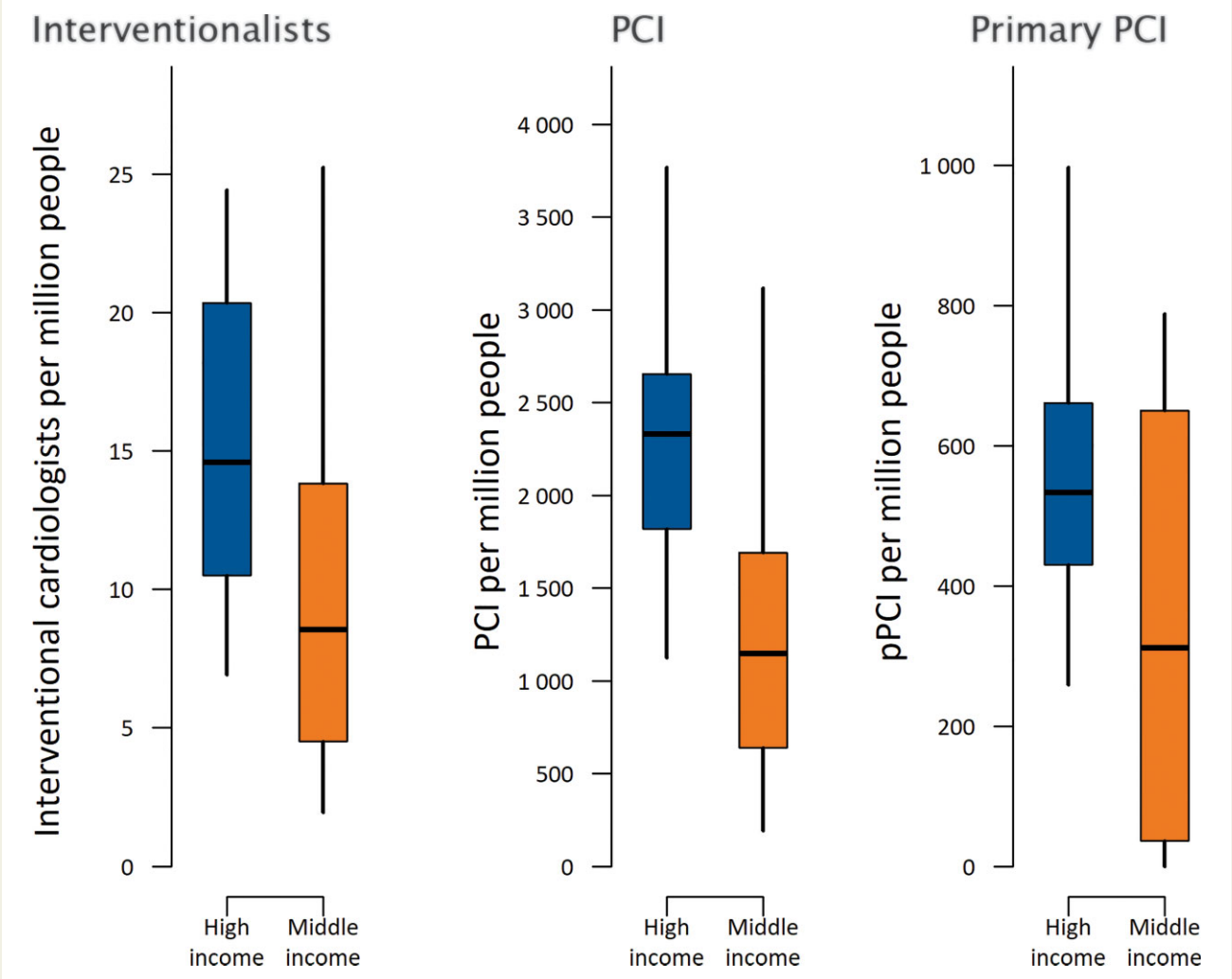


Figure 53 Interventional cardiologists, percutaneous coronary interventions, and primary percutaneous coronary interventions per million people in European Society of Cardiology member countries, stratified by national income status.

- **Stratification by national income status.** In the 2020 survey, the median number of hospitals per million inhabitants of ESC member countries that had catheter laboratories equipped to treat structural heart disease was lower in middle-income countries compared with high-income countries [0.5 (IQR 0.3–0.7) vs. 1.2 (IQR 0.9–1.9)]. Procedure rates per million people were reported by fewer than 15 middle-income countries where they were lower for both TAVI [1.1 (IQR 0.3–3.7) vs. 90.0 (IQR 60.6–155.0)] and percutaneous mitral valve repair [0 (IQR 0–1.6) vs. 9.4 (IQR 2.9–18.9)] compared with high-income countries (*Figure 55*).

Electrophysiology: ablation procedures and device implants

Ablation therapy in patients with tachyarrhythmias uses catheters for the delivery of targeted energy to interrupt conduction pathways within the heart. It has found wide application for rhythm control in atrial fibrillation and has revolutionized the management of Wolff–Parkinson–White syndrome and AV nodal re-entry tachycardia offering the potential for cure of these troublesome disorders. Pacemaker, cardiac resynchronization, and defibrillator therapy, using implantable devices, are essential for the prevention of syncopal attacks in patients with conduction tissue disease, restoration of synchronous biventricular activation in patients with heart failure, and electrical cardioversion of lethal arrhythmias, particularly in patients with prior myocardial infarction.

- **Infrastructure.** The 2020 survey of the ESC member countries recorded a median of 2.8 (IQR 1.7–4.4) hospitals per million people implanting pacemakers (see Supplementary material online, *Figure S79*), 1.9 (IQR 1.4–3.1) implanting implantable cardioverter defibrillators (see Supplementary material online, *Figure S79*) and 1.6 (IQR 1.0–2.4) implanting cardiac resynchronization therapy pacemakers (see Supplementary material online, *Figure S79*). In general, the number of hospitals performing device implantation procedures was low in middle-income compared with high-income countries. For example, pacemakers were implanted in <1 hospital per million people in Egypt, Kyrgyzstan,

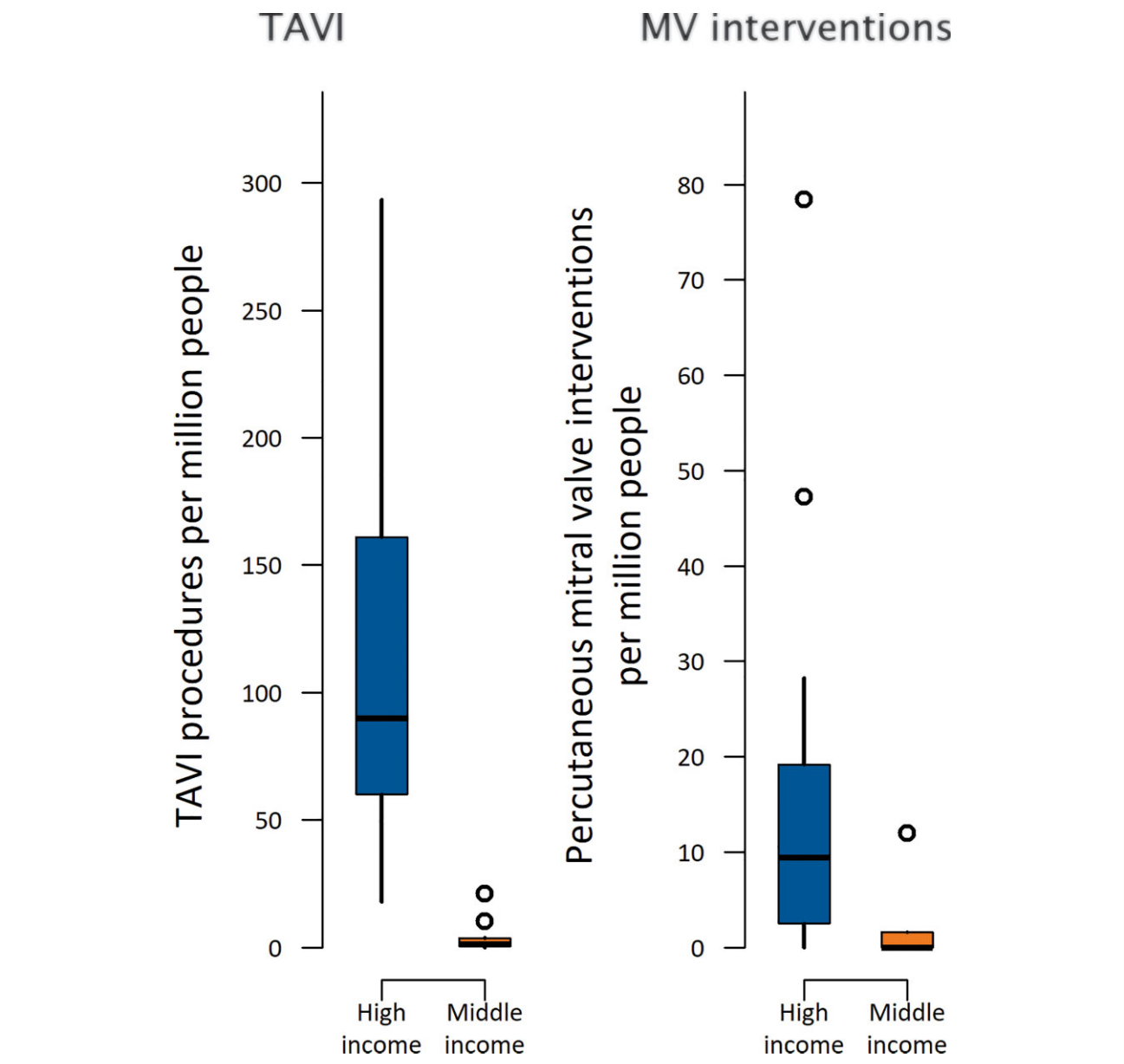


Figure 54 Transcatheter aortic valve implantation procedures per million people in European Society of Cardiology member countries.

and Uzbekistan compared with >7 hospitals per million people in Belgium, Cyprus, Germany, and Switzerland.

- **Service delivery**
  - (a) **Ablation procedures.** A median of 372.3 (IQR 145.2–518.8) ablation procedures per million inhabitants of the ESC member countries were performed for treatment of heart rhythm disorders (*Figure 56*). Rates ranged from <25 procedures per million people in Bosnia and Herzegovina, Egypt, Kyrgyzstan, and Uzbekistan to >700 procedures per million people in Belgium, Czech Republic, France, Germany, Iceland, and Switzerland.
  - (b) **Pacemaker implants.** A median of 652.2 (IQR 267.5–874.7) pacemaker implants per million inhabitants of ESC member countries were reported in the 2020 survey (*Figure 56*). Rates ranged from <40 implants per million people in Egypt, Kyrgyzstan, and Uzbekistan to >1000 per million people in France and Sweden.
  - (c) **Implantable cardioverter defibrillator implants.** A median of 105.0 (IQR 37.1–153.3) ICD implants per million inhabitants of ESC member countries were reported in the 2020 survey (*Figure 56*). Rates ranged from <6 implants per million people in Belarus, Egypt, Kyrgyzstan, Republic of Moldova, Ukraine, and Uzbekistan to more than 200 per million people in Czech Republic, Germany, Italy, The Netherlands, and Poland.
  - (d) **Cardiac resynchronization therapy implants.** A median of 63.6 (IQR 22.8–126.8) CRT implants per million inhabitants of ESC member countries were reported in the 2020

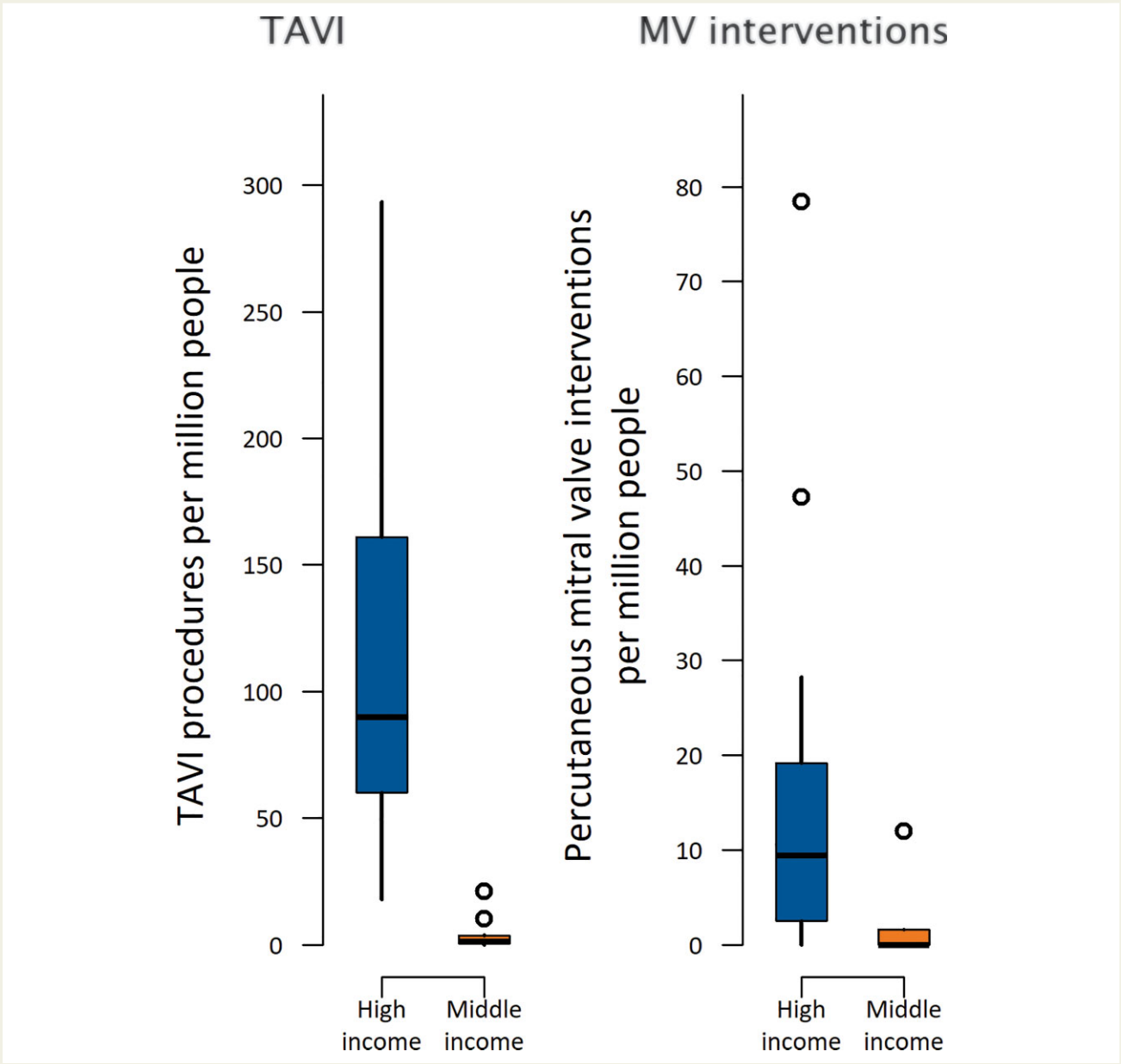


Figure 55 Transcatheter aortic valve implantation and percutaneous mitral valve procedures per million people in European Society of Cardiology member countries, stratified by national income status.

survey (*Figure 56*). Rates ranged from <1 implant per million people in Kyrgyzstan, Tunisia, and Uzbekistan to >150 per million in Austria, Belgium, Czech Republic, Germany, Italy, Malta, and the Netherlands.

- **Stratification by national income status.** The 2020 survey showed that, 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 for treatment of cardiac arrhythmias were performed [78.9 (IQR 30.0–186.3) vs. 438.2 (IQR 383.1–637.4)] (*Figure 57*) and fewer pacemakers [148.0 (IQR 54.7–309.6) vs. 830.4 (IQR 717.6–943.9)], ICDs [13.2 (IQR 5.6–71.7) vs. 134.8 (IQR 94.2–164.5)] and CRT devices [9.1 (IQR 3.1–34.9) vs. 114.1 (IQR 71.1–146.2)] were implanted (*Figure 57*). Concealed within these averaged data, however, were some outliers with Armenia and Serbia implanting more ICDs than many high-income countries.

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 symptomatic improvement in patients with angina. In left main and multivessel coronary artery disease, CABG can prolong life compared with medical therapy, particularly when left ventricular function is impaired.[285,286] Revascularization by PCI is often

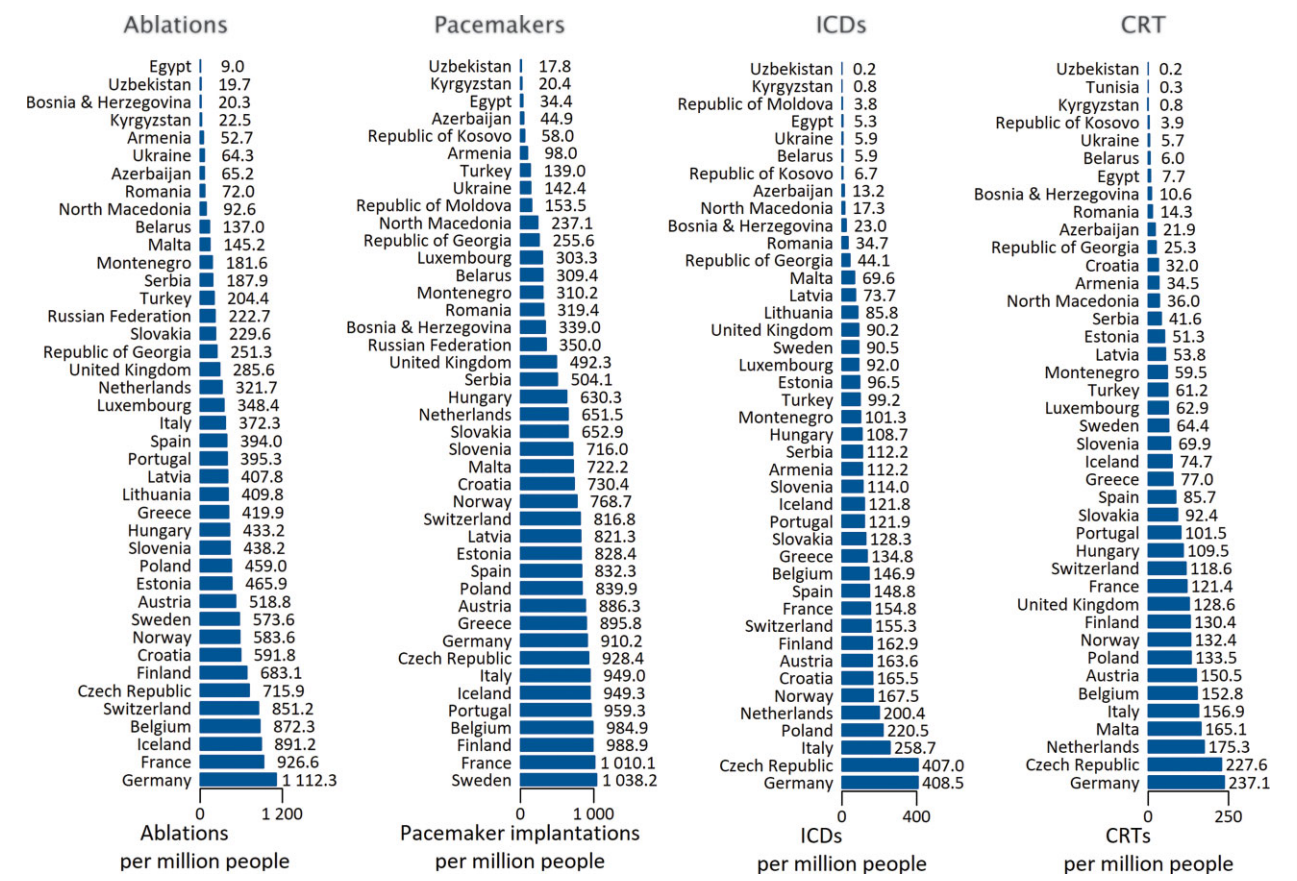


Figure 56 Ablation procedures, pacemaker implantations, implantable cardioverter-defibrillator implantations, and cardiac resynchronization therapy implantations per million people in European Society of Cardiology member countries.

preferred in contemporary practice, and for most patients, outcomes are comparable to those achieved with CABG. In patients with diabetes, however, CABG outperforms PCI and is the procedure of choice.[287,288]

- **Human resource.** The 2020 survey identified a median of 8.0 (IQR 5.7–10.0) cardiac surgeons per million people working in the ESC member countries (*Figure 58*). Numbers ranged from <5 surgeons per million in Armenia, Azerbaijan, Ireland, Luxembourg, Republic of Kosovo, Kyrgyzstan, UK, and Uzbekistan to >15 per million in Austria, Finland, Lithuania, Sweden, and Russian Federation.
- **Infrastructure.** A median of 1.2 (IQR 0.9–1.6) hospitals per million inhabitants of ESC member countries were reported to have facilities for cardiac surgery in the 2020 survey, ranging from <0.7 hospitals in Denmark, Romania, Slovakia, UK, and Uzbekistan to >2.0 in Belgium, Greece, Cyprus, and Iceland (see Supplementary material online, *Figure S80*).
- **Service delivery.** A median of 272.0 (IQR 224.3–337.9) CABG procedures per million inhabitants of ESC member countries were reported in the 2020 survey (*Figure 58*). Rates ranged from <100 CABG procedures per million people in Kyrgyzstan, Republic of Kosovo, and Uzbekistan to >500 in Belgium, Lithuania, and the Netherlands.
- **Stratification by national income status.** The 2020 survey showed that the median number of cardiac surgeons per million inhabitants was lower in middle-income countries compared with high-income countries [7.9 (IQR 4.2–9.9) vs. 8.0 (IQR 6.6–10.0)] (*Figure 59*), although there was little difference in the median number of hospitals with cardiac surgical facilities [1.3 (IQR 1.0–1.4) vs. 1.1 (IQR 0.9–1.7)] or the median number of CABG procedures per million inhabitants [217.4 (IQR 101.6–279.3) vs. 278.5 (IQR 242.8–363.3)] with Serbia and Montenegro among middle-income countries reporting >400 procedures per million people per year, more than were reported by many of the high-income ESC member countries (*Figure 59*).

Heart transplant surgery and left ventricular assist devices

Heart transplant surgery is a life-saving treatment for patients with end-stage heart failure, delivering improved quality and duration of life. The orthotopic procedure is preferred in which the patient's own heart is removed and replaced by the donor heart. Survival at 1 year exceeds 85% and at 5 years is about 70%.[289] Rates of heart transplantation are limited internationally by the availability of donor hearts. Left ventricular assist devices are electromechanical devices designed to replace the function of the failing heart partially or

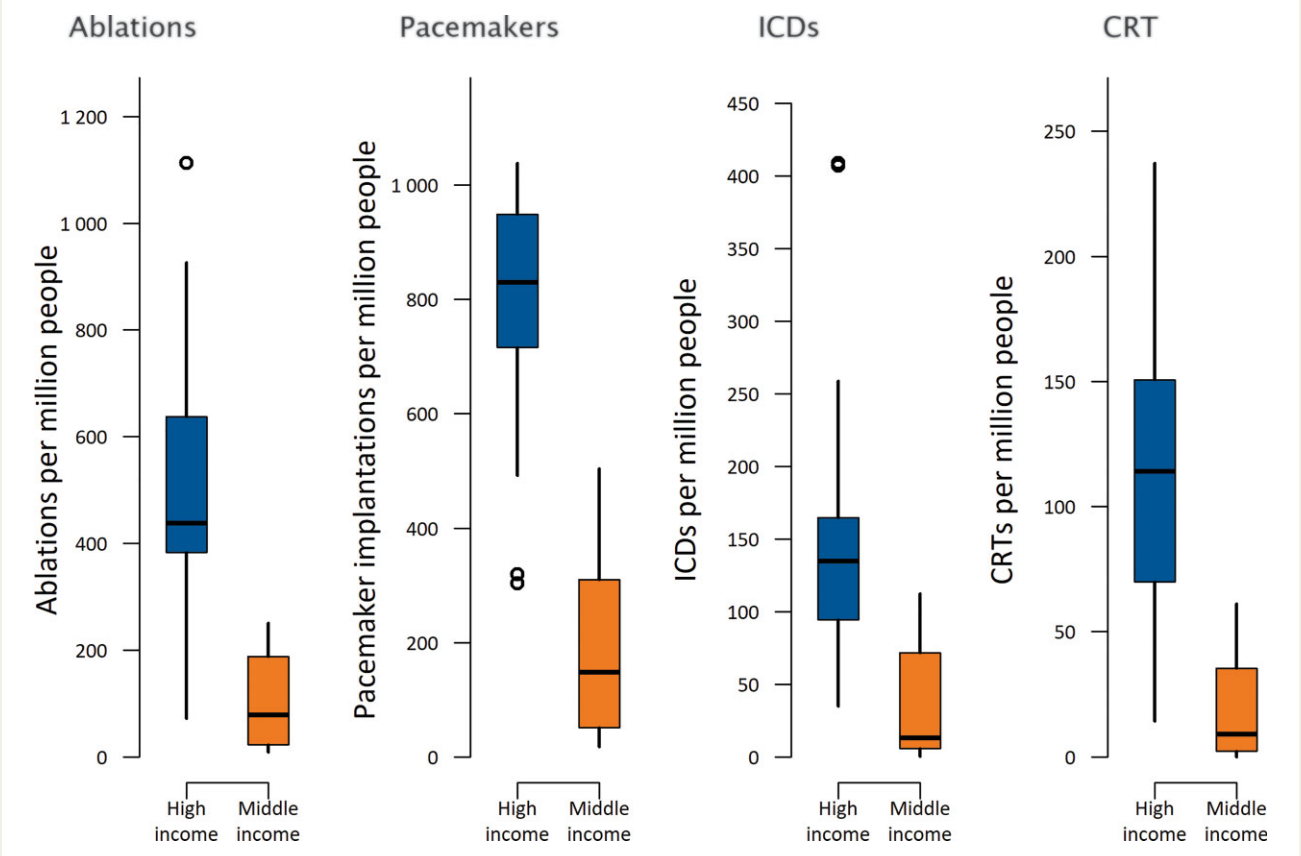


Figure 57 Ablation procedures, pacemaker implantations, implantable cardioverter-defibrillator implantations, and cardiac resynchronization therapy implantations per million in European Society of Cardiology member countries, stratified by national income status.

completely. Their principal use is for bridge-to-transplantation with a more limited application as destination therapy.

- **Infrastructure.** The median number of hospitals with heart transplant programmes across ESC member countries was 0.20 (IQR 0.14–0.37) per million inhabitants. Only Belgium, Latvia, Lithuania, and Malta reported more than 0.5 hospitals per million inhabitants with transplant programmes (see Supplementary material online, *Figure S81*).
- **Service delivery.** Across ESC member countries, a median of 3.2 (IQR 1.4–5.7) heart transplant procedures per million people were reported in the 2020 survey. Rates ranged from <2 transplants per million people per year in Greece, Malta, North Macedonia, Romania, and Serbia and to >7 in Belgium, Croatia, and Norway (see Supplementary material online, *Figure S81*). The variation in LVAD implants was even greater with a median rate among all countries of 3.0 (IQR 0.9–5.2) per million people per year, ranging from <0.5 in Romania, Belarus, Bosnia and Herzegovina, and Egypt, to >10.0 in Czech Republic, France, Germany, and Luxembourg (see Supplementary material online, *Figure S81*).
- **Stratification by national income status.** Transplant activity was generally greater in high-income countries where a median of 4.0 (IQR 2.1–5.9) procedures per million people were reported in the 2020 survey. Only three middle-income countries, Belarus, North Macedonia, and Serbia reported transplant programmes, performing 3.0, 0.5, and 1.4 procedures per million people, respectively. Left ventricular assist devices too were largely the preserve of high-income countries where a median of 3.3 (IQR 1.6–7.0) implants per million people were reported in the 2020 survey. Among the five middle-income countries that reported active LVAD programmes, only North Macedonia and Serbia reported >3 LVAD implants.

Congenital heart disease

Congenital heart defects are the most common birth defect and the leading cause of birth defect-related deaths. Some defects such as pulmonary stenosis, atrial septal defect, persistent arterial duct, and coarctation of the aorta may be effectively treated with catheter-based procedures. For more complex defects, surgical treatment may be necessary and allows many infants and children to live into adulthood.

- **Infrastructure.** In the 2020 survey, a median of 0.3 (IQR 0.2–0.5) per million inhabitants of ESC member countries reported hospitals with catheter laboratory facilities for structural heart disease interventions in children (*Figure 60*). Numbers ranged from <0.1 hospitals per million people undertaking percutaneous procedures Uzbekistan to >0.75 in Croatia, Cyprus, Estonia, Iceland, Malta, and North Macedonia. Surgical facilities

Figure 58 Cardiac surgeons and coronary artery bypass graft surgery per million people in European Society of Cardiology member countries.

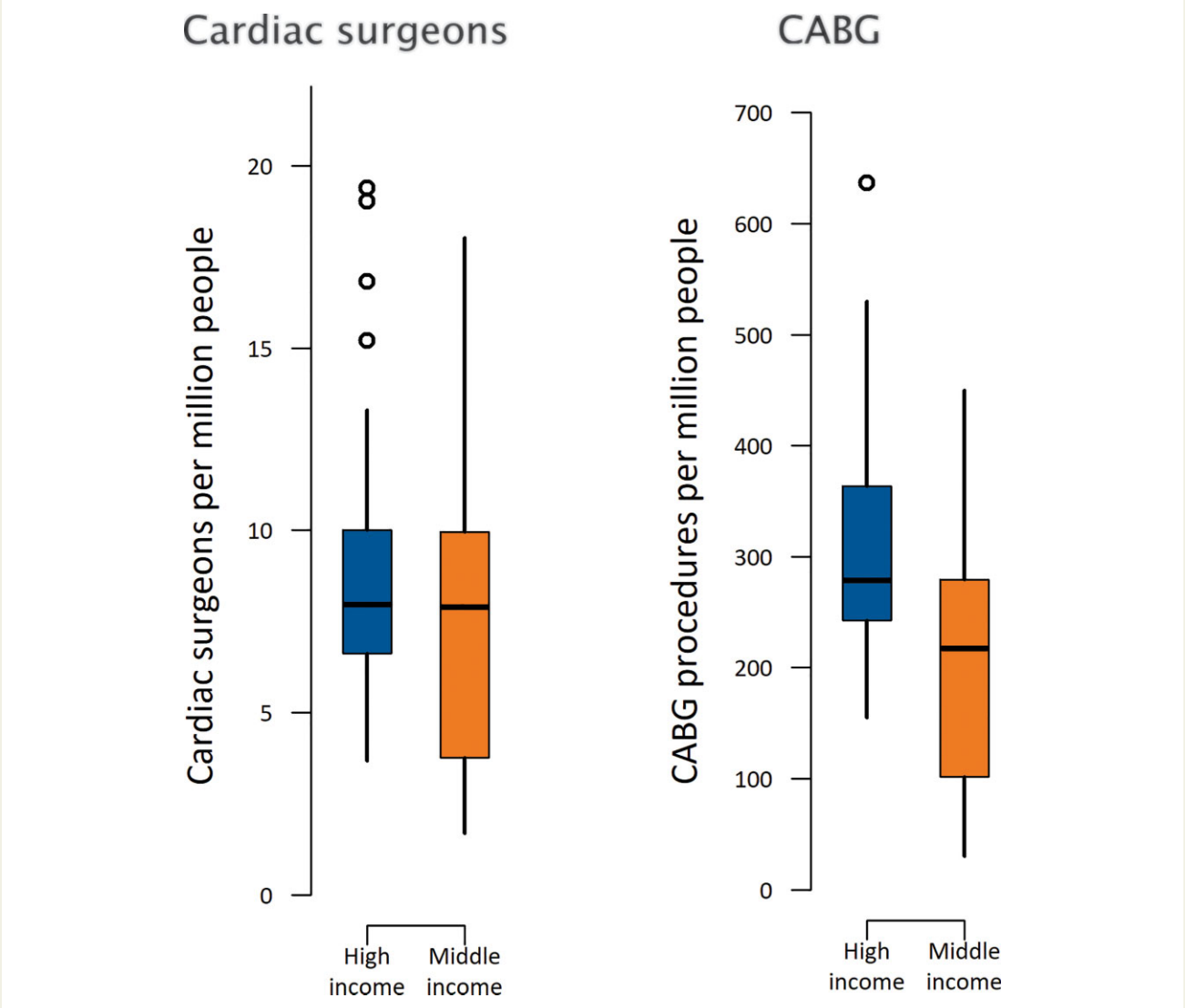


Figure 59 Cardiac surgeons and coronary artery bypass graft surgery per million people in European Society of Cardiology member countries, stratified by national income status.

for congenital heart disease were available in a median of 0.7 (IQR 0.4–0.9) and 0.4 (IQR 0.2–1.0) hospitals per million inhabitants of middle- and high-income ESC member countries.

- **Service delivery.** Across the ESC member countries, a median of 33.3 (IQR 11.6–52.6) percutaneous procedures and 54.4 (IQR 25.5–71.7) surgical procedures for congenital heart disease were reported in the 2020 survey. Rates ranged from <10 percutaneous procedures per million people per year in Bosnia and Herzegovina, Bulgaria, Egypt, Kyrgyzstan, Montenegro, Portugal, Romania, and Serbia to >90 in Belgium, Iceland, Italy, and Poland and from <10 surgical procedures per million people per year in Latvia, Luxembourg, Malta, and Montenegro to >90 in, Republic of Georgia, Republic of Republic of Moldova, and Switzerland (see Supplementary material online, *Figure S82*).
- **Stratification by national income status.** Facilities for interventional management of congenital heart disease were similar in middle-income and high-income ESC member countries included in the 2020 survey. A median of 0.3 (IQR 0.1–0.4) and 0.4 (IQR 0.2–0.6) hospitals per million inhabitants of middle- and high-income ESC member countries, respectively, reported hospitals with catheter laboratory facilities for structural heart disease interventions in children (see Supplementary material online, *Figure S83*). Despite similar facilities for interventional management of congenital heart disease, procedure rates per million people were lower in middle-income compared with high-income countries both for percutaneous procedures [9.8 (IQR 4.8–14.0) vs. 48.6 (IQR 31.4–66.1)] and for surgical procedures [50.0 (IQR 25.4–68.5) vs. 56.6 (IQR 34.7–74.9)] (*Figure 61*).

Summary

- Completeness (%) of the healthcare statistics presented in this section was variable. Middle-income countries in

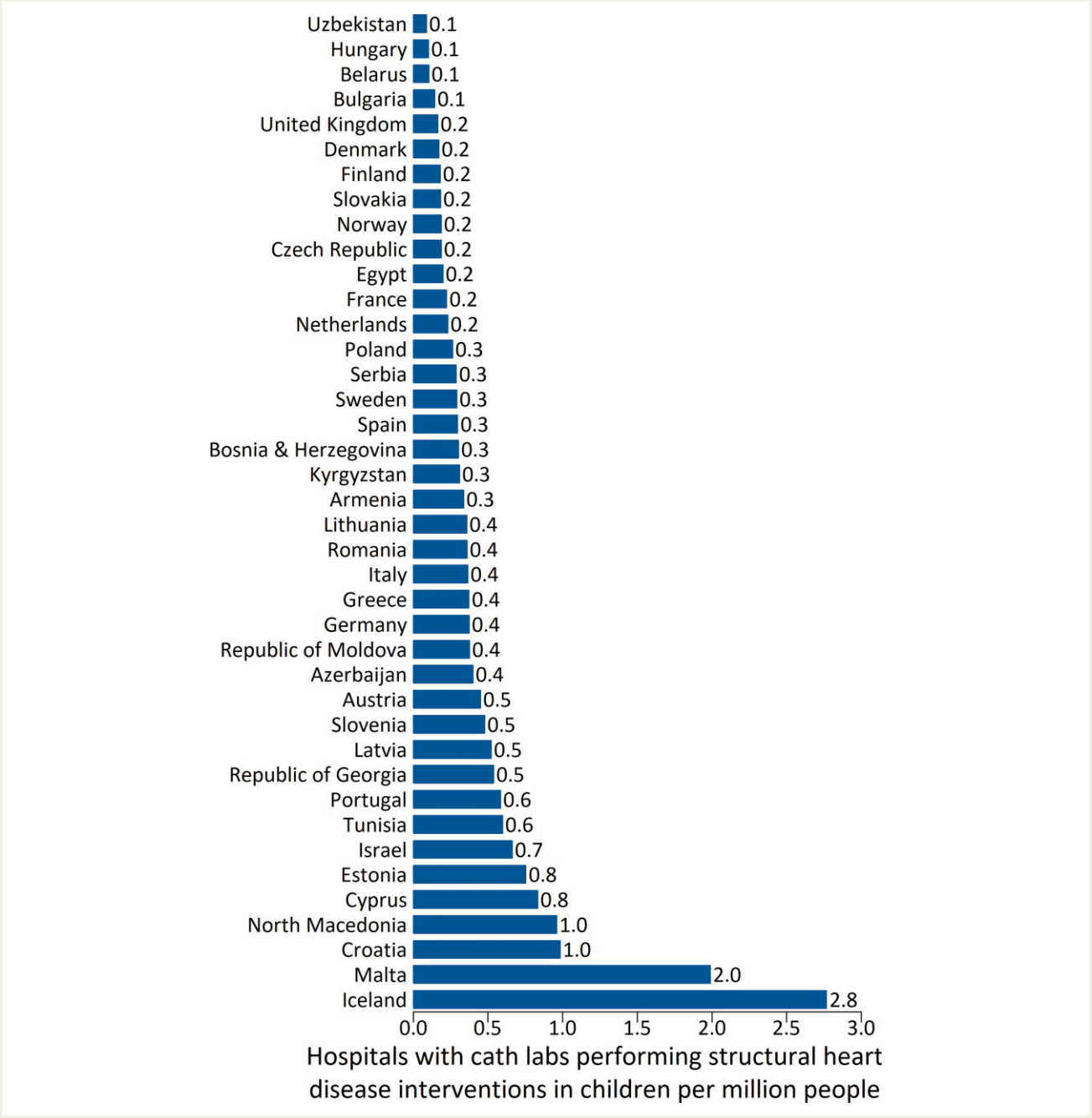


Figure 60 Hospitals with catheter laboratories for structural heart disease in children per million people in European Society of Cardiology member countries.

particular were often unable to provide data requested in the 2020 survey.

- There is considerable heterogeneity across ESC member countries in cardiological person-power which likely reflects specialist under-provision in many countries although definitions of what constitutes a cardiologist may also contribute to the heterogeneity.
- There is additional heterogeneity in proportions of female cardiologists whose contributions to national workforces range from <15 to >70%. Overall, there is a substantial under-representation of females.
- Middle-income countries are severely under-resourced compared with high-income countries both in terms of cardiological person-power and technological infrastructure.
- The under-resourced status of middle-income countries is associated with a severe procedural deficit compared with high-income countries in terms of coronary intervention, ablation procedures, device implantation, and cardiac surgical procedures.
- Novel treatments such as percutaneous heart valve and LVAD implants are largely the preserve of high-income countries with very few middle-income countries involved in the development and utilization of these technologies.

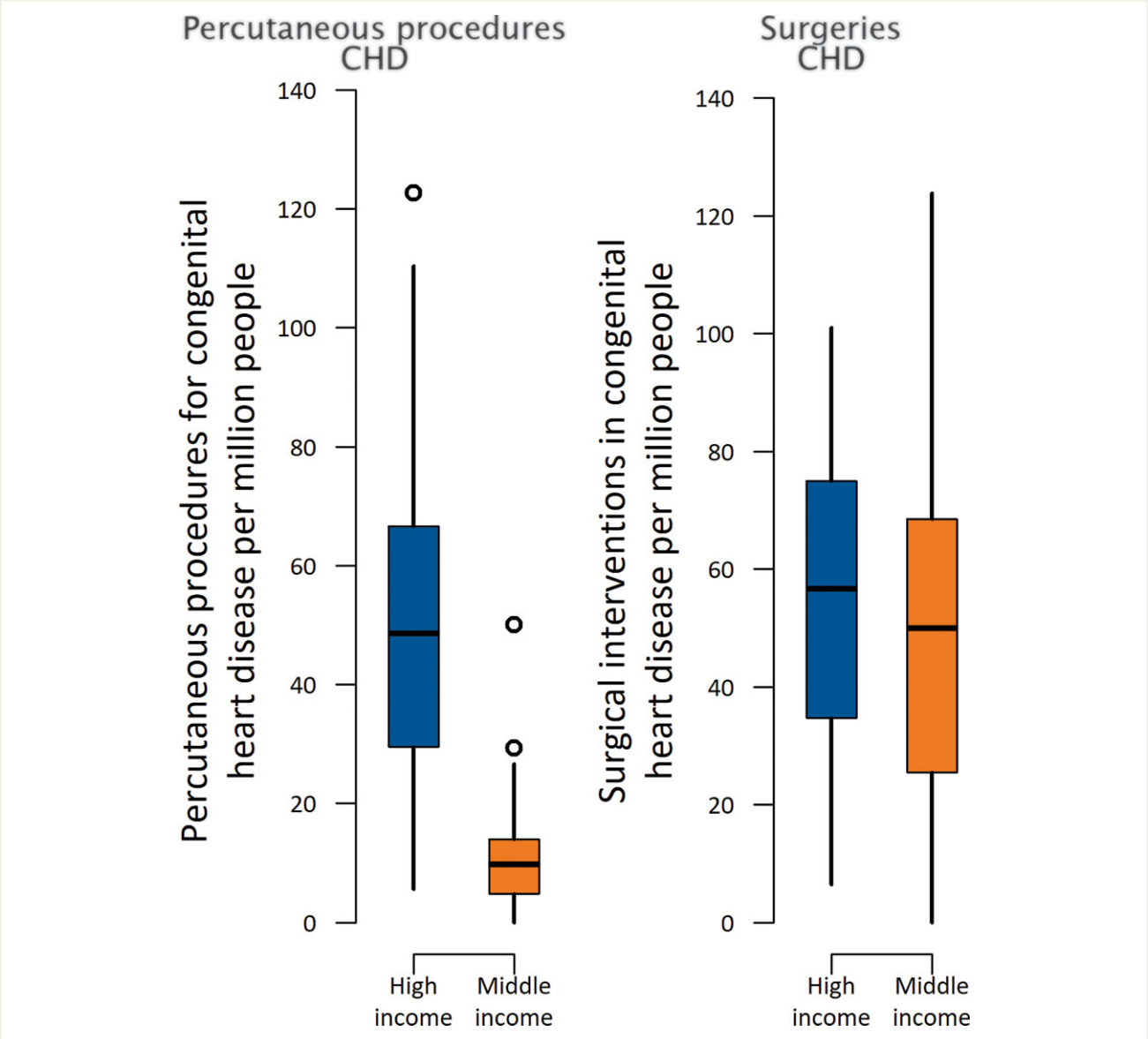


Figure 61 Percutaneous procedures and surgical procedures for congenital heart disease per million people in European Society of Cardiology member countries, stratified by national income status.

Comment

The 2020 ESC ATLAS survey of ESC member countries has shown continuing heterogeneity in cardiological services in terms of human and capital resource and the delivery of high-quality healthcare. It is important to emphasize however that optimal service provision cannot be deduced from the data presented in this section. The fact that some countries have many times the number of cardiologists or perform many times the number of PCIs compared with others does not necessarily mean that the quality of CV healthcare is similarly increased. Nevertheless, wide variation between ESC member countries in the availability of cardiologists does suggest significant under-provision in many countries and cannot be explained simply by national differences in how cardiologists are defined. Specialist involvement in patient care improves outcomes[273] and, with heart disease the leading cause of death across ESC member countries, workforce initiatives need implementation, particularly in those middle-income countries where specialist provision is low and CV mortality is high. Consideration should also be given to redressing the gender imbalance among cardiologists, recognizing that the absence of diverse voices contributes to poorer collective wisdom within the speciality.

Cardiology is increasingly a technologically driven speciality. For all the common cardiac disorders, contemporary management has moved beyond diagnosis to the delivery of treatments that can correct symptoms and improve prognosis.[272,290] To take full advantage of these treatments, access is required to a range of diagnostic, interventional, and surgical technologies that are contributing importantly to steeply rising healthcare costs.[272] The 2020 ESC ATLAS survey shows considerable heterogeneity

in these technologies across ESC member countries which, like the heterogeneity in numbers of cardiologists, suggests under-provision in many, mainly middle-income, countries. However, the heterogeneity does not rule-out over-provision. For example, the high rates of invasive cardiac catheterization in many high-income countries are increasingly seen as inappropriate when less expensive and safer non-invasive tests are often available and preferentially recommended by clinical guidelines.[280,291] Programmes to enhance the more appropriate use of investigational and treatment technologies have been developed internationally,[292–294] including the European Network for Health Technology Assessment which aims at creating, facilitating, and promoting sustainable health technology assessment cooperation across Europe.[295]

The under-provision of cardiological healthcare is of major importance in many middle-income ESC member countries. This is reflected in the 2020 ESC ATLAS survey which confirms that middle-income countries have fewer hospitals equipped for contemporary cardiac care and a corresponding deficit in procedure rates compared with high-income countries. These same middle-income countries are often those with continuing high CV mortality rates. Indeed, such under-provisions perpetuate the poorer CV health of these populations, consistent with Tudor-Hart's inverse care law of less healthcare where it is most needed.[296] Increasing healthcare provision in these countries requires additional spending directed towards diagnostic and therapeutic technologies where stretched national budgets allow. However, a more amenable and cost-effective target for CV mortality reduction must be the high rates of hypertension and smoking which characterize many middle-income countries. There is convincing evidence that modification of lifestyle and risk factors is no less effective than treatment technologies in its contribution to CV mortality reduction.[269–297]

Responses to the 2020 ESC Atlas survey showed variable completeness, with middle-income countries in particular often unable to provide information about key components of cardiological healthcare delivery. This information shortfall is itself a likely contributor to under-provision of healthcare by making treatment needs difficult to evaluate and the development of coherent healthcare policy almost impossible. National electronic record systems that are amenable to interrogation and linkage are critical for service planning and need to be given high priority if the healthcare deficits of middle-income countries in the 2020 ESC ATLAS survey are to be rectified. Improved data availability will act as a driver for research to better understand how CV healthcare might be enhanced through reductions in inequalities and improvements in access to healthcare services.

Progress towards meeting who non-communicable disease targets for 2025

The WHO reminds us that NCDs kill 41 million people each year, equivalent to 71% of all deaths globally.[298] Each year, more than 15 million people die from NCDs between the ages of 30 and 69 years; 85% of these 'premature' deaths occur in low- and middle-income countries. Cardiovascular diseases account for most NCD deaths (17.9 million annually), followed by cancers (9.3 million), respiratory diseases (4.1 million), and diabetes (1.5 million).

In its campaign to control NCDs, the WHO has set nine targets relevant to global CV health to be met by 2025.[299] Seven out of the nine targets call for reductions in CVD mortality and risk factors with reference to 2010 as follows:

- A 25% relative reduction in the premature mortality from CVDs, cancer, diabetes, or chronic respiratory diseases,
- At least 10% relative reduction in the harmful use of alcohol, as appropriate, within the national context,
- A 10% relative reduction in the prevalence of insufficient physical activity,
- A 30% relative reduction in the prevalence of current tobacco use in persons aged 15+ years,
- A 25% relative reduction in the prevalence of elevated blood pressure or contain the prevalence of elevated blood pressure, according to national circumstances, and
- Halt the rise in diabetes,
- Halt the rise in obesity.

In this section, progress made by ESC member countries in meeting these seven targets is summarized for all except 'insufficient physical activity' which lacks the availability of reliable longitudinal data during the period of interest.

Alcohol consumption

The WHO has called for a relative reduction of at least 10% in the harmful use of alcohol to be achieved by 2025. During the period 2010–2018, the median consumption of alcohol per capita across ESC member countries showed a small decline from 5.1 (IQR 2.7–5.9) to 4.5 (IQR 2.5–5.5) L in females and from 17.2 (IQR 9.9–19.3) to 15.0 (IQR 10.4–18.5) L in males. Although alcohol consumption was higher in high-income compared with middle-income countries, there was no significant change between 2010 and 2018 for either females or males. For this reason, our linear forecasts (*Figure 62*) make it unlikely the WHO alcohol consumption target for 2025 will be met unless there is a change in current trends.

Smoking

Longitudinal data for smoking in ESC member countries were patchy and incomplete for the years 2010–2018 when prevalence rates, year by year, were available for an average of 15.3 (range: 12–25) high-income countries and 4.6 (range: 3–6) middle-income countries. The data showed a 19.7% decline in the prevalence of smoking from 22.8% (IQR 19.5–26.5%) to 18.3% (IQR 15.1–21.8%) among adults. Declines in the prevalence of smoking during the years of interest were largely confined to high-income countries where rates fell by 31.0% in females and 18.5% in males. In middle-income countries, smoking prevalence was higher and showed little change between 2010 and 2018. Our linear forecasts (*Figure 63*) suggest the WHO smoking target will likely be achieved for females and males in high-income countries if current trends continue, but there is little prospect of it being achieved in

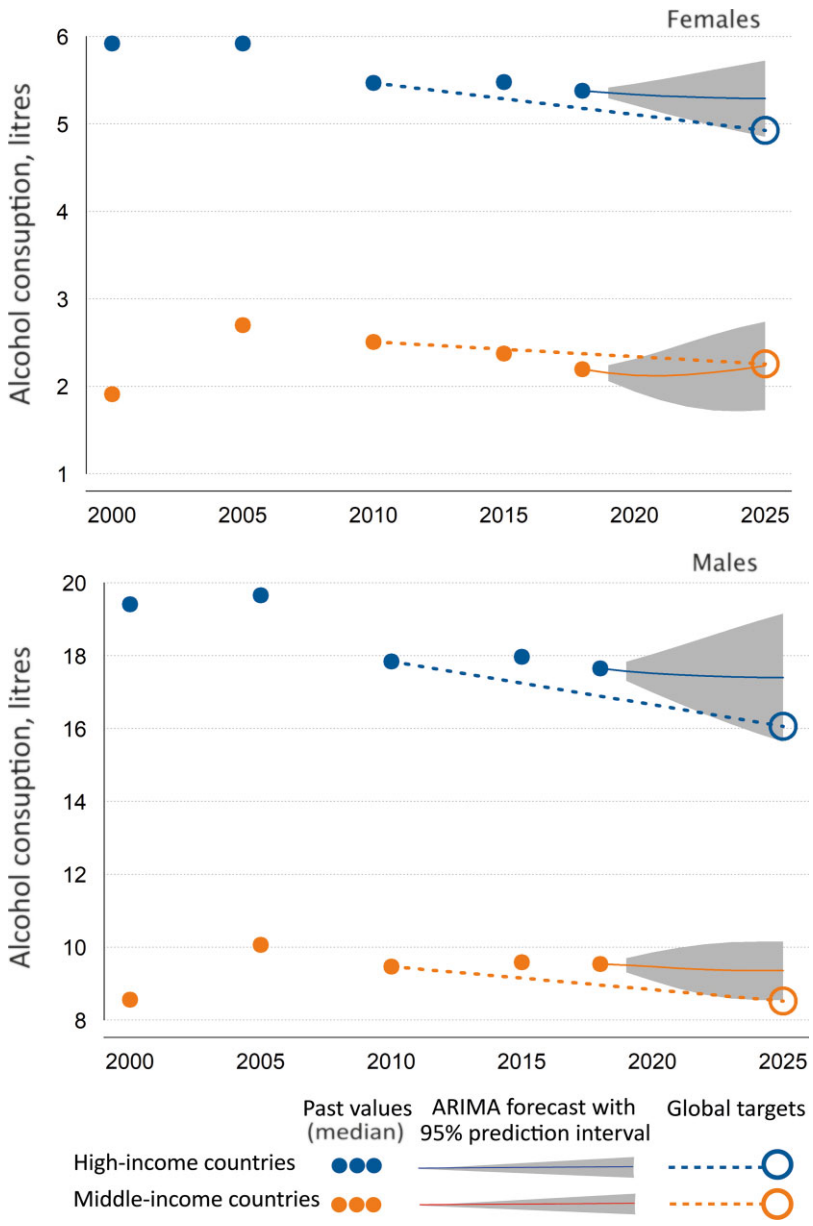


Figure 62 Alcohol consumption in European Society of Cardiology member countries. ARIMA forecast.

middle-income countries even allowing for the imprecision of our estimates

Elevated blood pressure

The WHO has set a target of a 25% reduction (with reference to 2010) in the prevalence of elevated blood pressure, to be achieved by 2025. During the period 2010–2015 (or most recent available), the median age-standardized prevalence of elevated blood pressure across ESC member countries has declined by 3.4% from 25.9% (IQR 22.3–29.6%) in 2010 to 25.0% (IQR 19.9–28.5%). Declines were greater in high-income countries than middle-income countries for both females (12.6 vs. 3.3%) and males (11.0 vs. increase 1.0%). Our linear forecasts (*Figure 64*) suggest there is little prospect the WHO blood pressure target for 2025 will be achieved across all ESC member countries but a good prospect that it will be achieved in high-income countries if present trends continue.

Diabetes

The WHO has called for a halt (with reference to 2010) to the rise in prevalence of diabetes, to be achieved by 2025. However, analysis of complete paired 2010 and 2015 data from 26 countries showed a 32% increase in the median prevalence of diabetes from 2.6 to 3.4% during that period. This was particularly marked in middle-income countries where the prevalence of diabetes increased by 42.1 compared with 15.7% in high-income countries. Based on these statistics, our forecasts (*Figure 65*) make it almost

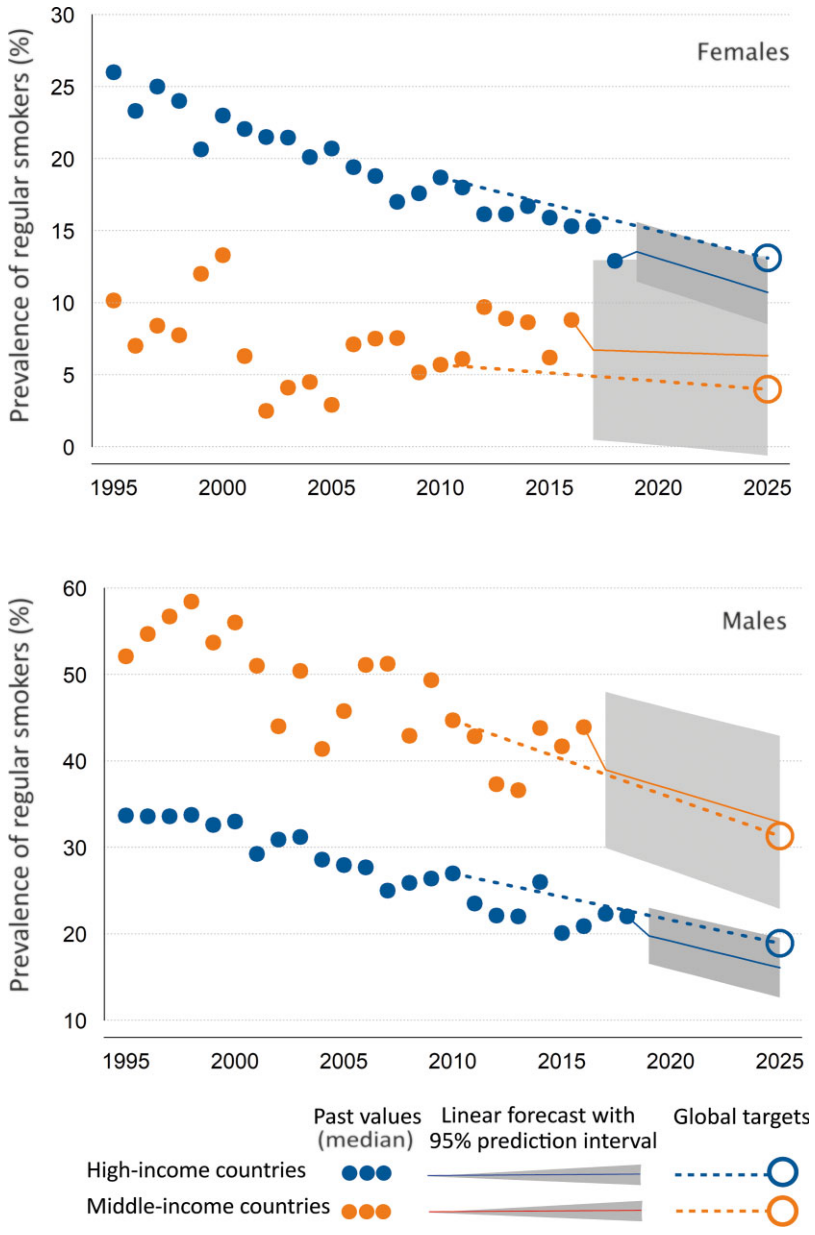


Figure 63 Smoking prevalence in European Society of Cardiology member countries. Linear forecast.

certain the WHO diabetes target will not be met, particularly in middle-income countries, unless trends are reversed.

Obesity

The WHO has called for a halt (with reference to 2010) to the rise in obesity, to be achieved by 2025. However, analysis of paired 2010 and 2016 national data showed an increase in the prevalence of obesity in females from 20.4% (IQR 18.9–24.7%) to 22.7% (IQR 20.9–26.0%) and males from 19.2% (IQR 17.0–21.0%) to 22.2% (IQR 20.2–24.2%). These increases have been seen in both middle- and high-income countries and suggest it is very unlikely the WHO obesity target will be met unless recent trends are substantially reversed (*Figure 66*).

Comment

The WHO's global targets on prevention and control of NCDs provide interesting context to the CVD healthcare needs of the ESC member countries. The ninth global target, not considered in the ESC Atlas, calls for an 80% availability of the affordable basic technologies and essential medicines required to treat major NCDs. Basic essential technologies are defined as a blood pressure measurement device, a weighing scale, height measuring equipment, blood sugar, and blood cholesterol measurement devices, and urine strips for albumin assay. It is reasonable to assume that this target has long been achieved by ESC member countries only one of which (Syrian Arab Republic) currently meets WB low-income criteria. Yet, the fact that low-income countries

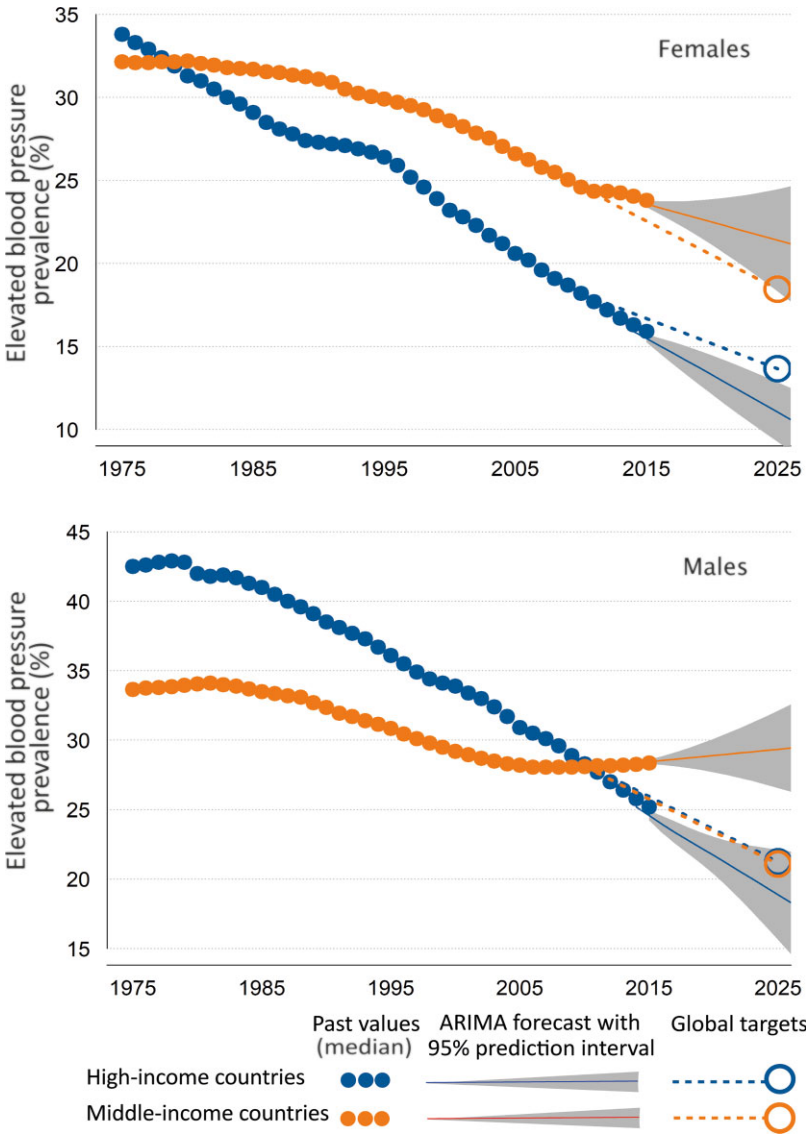


Figure 64 Prevalence of elevated blood pressure in European Society of Cardiology member countries. ARIMA forecast.

elsewhere in the world fail to meet this target, despite an increasing prevalence of CVD, puts into context the technological shortfalls of middle-income ESC member countries identified in the 2020 survey. This is not to say these shortfalls are not in need of correction, but it is a reminder of how much further the low-income countries of the world have to go in combating the emerging CVD epidemics they now face.

Risk factors and unhealthy behaviours are potentially reversible, and this provides huge opportunity to address the health inequalities across ESC member countries that are highlighted in this report. It seems clear, however, that efforts to seize this opportunity are falling short and present evidence suggests that most of the WHO NCD targets for 2025 are unlikely to be met across ESC member countries. Rates of obesity and diabetes in particular are increasing and the ESC's ambitious mission 'to reduce the burden of cardiovascular disease' will not be achieved until these trends are substantially reversed.

Cardiovascular disease advocacy roadmap

This ESC Atlas reports encouraging reductions in CV mortality and gains in life expectancy across ESC member countries, but 113 million people continue to live with CVD, which remains the most common cause of death within the region. The epidemic of obesity and type II diabetes is now contributing to a plateauing of CV mortality rates[300–303] and the ESC Atlas draws attention to seven middle-income ESC member countries that saw small increases in the incidence of CVD in 2019. Despite these disturbing observations, cancer is often perceived as the most important cause of death by members of the public and when they are asked about the harms of smoking, it is cancer not CVD that is seen as the main risk.[304,305] This stems from a variety of ill-informed beliefs about the mode and timing of cardiac death, which is often seen

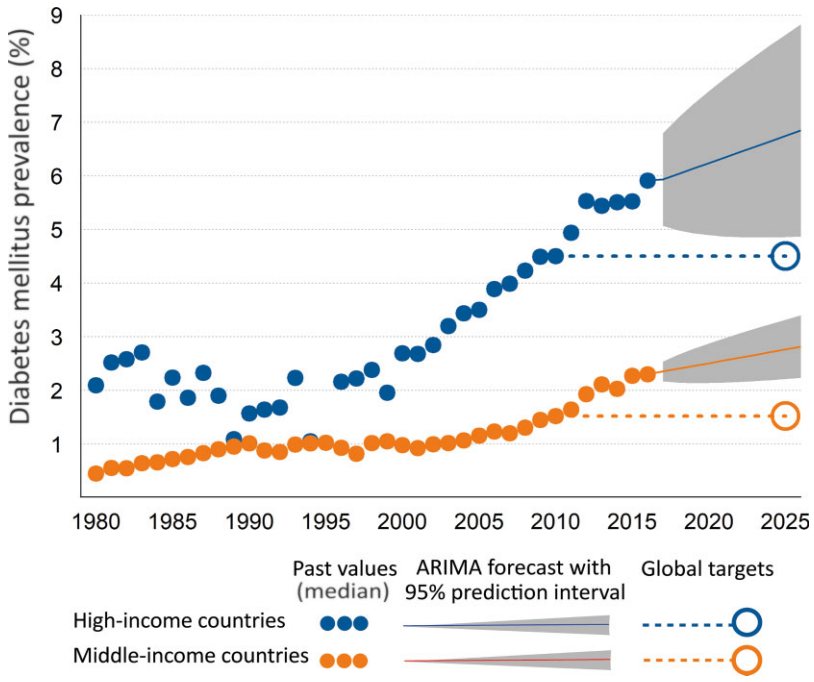


Figure 65 Prevalence of diabetes mellitus in European Society of Cardiology member countries. ARIMA forecast.

as a sudden event, not the endpoint of protracted diseases such as heart failure or stroke. There is also the common belief that CVD death occurs almost exclusively in the elderly despite age-group comparisons which show that rates are very comparable with cancer deaths in younger (<65 years) age groups.[306] There is misunderstanding too about the effects of treatment for CVD which, contrary to popular belief, is rarely curative but is usually protracted and associated with a persistently increased mortality risk.

Despite CVD accounting for a large percentage of all deaths across the European region, research spending is significantly lower compared with cancer[307,308] which, in recent years, has benefited from important national and international research initiatives such as Germany's 'decade against cancer' programme and the EU's 'Europe Beating Cancer Plan'. These ambitious projects in the fight against cancer are welcomed by the ESC but should act as a stimulus for increased research funding for CVD, as well as new policy initiatives aimed at reducing CVD mortality.[309]

The disproportionate spend on cancer research has been accompanied by a shift in focus of the med-tech and pharma industries away from CVD towards cancer. This has resulted in a significant decline in novel treatments approved for CVD. This move of focus away from CVD towards cancer is driven less by clinical need more by regulatory factors that make approval and facilitated reimbursement of drugs in certain clinical areas such as cancer easier to obtain compared with novel CVD therapies.[310–312]

This ESC Atlas report draws attention to the heterogeneity of risk factors, treatment facilities, and outcomes of CVD across ESC member countries. There is an important need for advocacy programmes to inform policymakers of the societal harms of CVD and the need for targeted action to reduce the burden of disease, especially in those ESC member countries where the burden is greatest. In response, the ESC has agreed upon an advocacy roadmap built around five key priorities:

- **Changing the perception of CVD.** Cardiovascular disease is often perceived as a lifestyle disorder that can be prevented by risk factor control and a healthy lifestyle. The first advocacy priority requires that this perception is widened to include the broad range of CVD phenotypes that are unrelated to risk factors or lifestyle, some of which are presented in this ESC Atlas report. These include degenerative valve disease, cardiomyopathies, congenital heart disease, and inherited/familial CVD. In widening the perception of CVD, the scale of the disease burden and the need for new therapeutic strategies that go beyond lifestyle and risk factor control can be better understood in advocating for the many patients living with non-preventable CVD who are exposed to a high risk of premature mortality.
- **Making CVD a health priority.** The morbidity and mortality attributes of CVD have been emphasized in this ESC Atlas report, but the second advocacy priority calls for a broader awareness of the burden of CVD and to involve patients as advocates. Patients and their families need to know the nature and the risks of their CVD and the adjustments they need to make in their personal and professional lives. Advocacy requires that their voices, together with the voices of all stakeholders, are heard in bringing CVD onto the policy agendas of national decision-makers.
- **Getting involved with decision-makers.** This ESC Atlas draws attention to the inequalities in CV morbidity and mortality across the ESC member states. The third ESC advocacy priority calls for NCS to establish regional advocacy structures aimed at improving CVD prevention and care. This requires

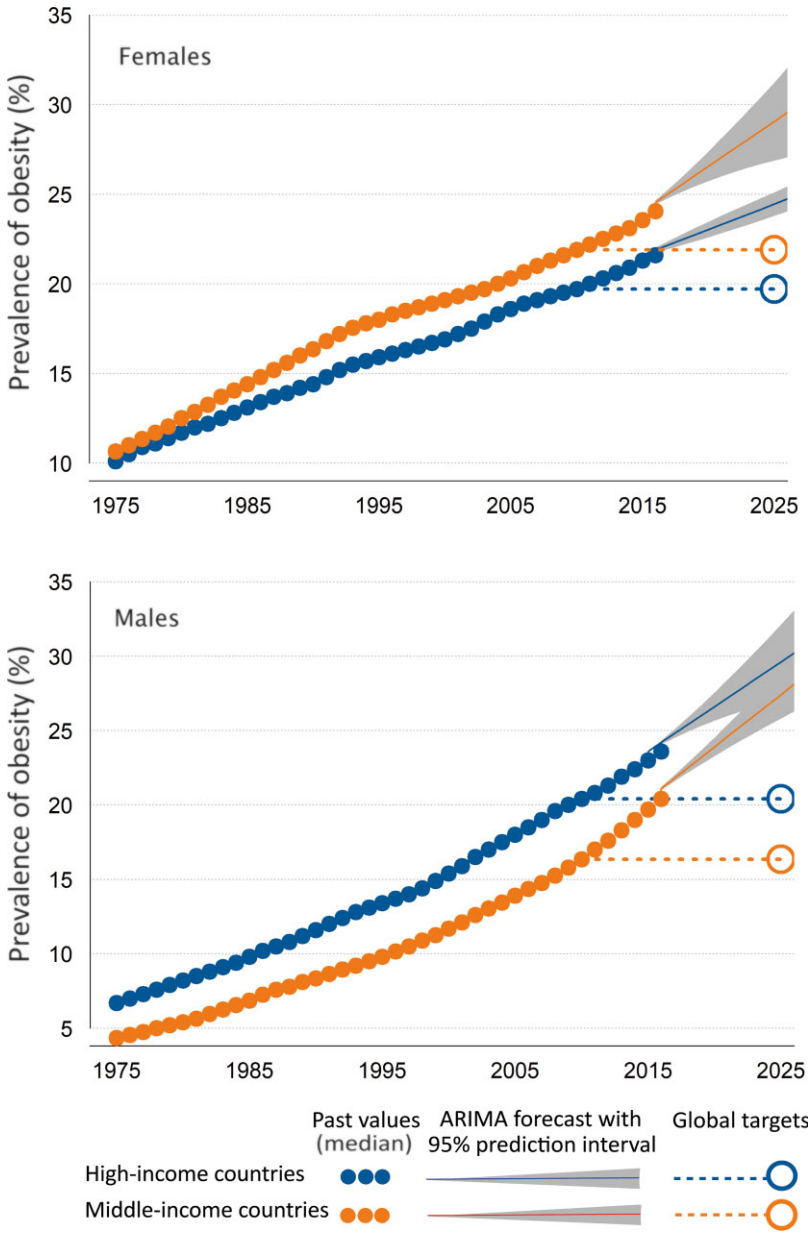


Figure 66 Prevalence of obesity in European Society of Cardiology member countries. ARIMA forecast.

provision of support and advice in cooperating with all stakeholders involved in CVD healthcare, particularly policymakers and those involved in regulatory processes. Advocacy in every ESC member state is key to the ESC's ambition to reduce the burden of CVD.

- **Promoting research and innovation.** Advocacy to promote CVD research and the clinical translation of innovative research findings is a key priority for meeting the challenges of CVD across ESC member states. Progress in molecular, genomic, and computational sciences, and the increasing availability of high-resolution imaging and bio-monitoring systems now permit detailed identification of many of the causes and mechanisms of CVD while making personalized CV care an ever-closer clinical reality. These technological advances call for more investment in CV research and innovation, yet at present, there is little accessible information about the extent of governmental, charitable, or industrial research spending for CVD or for other medical disciplines. This information is urgently needed in advocating for increased CVD research funding and reductions in the complexities of regulatory processes in order to facilitate the clinical translation of innovative research findings.
- **Coordinating and harmonizing ESC advocacy activities.** Advocacy, whether it is for patients living with CVD or for CVD research funding, requires the involvement of everyone involved in CV healthcare. Success is often measured in small incremental steps and often by personal activities at the local level. Advocacy is also a team effort, and the ESC is an intellectual powerhouse that is home to an army of dedicated

scientists and clinicians with unique expertise in CV science and healthcare. The fifth advocacy priority calls for mobilization and harmonization of this workforce in advocating on behalf of the 113 million people living with CVD across the member countries of the ESC.

Advocacy to increase awareness of policymakers, members of the public, and other stakeholders about the continuing importance of CVD as the leading cause of death among ESC member countries should be seen as a duty and responsibility of all who are involved in CV research and healthcare.

Data sharing

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

Supplementary material

Supplementary material is available at *European Heart Journal* online.

Acknowledgements

National Societies: We acknowledge the national societies of ESC member countries for their help in developing national infrastructure and healthcare data. Albania: Lezha Mimoza, Goda Artan, and Demiraj Aurel. Algeria: Mohammed Chettibi and Naima Hammoudi. Armenia: Katarine Vardanyan, Sergey Pepoyan, and Hamayak Sisakian. Austria: Daniel Scherr, Peter Siostrzonek, and Bernhard Metzer. Azerbaijan: Isah Mustafayev, Tofig Jahangirov, and Yasmin Rustamova. Belarus: Natalya Mitkovskaya, Natalya Shibeka, and Valeriy Stelmashok. Belgium: Michel De Pauw, Patrizio Lancellotti, and Marc Claeys. Bosnia and Herzegovina: Zumreta Kušljugić, Alen Džubur, and Elnur Smajić. Bulgaria: Mariya Tokmakova and Vassil Traykov. Croatia: Davor Milicic, Marijan Pasalic, and Sasa Pavasovic. Cyprus: Theodoros Christodoulides, Ilias Papasavvas, and Christos Eftychiou. Czech Republic: Aleš Linhart, Miloš Táborský, and Martin Hutyra. Denmark: Jacob Thorsted Sørensen, Mads Jønsson Andersen, and Steen Dalby Kristensen. Egypt: Magdy Abdelhamid and Khaled Shokry. Estonia: Priit Kampus. Finland: Mika Laine and Matti Niemelä. France: Bernard Iung, Ariel Cohen, and Christophe Leclercq. Georgia: Dali Trapaidze, Kakhaber Etsadashvili, and Alexander Aladashvili. Germany: Kurt Bestehorn, Stephan Baldus, and Andreas M. Zeiher. Greece: John Kanakakis, Alexandria Patrianakos, and Christina Chrysohoou. Hungary: Zoltán Csanádi, Dávid Becker, and Zoltán Járai. Iceland: Þórdís Jóna Hrafnkelsdóttir. Ireland: Vincent Maher, Jim Crowley, and Barbra Dalton. Israel: Arik Wolak, Eyal Ben Assa, and Barak Zafrir. Italy: Adriano Murrone, Carmen Spaccarotella, and Stefano Urbinati. Kazakhstan: Berkinbayev Salim, Sakhov Orazbek, and Abdrakhmanov Ayan. Republic of Kosovo: Gani Bajraktari, and Docor Afrim Poniku. Kyrgyzstan: Mirrakhimov Erkin, Abilova Saamay, and Kalysov Kurban. Latvia: Andrejs Erglis, Sanda Jegere, and Iveta Bajare. Lebanon: Malek Mohammed, Antoine Sarkis, and Georges Saadeh. Lithuania: Rimvydas Šlapikas, Tomas Lapinskas, and Jelena Čelutkienė. Libya: Khaled Ellafi and Fathi El Ghamari. Luxembourg: Jean Beissel and Cristiana Banu. Malta: Tiziana Felice and Robert Xuereb. Republic of Moldova: Mihail Popovici, Dorin Lisii, and Victor Rudi. Montenegro: Aneta Boskovic and Miroslav Rabrenovic. Morocco: Samir Ztot and Saadia Abir-Khalil. The Netherlands: J.G. Meeder, A.C. van Rossum, and M. Elsendoorn. North Macedonia: Jorgo Kostov, Elizabeta Srbinovska Kostovska, and Sasko Kedev. Norway: Kristin Angel, Ole Christian Mjølstad, and Øyvind Bleie. Poland: Marek Gierlotka, Rafał Dąbrowski, and Piotr Jankowski. Portugal: Sérgio Bravo Baptista, Jorge Ferreira, and Victor Gil. Romania: Elisabeta Badila, Dan Gaita, and Bogdan A. Popescu. Russian Federation: Evgeny Shlyakhto, Nadezhda Zvartau, and Evgenia Kotova. Republic of San Marino: Marina Foscoli and Marco Zavatta. Serbia: Sinisa Stojkovic, Milorad Tesic, and Stefan Juricic. Slovakia: Gabriela Kaliská, Robert Hatala, and Peter Hlivák. Slovenia: Zlatko Fras, Matjaž Bunc, and Andrej Pernat. Spain: Ángel Cequier, Manuel Anguita, and Javier Muñiz. Sweden: Bengt Johansson and Pyotr Platonov. Switzerland: David Carballo, Marjam Rüdiger-Stürchler, and Felix C. Tanner. Syrian Arab Republic: Hussam Eddin Shebli and Samer Kabbani. Tunisia: Leila Abid, Addad Faouzi, and Salem Abdessalem. Turkey: Vedat Aytekin and Ilyas Atar. Ukraine: V. Kovalenko and E. Nesukay. UK: Andrew Archbold, Upasana Tayal, and Chris Wilkinson. Uzbekistan: Ravshanbek Kurbanov, Khurshid Fozilov, and Mirakhmadjon Mirmaksudov. For support in developing the ESC Atlas: Dennis Boateng, Ghislain Daval, Ganna Momotyuk, and David Sebastiao.

Funding

The ESC Atlas project continuously collects data from a wide variety of organizations, including NCS, and seeks funding from multiple sources. For the timeframe covered in the manuscript, the project was supported by Janssen. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

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

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Erratum

https://doi.org/10.1093/eurheartj/ehac064
Online publish-ahead-of-print 5 February 2022

Erratum to: European Society of Cardiology: cardiovascular disease statistics 2021

European Heart Journal, https://doi.org/10.1093/eurheartj/ehab892.

In the originally published version of this manuscript, the reference for a group of co-authors was missed from the authorship list. The list should include: "on behalf of the Atlas Writing Group, European Society of Cardiology." instead of only "Atlas Writing Group." This omission has now been corrected online.