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SPECIAL ARTICLE
Coronary artery disease

European Society of Cardiology: Cardiovascular Disease Statistics 2019

On behalf of the Atlas Writing Group

The ESC Atlas of Cardiology is a compendium of cardiovascular statistics compiled by the European Heart Agency, a department of the European Society of Cardiology

Developed in collaboration with the national societies of the European Society of Cardiology member countries

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Aims The 2019 report from the European Society of Cardiology (ESC) Atlas provides a contemporary analysis of cardiovascular disease (CVD) statistics across 56 member countries, with particular emphasis on international inequalities in disease burden and healthcare delivery together with estimates of progress towards meeting 2025 World Health Organization (WHO) non-communicable disease targets.

Methods and results In this report, contemporary CVD statistics are presented for member countries of the ESC. The statistics are drawn from the ESC Atlas which is a repository of CVD data from a variety of sources including the WHO, the Institute for Health Metrics and Evaluation, and the World Bank. The Atlas also includes novel ESC sponsored data on human and capital infrastructure and cardiovascular healthcare delivery obtained by annual survey of the national societies of ESC member countries. Across ESC member countries, the prevalence of obesity (body mass

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index ≥30 kg/m^2) and diabetes has increased two- to three-fold during the last 30 years making the WHO 2025 target to halt rises in these risk factors unlikely to be achieved. More encouraging have been variable declines in hypertension, smoking, and alcohol consumption but on current trends only the reduction in smoking from 28% to 21% during the last 20 years appears sufficient for the WHO target to be achieved. The median age-standardized prevalence of major risk factors was higher in middle-income compared with high-income ESC member countries for hypertension {23.8% [interquartile range (IQR) 22.5–23.1%] vs. 15.7% (IQR 14.5–21.1%)}, diabetes [7.7% (IQR 7.1–10.1%) vs. 5.6% (IQR 4.8–7.0%)], and among males smoking [43.8% (IQR 37.4–48.0%) vs. 26.0% (IQR 20.9–31.7%)] although among females smoking was less common in middle-income countries [8.7% (IQR 3.0–10.8) vs. 16.7% (IQR 13.9–19.7%)]. There were associated inequalities in disease burden with disability-adjusted life years per 100 000 people due to CVD over three times as high in middle-income [7160 (IQR 5655–8115)] compared with high-income [2235 (IQR 1896–3602)] countries. Cardiovascular disease mortality was also higher in middle-income countries where it accounted for a greater proportion of potential years of life lost compared with high-income countries in both females (43% vs. 28%) and males (39% vs. 28%). Despite the inequalities in disease burden across ESC member countries, survey data from the National Cardiac Societies of the ESC showed that middle-income member countries remain severely under-resourced compared with high-income countries in terms of cardiological person-power and technological infrastructure. Under-resourcing in middle-income countries is associated with a severe procedural deficit compared with high-income countries in terms of coronary intervention, device implantation and cardiac surgical procedures.

Conclusion A seemingly inexorable rise in the prevalence of obesity and diabetes currently provides the greatest challenge to achieving further reductions in CVD burden across ESC member countries. Additional challenges are provided by inequalities in disease burden that now require intensification of policy initiatives in order to reduce population risk and prioritize cardiovascular healthcare delivery, particularly in the middle-income countries of the ESC where need is greatest.

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

Table of Contents

Abbreviations

AF	Atrial fibrillation
AMI	Acute myocardial infarction
ASMR	Age-standardized mortality rate
BMI	Body mass index
CABG	Coronary artery bypass graft
CHE	Current healthcare expenditure
COI	Cost of illness
CRT-D	Cardiac resynchronization pacemaker with implantable cardioverter-defibrillator
CRT-P	Cardiac resynchronization pacemaker ('biventricular pacemaker')
CVD	Cardiovascular disease
DALY	Disability-adjusted life year
€	Euro
EHN	European Heart Network
EHRA	European Heart Rhythm Association
ESC	European Society of Cardiology
ESP	European Standard Population
EU	European Union
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
ICD	Implantable cardioverter-defibrillator
IHD	Ischaemic heart disease
IHME	Institute for Health Metrics and Evaluation
IQR	Interquartile range
LVAD	Left ventricular assist device
NCD-RisC	Non-communicable Diseases Risk Factor Collaboration
NCS	National cardiac societies
OECD	Organization for Economic Co-Operation and Development
PCI	Percutaneous coronary intervention
PPP	Purchasing power parity
PVD	Peripheral vascular disease
PYLL	Potential years of life lost
SHA	System of Health Accounts
TAVI	Transcatheter aortic valve implantation
UK	United Kingdom
USA	United States of America
USD	US dollars
WB	World Bank
WHO	World Health Organization

Executive summary

This is the second report on cardiovascular disease (CVD) statistics for the member countries of the European Society of Cardiology (ESC). It updates and expands upon the widely cited 2017 report[1] and now includes data from 56 of the 57 member countries (Uzbekistan's data contribution was unavailable at the time of writing). Contributing member countries are:

- All European countries except Andorra, Liechtenstein, Monaco, and Vatican City
- Non-European countries
  - Asia: Kazakhstan and Kyrgyzstan
  - East Mediterranean: Israel, Lebanon, and Syrian Arab Republic
  - North Africa: Algeria, Egypt, Libya, Morocco, and Tunisia

1. *ESC Atlas of Cardiology*: The CVD statistics that constitute this report are drawn from the ESC Atlas of Cardiology that is compiled and regularly updated by the European Heart Agency in Brussels.[2] The key objectives of the ESC Atlas of Cardiology are to:

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

2. *Data sources and presentation*: The ESC Atlas is a repository of CVD data collected by groups such as the World Health Organization (WHO), the Institute for Health Metrics and Evaluation (IHME), and the World Bank (WB). It also includes novel ESC sponsored data on human and capital infrastructure and cardiovascular healthcare delivery

obtained by annual survey of the national societies of ESC member countries.

Throughout the 2019 report, ESC member countries are categorized according to 2018 WB definitions as high-income and middle-income (a composite of lower- and upper-middle-income) to permit stratified presentations of CVD statistics by national income status.[3]

The data sources come with important limitations that include:

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

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

3. *Financial and economic burden of cardiovascular disease*: The ESC Atlas provides a potential platform for collecting economic data relevant to CVD in ESC member countries. In a European Heart Network study, CVD was estimated to cost the European Union economy €210 billion a year in 2015, 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.[4] The study highlighted substantial variation in CVD economic burden with direct healthcare cost per capita ranging from €48 in Bulgaria to €365 in Finland. In Germany, the cost of CVD comprised 13% of national health expenditure and is projected to surpass €40 billion by 2020.[5] The data presented in this report show that the burden of CVD disease is not only a health issue, but an economic challenge to the healthcare systems of ESC member countries that is expected to grow exponentially in future years.[6]
4. *Risk factors and health behaviours*: Nine risk factors and health behaviours, accounting for >90% of the population attributable risk of acute myocardial infarction, were identified in the INTERHEART study.[7] National statistics relevant to eight of these risk factors and health behaviours are available in the ESC Atlas as follows:
   - *Blood pressure*: Across ESC member countries, almost one in four people had elevated blood pressure (≥140/90 mmHg) in 2015. Systolic blood pressure was higher in males compared with females and in middle-income compared with high-income countries. The median age-standardized prevalence of elevated blood pressure trended downwards between 1980 and 2015 from 35.3% to 24.8%.
   - *Cholesterol*: Across ESC member countries, about one in seven people had hypercholesterolaemia (≥6.2 mmol/L) in 2009. Rates were similar in females and males but were substantially lower in middle-income compared with high-income countries. Median age-standardized blood cholesterol concentrations declined from 5.5 to 5.1 mmol/L between 1980 and 2009.
   - *Diabetes*: Across ESC member countries, more than one in 20 adults had diabetes with prevalence higher in middle-income compared with high-income countries. Prevalence has increased three-fold during the last 25 years.
   - *Obesity*: Across ESC member countries, age-standardized data showed that one in five adults was obese in 2016, as defined by a body mass index of ≥30 kg/m^2 with prevalence similar in high-income and middle-income countries. Prevalence across ESC member countries increased sharply between 1980 and 2016 from 9.6% to 22.6%.
   - *Smoking*: Across ESC member countries, more than one in five adults smoked tobacco according to 2014 estimates. Smoking was less common in females than males, particularly in middle-income countries. Between 1995 and 2014, the prevalence of smoking across ESC member countries declined from 28.0% to 21.0%.
   - *Alcohol*: Across ESC member countries alcohol consumption was more than three times higher in males compared with females, and almost twice as high in high-income compared with middle-income countries. Since 2010 consumption has declined by nearly 9% in middle-income countries but in high-income countries little change has occurred.
   - Vegetable and fruit consumption: Across ESC member countries just over half of all adults consumed at least one portion of both vegetables and fruit, with consumption greater in females than males.
   - *Physical activity*: Across ESC member countries, physical activity was graded insufficient in one in three adults. Rates of inactivity were somewhat higher in females compared with males, and in high-income compared with middle-income countries.

   The WHO has set non-communicable disease targets relevant to global cardiovascular health to be achieved by 2025 (with reference to 2010).[8] If current trends recorded in the ESC Atlas continue, the target for a 30% relative reduction in tobacco use appears feasible for ESC member countries and also the target for a 10% relative reduction in harmful use of alcohol for middle-income (not high-income) countries. Trends documented in the ESC Atlas make targets for a 25% relative reduction in the prevalence of elevated blood pressure and for a halt in the rise of diabetes and obesity unlikely to be achieved.
5. *Cardiovascular disease morbidity*: During the last 27 years, declines in the age-standardized incidence of CVD across ESC member countries have been small and in 11 countries non-existent. The incidence of CVD's major components, ischaemic heart disease (IHD), and stroke, have both shown a downward trend but changes in prevalence have been small. The age-standardized incidence and prevalence of IHD and stroke were lower in females than males and in high-income compared with middle-income ESC member countries. Ischaemic heart disease and stroke accounted for 82% of disability-adjusted life years (DALYs) due to CVD in ESC member countries. Age-standardized DALYs due to CVD have been in steep decline the last 27 years, with just two middle-income countries recording an increase. Disability-adjusted life years due to CVD were almost twice as high in males compared with females and three times as high in middle-income compared with high-income ESC member countries.

   The morbidity statistics recorded in the ESC Atlas confirm persisting inequalities in disease burden by gender 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.

6. *Cardiovascular disease mortality*: Cardiovascular disease remains the most common cause of death across ESC member countries with age-standardized rates greater for males than females. It accounts for more than one in three of all potential years of life lost (PYLL). Cardiovascular disease is also the most common cause of premature (age <70 years) death in males but in females cancer is now more common. In both sexes, premature CVD death is more common in middle-income countries where it accounts for a greater proportion of PYLL compared with high-income countries.

   Inequalities in CVD mortality recorded in the ESC Atlas largely mirror those for morbidity with the CVD burden falling hardest on middle-income countries that are less able to meet the costs of contemporary healthcare compared with high-income countries. Cardiovascular disease prevention is less affected by resource constraints and the potential reversibility of risk factors and unhealthy behaviours provides a huge opportunity to address the health inequalities documented in this report. Meanwhile, the WHO target for a 25% relative reduction in mortality from CVD, cancer, diabetes, and chronic respiratory disease by 2025[8] is unlikely to be achieved with the downward CVD trends documented in this report concealing alarming increases in mortality in some member countries.
7. *Cardiovascular healthcare delivery*: The 2018/19 survey data recorded in the ESC Atlas shows a 15-fold variation in cardiologists per million people across ESC member countries, with females comprising just 28% of all cardiologists. Middle-income member countries are severely under-resourced compared with high-income countries in terms of cardiological person-power and technological infrastructure. Under-resourcing in middle-income countries is associated with a severe procedural deficit compared with high-income countries in terms of coronary intervention, device implantation, and cardiac surgical procedures. Despite this, outliers can often be identified emphasizing that national income status is not the only driver for cardiological healthcare delivery.

   The 15-fold variation in cardiologists per million people across ESC member countries suggests that under-provision may be common. Under-representation of females is also common and is now recognized as a particular problem for cardiology.[9,10] Contemporary CVD investigation and treatment represents a substantial challenge to national economies and this no doubt contributes to the under-provision of capital resource, manpower, and interventional technologies in many middle-income ESC member countries. Technological costs are predicted to increase steeply in coming years, and this will exacerbate the challenge to middle-income economies. Cardiovascular disease prevention is surely the solution, being less dependent on financial muscle and providing a more effective means of managing the CVD epidemic and reducing disease burden.
8. *Conclusion*: This report gives much attention to the inequalities that persist between high-income and middle-income ESC member countries. Inequalities impact upon healthcare delivery and disease prevalence, the availability of good cardiological care tending to vary inversely with national needs. The paradox of greater cardiological provision in those high-income ESC member countries where need is manifestly less must contribute to the continued imbalance in cardiovascular mortality between high- and middle-income member countries. Resolution of this paradox is now a major goal of the ESC in its global mission to reduce the burden of CVD.

1 Introduction

This is the second report on cardiovascular disease (CVD) statistics for the member countries of the European Society of Cardiology (ESC). It updates and expands upon the widely cited 2017 report[1] and now includes data from 56 of the 57 member countries, with Uzbekistan's data contribution unavailable at the time of writing. Contributing member countries are not restricted to Europe and include:

- All European countries except Andorra, Liechtenstein, Monaco, and Vatican City
- Non-European countries
  - Asia: Kazakhstan and Kyrgyzstan
  - East Mediterranean: Israel, Lebanon, and Syrian Arab Republic
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The CVD statistics that constitute this report are drawn from the ESC Atlas of Cardiology that is compiled and regularly updated by the European Heart Agency in Brussels.[2] The ESC Atlas of Cardiology is a repository of CVD data collected by groups such as the World Health Organization (WHO), the Institute for Health Metrics and Evaluation (IHME), and the World Bank (WB). It also includes novel ESC sponsored data on human and capital infrastructure and cardiovascular healthcare delivery obtained by annual survey of the national societies of ESC member countries. The key objectives of the ESC Atlas are to:

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

The 2019 report, like its predecessor, includes chapters on risk factors and health behaviours, CVD morbidity and mortality, and cardiovascular healthcare delivery across the ESC member countries. The chapters have been updated with presentation of the latest available disease statistics and expanded to include a broader range of CVD phenotypes as well as additional information about human and capital resources and interventional treatments. Again, much attention has been given to the inequalities that persist between high-income and middle-income ESC member countries.[11] Inequalities impact upon healthcare delivery and disease prevalence, the availability of good cardiological care tending to vary inversely with national needs according to the predictions of Tudor Hart's inverse care law.[12] The causes of these inequalities are complex, but economic context is clearly an important factor that now receives further attention in a new chapter on the cardiovascular healthcare economics of selected ESC member countries.

The 2019 report also provides a focus on the WHO non-communicable disease (NCD) targets relevant to global cardiovascular health.[8] Six out of the nine targets call for reductions in CVD mortality and risk factors with reference to 2010 as follows:

(1) a 25% relative reduction in the overall mortality from CVDs, cancer, diabetes, or chronic respiratory diseases;
(2) at least 10% relative reduction in the harmful use of alcohol, as appropriate, within the national context;

(3) a 10% relative reduction in prevalence of insufficient physical activity;
(4) a 30% relative reduction in prevalence of current tobacco use in persons aged 15+ years;
(5) a 25% relative reduction in the prevalence of elevated blood pressure or contain the prevalence of elevated blood pressure, according to national circumstances; and
(6) Halt the rise in diabetes and obesity.

The deadline for meeting these targets is 2025; the progress being made by ESC member countries is summarized in relevant sections of this report.

This report of cardiovascular statistics for ESC member countries responds to the WHO recommendations for the development of surveillance and monitoring programmes in order to understand the international prevalence of CVD, and predict future trends.[13] It provides an essential resource to guide national policy directives aimed at reducing the burden of CVD according to the mission statement of the ESC.

2 Data sources and presentation

Key data sources for the European Society of Cardiology Atlas include:

- European Society of Cardiology (ESC): statistics on national cardiovascular infrastructure and procedures derived from a survey of the National Cardiac Societies (NCS) of 41 ESC member countries
- World Health Organization (WHO): risk factor and mortality statistics
- Institute for Health Metrics and Evaluation (IHME): morbidity and disease burden statistics from the Global burden of disease (GBD) study
- World Bank (WB): economic indicators
- Food and Agriculture Organization of the United Nations (FAO): dietary data

2.1 European Society of Cardiology cardiovascular healthcare data

The ESC Atlas contains more than 100 variables relating to human and capital infrastructure and major cardiovascular interventions and services from 41 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.[2]

The survey yields absolute numbers for resources and procedures. Crude rates per million people are computed from WB population estimates.[14]

2.2 World Health Organization data

Mortality data come from the WHO Mortality Database[15] using the May 2018 update of age- and cause-specific mortality data by country. These data are publicly available. This manuscript presents mortality data for 51 of the 56 ESC member countries, all from the WHO European Region. No data are presented for Albania, Algeria, Lebanon, 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 better reflect the age structure of the current European population.[16]

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 six of the 51 countries dating from 2013 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 Non-communicable Diseases Risk Factor Collaboration (NCD-RisC). Estimates are age-standardized to facilitate international comparisons. Details of methods and data sources are described elsewhere.[17–19]

2.3 Global burden of disease—Institute for Health Metrics and Evaluation data

Estimates of CVD prevalence come from the GBD study, conducted by the IHME.[20] The estimates are derived using modelling software and data from health surveys, prospective cohorts, health system administrative data and registries.[21,22] 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. It is also possible that current estimates may change, as more recent data become available. 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).[23] The GBD has also received critique in recent years on methodology, culture, and qualitative difference in addition to a lack of homogeneity in access to resources.[24]

2.4 World Bank data

Data on various economic indicators come from the WB.[25] 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.

2.5 Data presentation and analysis

Data from the ESC Atlas are presented for 56 ESC member countries, stratified according to the 2018 WB definitions of income status[3]: (*Figure 1*, Supplementary material online, *Figure S2.1*)

- high-income: GNI per capita USD≥12 055;
- upper-middle-income GNI per capita USD3896−12 055; and
- lower-middle-income GNI per capita USD996−3895.

Throughout the manuscript, the term 'middle-income countries' represents a composite of upper- and lower-middle-income ESC member countries. 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, 'averaged' statistics across groups of countries are presented as medians in the manuscript and values >1000 are not decimalised. 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).[26] 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 outliers and are plotted individually.

2.6 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 throughout the article in the relevant section headings. General limitations of the data include the adjustment applied by all the main providers to account for missing data, and differences in reporting practices such that precision of the estimates they provide often varies by country. Misclassification bias due to miscoding of diagnostic groups and death certificates is another potential limitation. Data completeness also varies by country and is defined within each section of the manuscript in the data provenance statements under the section headings and in the figure legends. The ESC Atlas does not provide information about within-country inequalities.[27,28] 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 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 emphasize the need for cautious interpretation of the CVD statistics presented in this report.

3 Financial and economic burden of cardiovascular disease

3.1 Introduction

Cardiovascular healthcare constitutes a significant proportion of total healthcare expenditure across ESC member countries. In this chapter, we focus on the financial burden of CVD across the limited number of countries that have been the subject of systematic reviews and comparative health economic studies.[29,30] Incomes and costs are quoted in USD according to WB convention, or in Euros (€), depending on the data source.

3.2 Health expenditure across European Society of Cardiology member countries

Data: Current health expenditure per capita, current health expenditure as percentage of gross domestic product; Data source: World Bank, https://data.worldbank.org/indicator/SH.XPD.CHEX.PP.CD **and** https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS, **respectively; Completeness: High-income countries 31/31 (100%), middle-income countries 23/25 (92%); Year of data: 2000−2016.**

3.2.1 Current health expenditure

This quantifies the total healthcare spend using a common currency unit that is 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 and it is not surprising that current healthcare expenditure (CHE) per capita in 2016 varied widely from approximately USD 240 in Kyrgyzstan to almost USD 7900 in Switzerland.[31] Even after adjusting for local purchasing power, high-income countries spent, on average, four times more on healthcare than those in the lower-middle-income group. Within the high-income group the expenditure range was considerable (*Figure 2*) with Switzerland, Luxembourg, and Norway all spending more than USD 6000 per capita followed by Germany, Sweden, and Ireland spending more than USD 5000 per capita. Among middle-income countries Bulgaria, Russian Federation, and Serbia had the highest expenditure at more than USD 1300 per capita while Morocco and Kyrgyzstan were at the bottom of the list spending just USD 466 and 240 per capita, respectively (*Figure 2*).

3.2.2 Ratio of current health expenditure to gross domestic product

This is an indicator of how much a country spends on healthcare in relation to all other goods and services. Across the 52 ESC member countries, the ratio in 2016 averaged 7.4%, ranging from 6.7% in middle-income countries to 8.5% in high-income countries.[32] Within middle-income countries, the health expenditure ranged from 3.5%

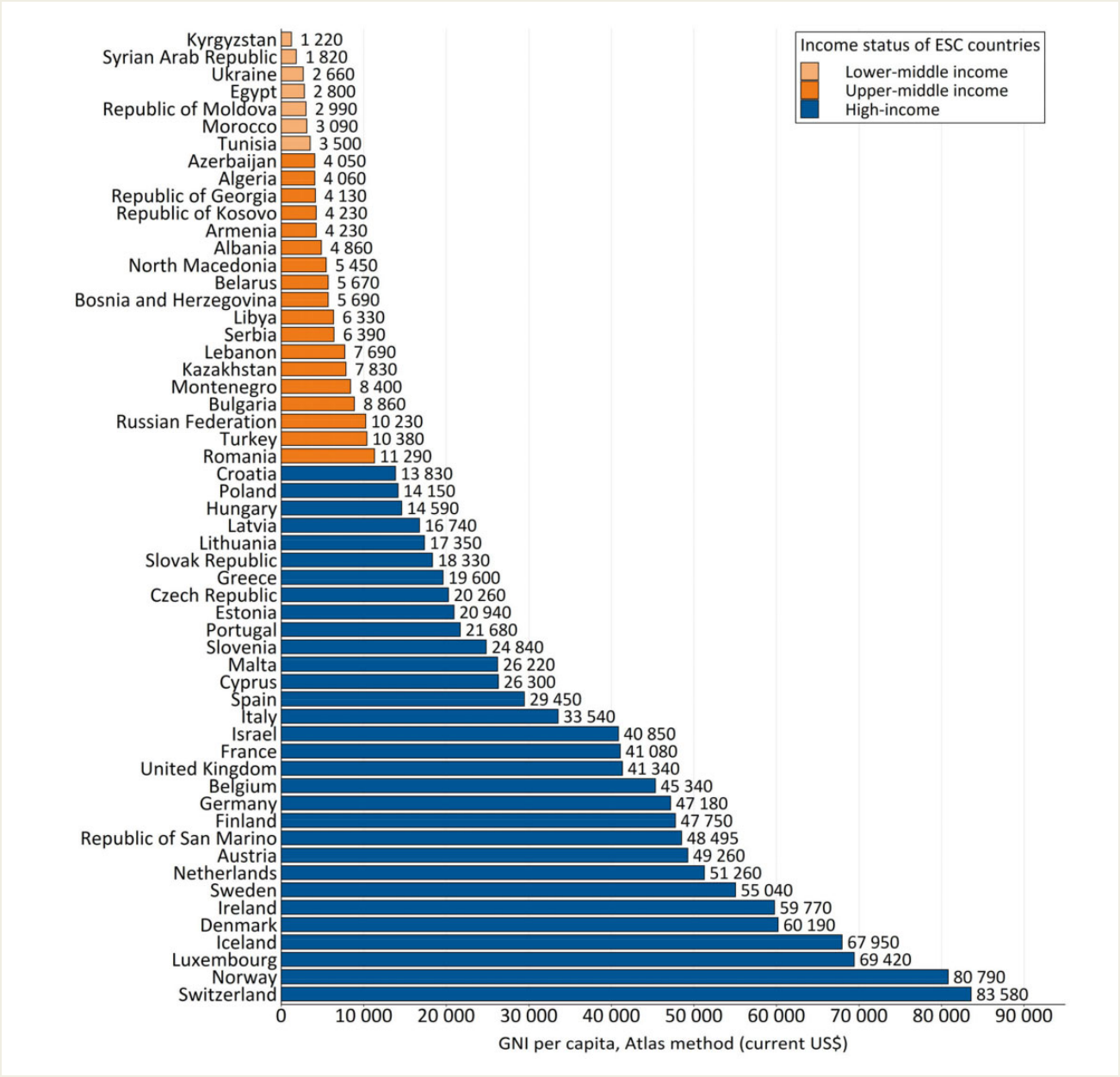

Figure 1 ESC member countries stratified by gross national income per capita (2018). *Data source*: World Bank, https://data.worldbank.org/indicator/NY.GNP.PCAP.CD. *Data not available*: Syrian Arab Republic (value for latest available year was used) and San Marino (gross national income was used).

to 9.9% of gross domestic product (GDP) with Kazakhstan, Turkey, Egypt, and Romania each spending less than 5% of GDP on healthcare. Within high-income countries, the health expenditure ranged from 6.2% to 12.2% of GDP with Switzerland, France, and Germany topping the list, while Estonia, Lithuania, Poland, and Latvia spent less than 7% of their GDP on healthcare. Luxembourg too spent less than 7% of GDP on healthcare despite its USD 6374 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, both middle- and high-income, resulting in an increase in the proportion of GDP dedicated to health (*Figure 3*).

3.3 Financial burden of cardiovascular disease

Data: Spending on CVD expressed as percentage of current health expenditure; Data source: OECD, https://stats.oecd.org/index.aspx?DataSetCode=SHA**; Completeness: High-income countries 5/31 (16%), middle-income countries 0/25 (0%); Year of data: Latest available between 2006 and 2011, median 2008.**

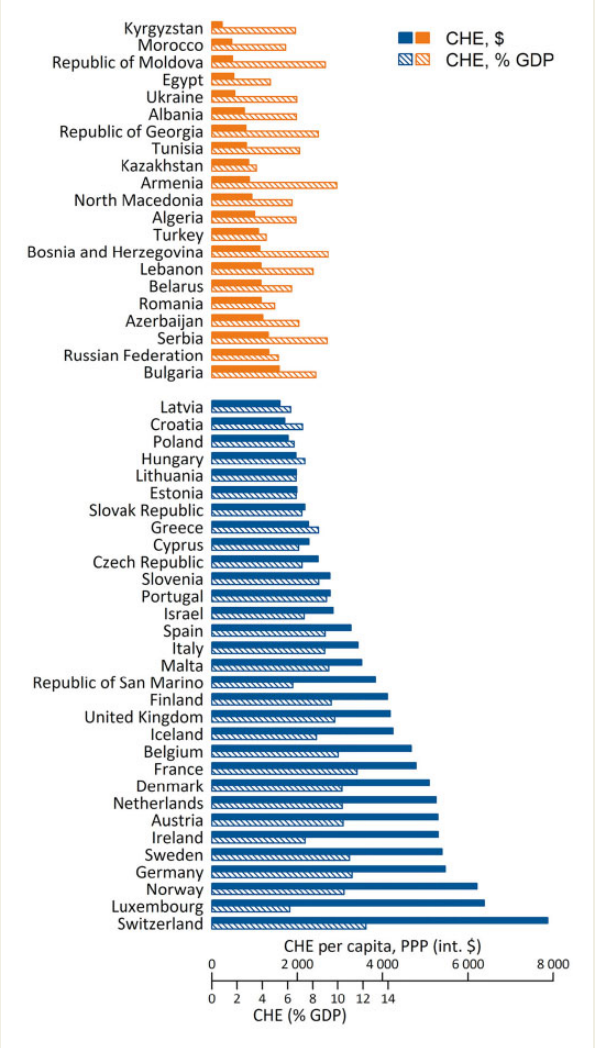

Figure 2 Current health expenditure per capita in middle-income (orange) and high-income (blue) ESC member countries. The broken bars express current health expenditure as a percentage of gross domestic product (2016). *Data source*: World Bank, https://data.worldbank.org/indicator/SH.XPD.CHEX.PP.CD and https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS. *Data not available for the following middle-income countries*: Libya, Montenegro, Republic of Kosovo, and Syrian Arab Republic (Supplementary material online, file: S3.xlsx).

In recent years, Eurostat and Organization for Economic Co-Operation and Development (OECD) have collaborated in developing guidelines for the distribution of health spending by disease, age and gender. To increase the comparability of the estimates, the OECD adopted the System of Health Accounts (SHA) to provide an updated and systematic description of financial flows related to the consumption of health care goods and services at an international level.[33] This led to the development of a set of guidelines which were tested in six countries (Australia, Germany, Hungary, South Korea, Slovenia, and Sweden).[34] In 2016, for the first time, OECD released data on health spending by disease, age, and gender, reporting that CVD accounted for more than 10% of current health expenditure as well as the largest share of inpatient and pharmaceutical spending.[35] In 2006, Hungarian CVD expenditure reached almost 16% of total CHE compared with 11% in the Netherlands in 2011.[35] In 2013, Eurostat commissioned the Health Expenditures by Diseases and Conditions (HEDIC) project,[36] which included Bulgaria, Czech Republic, Germany, Greece, Latvia, Lithuania, Hungary, 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. Cardiovascular disease healthcare expenditure as a proportion of total healthcare expenditure ranged from 10% in Sweden to more than 22% in Bulgaria and almost 24% in Lithuania. The Eurostat report concluded that although the share of health expenditure devoted to CVD has been diminishing in recent years, it remains a highly significant component of the overall spend.

Both the OECD and HEDIC study demonstrated the feasibility of estimating expenditures by disease, in a wide range of national settings and data contexts. However, as of today, there are no systematic data on CVD health expenditure across the majority of the 56 countries included in the ESC Atlas. This evidence gap raises a significant challenge that must be addressed.

It needs emphasizing that OECD and Eurostat only provide estimates of the *financial* burden of CVDs. Although potentially useful for informing policy, there are significant limitations to this approach. Foremost, financial analysis is limited to healthcare expenditure and reflects only the portion of the costs associated with CVD. From a methodological point of view, financial costs are inherently different from *economic* costs, which reflect the total burden of a specific disease (or group of diseases) from a societal perspective.

3.4 Economic burden of cardiovascular diseases

Data: Distribution of costs of cardiovascular disease in the EU member states; Data source: The European Heart Network[35]; Completeness: High-income countries 26/31 (84%), middle-income countries 2/25 (8%); Year of data: 2015.

Cost-of-illness (COI) analysis seeks to evaluate the economic burden diseases impose on society as a whole. This societal perspective implies consideration of not only direct healthcare costs but also indirect costs including opportunity costs associated with unpaid care (i.e. informal care) and productivity losses associated with premature death or morbidity.

Two international COI studies provide useful insights into the economic burden of CVD in ESC member countries. Leal *et al.*[30] were first to assess the economic burden of CVD across the European Union (EU). Cardiovascular disease was estimated to cost the EU €169 billion annually in 2006, with healthcare accounting for 62% of costs. Productivity losses and informal care represented 21% and 17% of costs, respectively. Coronary heart disease represented 27% and cerebrovascular diseases 20% of overall CVD costs.[30] The European Heart Network (EHN) conducted a similar updated exercise in which CVD was estimated to cost healthcare systems of the EU over €106 billion in 2009.[37] This equated to around 9% of total healthcare expenditure across the EU. More recent estimates of the

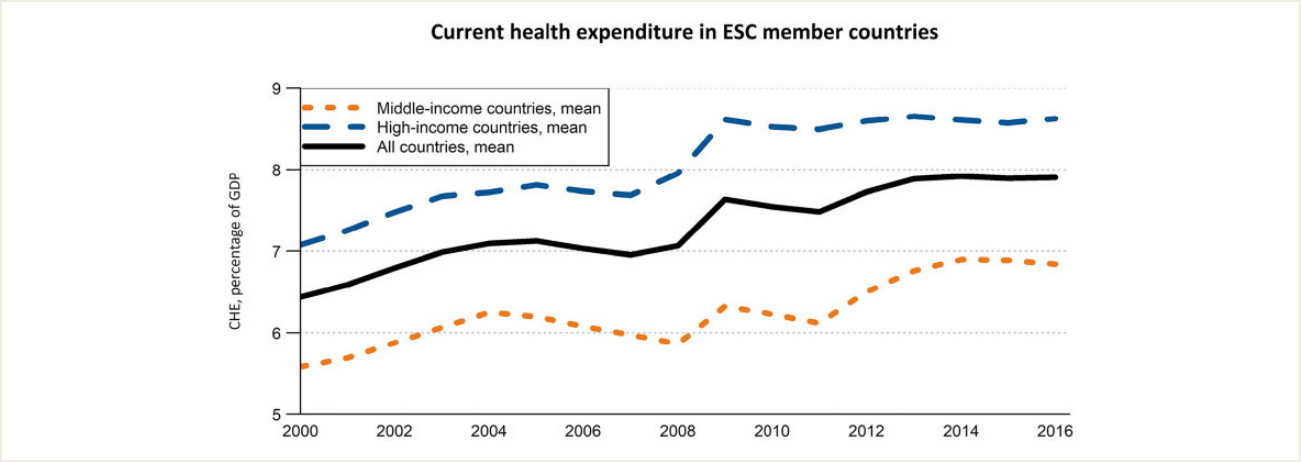

Figure 3 Current health expenditure in ESC member countries, expressed as percentage of gross domestic product (2000–2016). *Data source*: World Bank, https://data.worldbank.org/indicator/SH.XPD.CHEX.GD.ZS. *Data not available for the following middle-income countries*: Montenegro and Republic of Kosovo (Supplementary file: S3.xlsx).

economic burden of CVD are now available from the EHN which include healthcare costs (primary care, outpatient care, A&E, inpatient care, and medications), informal care, and productivity losses both due to premature mortality and morbidity.[4] Cardiovascular disease was estimated to cost the EU economy €210 billion a year in 2015, of which 53% (€111 billion) is due to healthcare costs, 26% (€54 billion) to productivity losses and 21% (€45 billion) to the informal care of people with CVD (*Figure 4*). Within healthcare costs, the cost of inpatient hospital care for CVD patients accounted for about 51%, and that of medications for about 25%. Total costs of ischaemic heart disease (IHD) amounted to approximately €59 billion in 2015, with informal care costs representing the highest percentage of the total expenses (€20 billion, 35%). Cerebrovascular disease accounted for nearly €45 billion, with direct healthcare costs consuming the largest share (€20 billion, 44%).[4]

The EHN study highlighted substantial variation in CVD economic burden with direct healthcare cost per capita ranging from €48 000 in Bulgaria to €365 000 in Finland. In Bulgaria, Croatia, Romania, Latvia, Lithuania and Cyprus, direct healthcare costs per capita were below €100 000, while Hungary had the highest proportion of total healthcare expenditure consumed by CVD (19% of the total healthcare expenditure).[4] There was similar variation in the distribution of costs across different categories (*Figure 5*) with the proportion of CVD costs associated with inpatient care, for example, less than 10% in Cyprus, Latvia, Portugal, and Croatia compared with more than 40% in France and Finland. Pharmaceutical expenditure was particularly important in Greece where it consumed 28% of total CVD costs, compared with just 7% in Sweden, Finland, and Estonia. The proportion of total expenses dedicated to informal care ranged from a minimum of 7% in Finland to more than 30% in southern European countries such as Portugal and Croatia.[37]

3.5 National cost of cardiovascular disease

UK, France, and Germany have provided estimates of the financial and economic burden of CVD at national level. 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.[38] In France, the estimated cost of CVD, based on individuals covered under the national health insurance system, was €15.1 billion (10% of all reimbursed health expenditure).[39] Germany incurred the highest financial and economic burden from CVD among EU countries at €34.7 billion (13% of total health expenditure) and is projected to surpass €40 billion by 2020.[5]

Further studies have examined the contribution CVD makes to the financial burden of other diseases.[40] A 2018 systematic review, for example, calculated that CVD accounted for 20–49% of the direct cost of treating type two diabetes. Furthermore, the cost of care for patients with type 2 diabetes and CVD was 112% higher than diabetes alone.

3.6 Summary

- The global burden of CVD disease is not only a health issue, but an economic challenge to healthcare systems that is expected to grow exponentially in future years.[41]
- To meet this challenge across ESC member countries, policymakers need access to reliable information about the financial and economic burden of CVD.
- OECD, Eurostat, and EHN have made essential contributions, and meanwhile the ESC Atlas initiative provides a platform for collecting relevant data on the economic aspects of CVD burden as it affects ESC member countries.
- National costs of CVD in selected high-income European countries comprise up to 19% of total healthcare expenditure.[4]

3.7 Comment

Cardiovascular disease has major economic consequences that affect individuals, health systems and societies across the globe. The World Heart Federation has estimated that by 2030, the total global cost of CVD is set to rise from approximately USD 863 billion in 2010 to a staggering USD 1044 billion.[42]

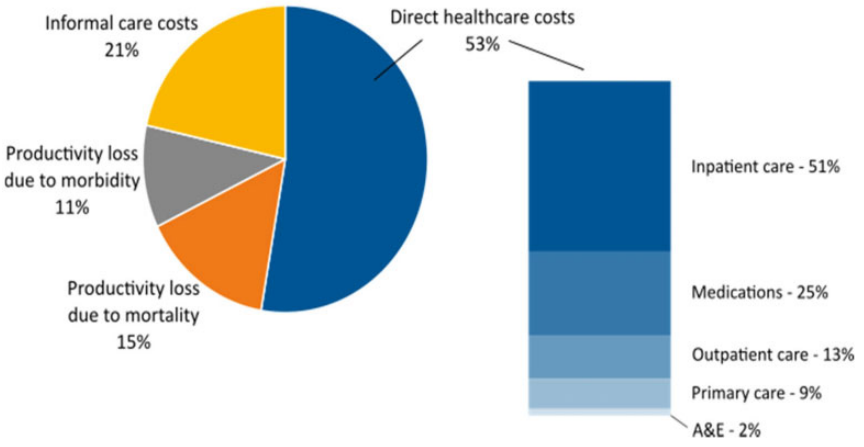

Figure 4 Cost of cardiovascular disease, ischaemic heart disease, and stroke in the EU by category (2015). *Data source*: Wilkins *et al.*[4] (Supplementary file: S3.xlsx).

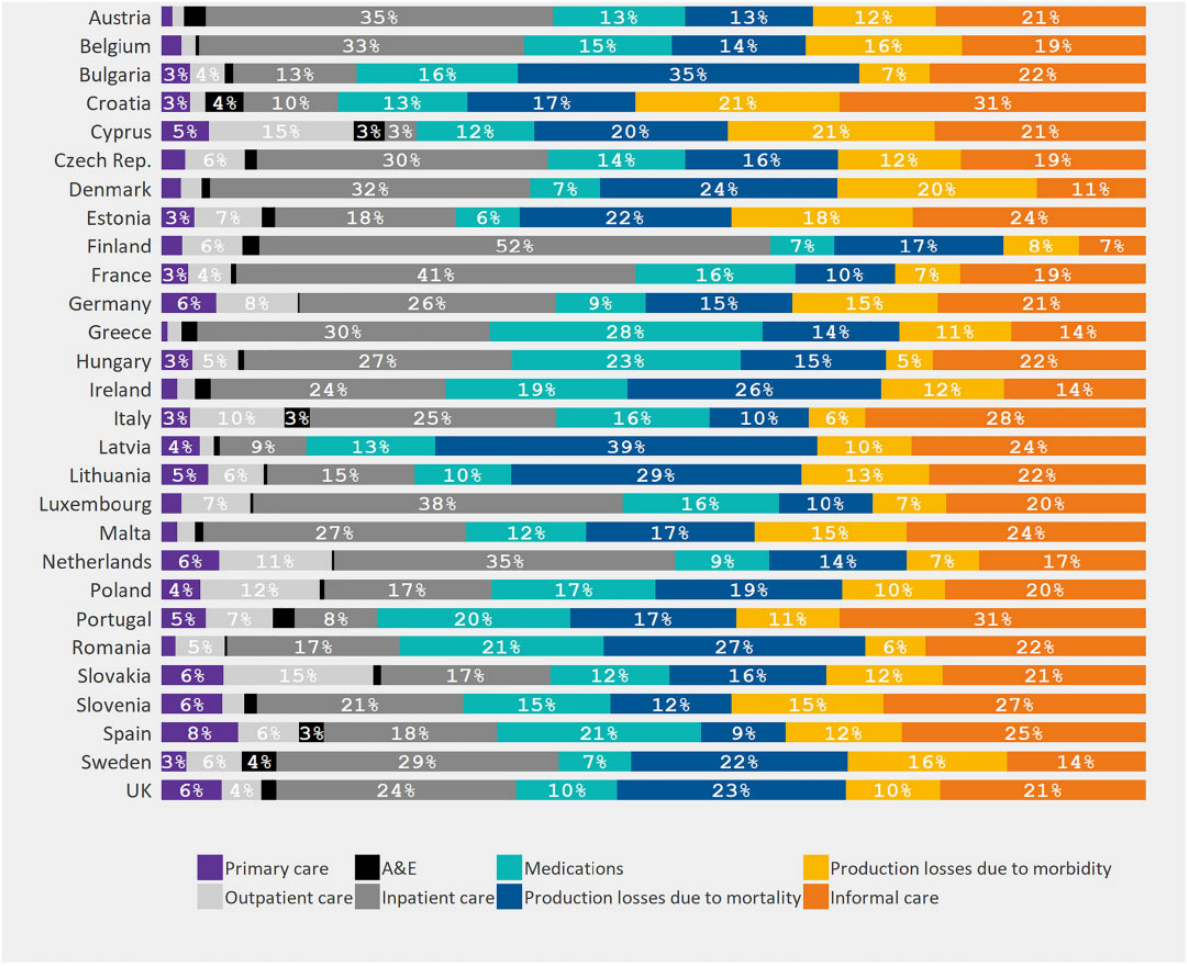

Figure 5 Distribution of costs of cardiovascular disease in the EU member countries by category (2015). *Data source*: Wilkins *et al.*[4] *Data not available for the following high-income countries*: Iceland, Israel, Norway, Republic of San Marino, and Switzerland; *middle-income countries*: Albania, Algeria, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Egypt, Kazakhstan, Kyrgyzstan, Lebanon, Libya, Montenegro, Morocco, North Macedonia, Republic of Georgia, Republic of Kosovo, Republic of Moldova, Russian Federation, Serbia, Syrian Arab Republic, Tunisia, Turkey, and Ukraine (Supplementary file: S3.xlsx).

Information about the economic and financial burden of CVD in ESC member countries is incomplete and health economic estimates are often unreliable. Positive contributions have come from OECD and Eurostat with demonstration of the general feasibility of estimating health expenditures by disease.[34–36] The SHA framework has the potential to provide a solid basis for the analysis of health resource allocation in the European health system but at present data are available for only a few countries. Progress has been slow because of differences between countries in healthcare systems, availability of essential data and disease registrations. These combine to make difficult the development of cost-units along a functional dimension which is a central requirement of SHA.

Studies on economic costs of CVD have limited their focus to European countries.[4,30,37] These have been constrained by variable data availability across ESC member countries such that in the most recent EHN study data required for most healthcare cost categories were only available for a small subset of countries.[4] Only costs related to hospital inpatient care were available for all countries but for other healthcare cost categories including primary care, outpatient and emergency care and medications, costs were estimated based on complex assumptions. For example, in the majority of countries (17 out of 28), costs of CVD-related primary care visits were estimated by multiplying the total number of primary care visits with the proportion of patients discharged from hospital with a CVD diagnosis, based on the assumption that these patients would receive primary care follow-up.[4]

4 Risk factors and health behaviour

The Framingham Heart Study identified major risk factors predisposing to the development of CVD.[43] These have been extensively validated and now populate widely used predictive risk models.[44] INTERHEART,[7] a case–control study conducted in 52 countries, has identified nine risk factors and health behaviours that account for >90% of the population attributable risk of acute myocardial infarction (AMI) and their control or elimination is calculated to make a substantial reduction in incident CVD at population level.[45] Only psychological and social factors are not currently recorded in the ESC Atlas, although they are well established as contributors to CVD risk.[46,47] The remaining eight risk factors and health behaviours (hypertension, dyslipidaemia, diabetes, obesity, smoking, alcohol, diet, and sedentary lifestyle) are the WHO's targets for reduction by 2025 and are discussed below.[8]

In this section, the prevalence and time course of risk factors and health behaviours are presented for a maximum of 54 contributing ESC member countries, or fewer depending upon how complete are the CVD statistics of interest. There are no data for Republic of Kosovo or Republic of San Marino.

4.1 Risk factors

4.1.1 Blood pressure

Data: Prevalence of elevated blood pressure, by gender; Data source: WHO, http://apps.who.int/gho/data/node.main.A875STANDARD?lang=en**; Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1980–2015.Data: Mean systolic blood pressure, by gender; Data source: WHO,** http://apps.who.int/gho/data/node.main.A882?lang=en**; Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 2015.**

There is a continuous linear relationship between blood pressure levels and the risk of stroke or myocardial infarction.[48] International surveys show that the rate of elevated systolic blood pressure (≥140 mmHg) has increased substantially between 1990 and 2015 with knock-on effects on DALYs and deaths attributable to hypertension.[49] The INTERHEART study estimated that 22% of myocardial infarctions in Europe are related to hypertension, which almost doubles the risk compared with people with no history of hypertension.[7] Treatment to lower blood pressure provides significant protection against cardiovascular events, with incremental benefits of more intensive treatment in patients at higher risk (concomitant vascular disease, renal disease or diabetes).[50]

- *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) across the ESC member countries was 24.8% [interquartile range (IQR) 19.8–28.5%], ranging from 15.2% in the UK to 32.4% in Croatia (*Figure 6*). Blood pressure levels also varied across countries, with mean systolic values in females of 115 mmHg in Switzerland compared with 130 mmHg in Republic of Moldova; and in males of 120 mmHg in Turkey compared with 137 mmHg in Croatia, Lithuania, and Slovenia.
- *Stratification by gender*: The prevalence of hypertension in all the ESC member countries with data available in 2015 was lower in females than in males (*Figure 7*), with median rates of 22.3% (IQR 15.5–23.9%) and 27.0% (IQR 24.2–33.6%), respectively. This was reflected in median systolic blood pressure levels of 123.0 (IQR 118.9–126.1) mmHg in females and 130.0 (IQR 127.4–134.3) mmHg in males averaged across ESC member countries.
- *Stratification by national income status*: The median age-standardized prevalence of elevated blood pressure in middle-income countries was 23.8% (IQR 22.5–23.1%) compared with 15.7% (IQR 14.5–21.1%) in high-income countries. Differences were consistent by gender with the prevalence of hypertension in females and males 15.7% (IQR 14.5–21.1%) and 25.2% (IQR 23.6–34.3%) in high-income ESC member countries and 23.8% (IQR 22.5–25.1%) and 29.7% (IQR 25.4–33.2%) in middle-income countries in 2015 (*Figure 7*). Systolic blood pressure levels also varied by national income status, with median levels for females and males of 119.5 (IQR 117.3–121.4) mmHg and 128.1 (IQR 126.9–132.2) mmHg in high-income countries and 126.0 (IQR 124.8–127.5) mmHg and 133.1 (IQR 129.6–134.9) mmHg in middle-income countries (*Figure 8*).
- *Time series data*: The median age-standardized prevalence of elevated blood pressure across all ESC member countries trended downwards between 1980 and 2015 from 35.3% (IQR 31.7–38.4%) to 24.2% (IQR 19.8–28.5%) (*Figure 9*). The declines were greater in high-income countries [37.1% (IQR 34.2–39.9%) to 20.3% (IQR 19.3–27.8%)] compared with middle-income

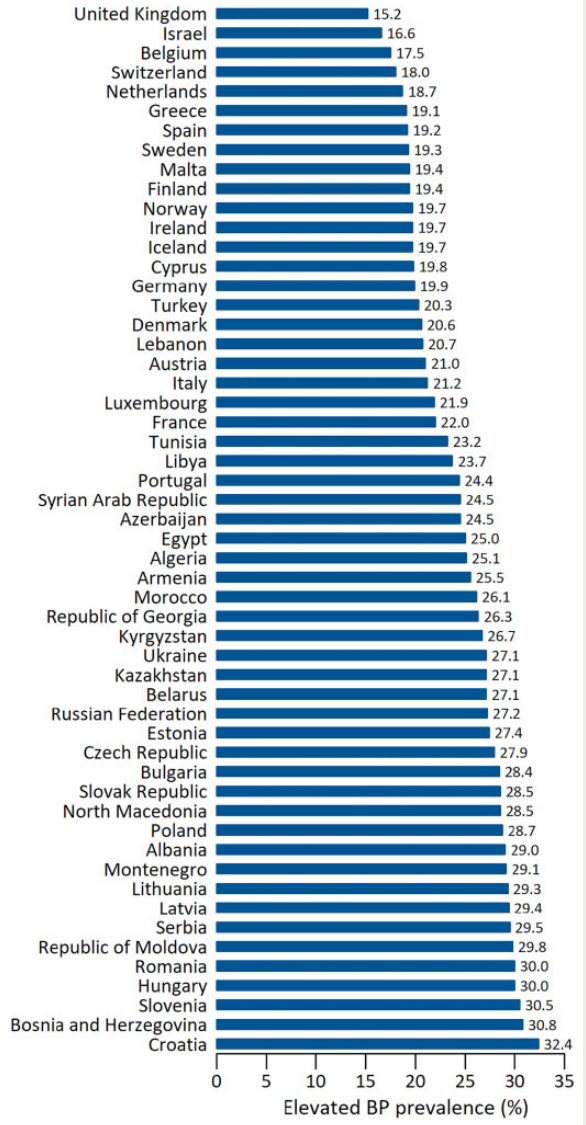

Figure 6 Age-standardized prevalence of elevated blood pressure in ESC member countries (2015). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A875STANDARD?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

countries [33.1% (IQR 31.0–36.1%) to 26.9% (IQR 24.9–28.6%)].

- *WHO non-communicable disease targets*: 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 prevalence of elevated blood pressure across ESC member countries has declined by 8.4% (IQR 12.0–5.6%) with declines of 10.7% (IQR 12.9–7.5%) and 6.0% (IQR 8.3–3.0%) in high-income and middle-income countries. Our extrapolations suggest it is possible but unlikely the WHO blood pressure target for 2025 will be achieved.

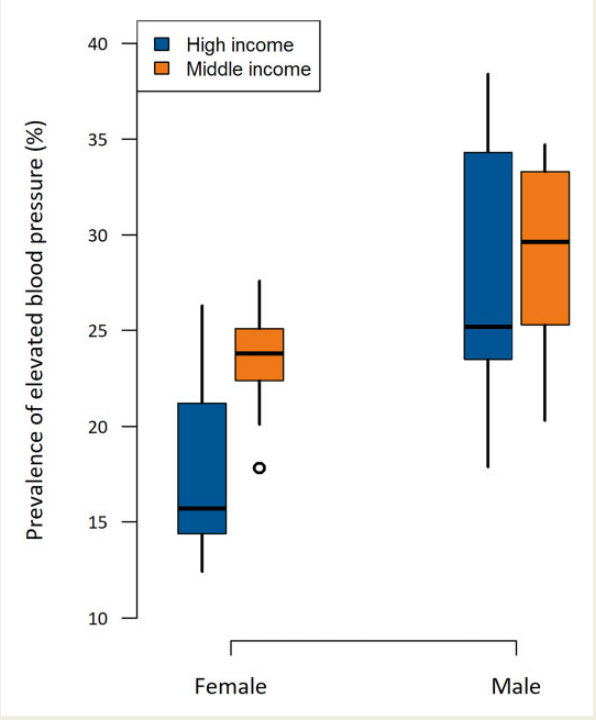

Figure 7 Age-standardized prevalence of elevated blood pressure in ESC member countries by sex and national income status (2015). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A875STANDARD?lang=en. *Data not available* Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

4.1.2 Cholesterol

Data: Mean total cholesterol level; Data source: WHO, http://apps.who.int/gho/data/node.main.A891?lang=en; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1980–2009. Data: Prevalence of elevated total cholesterol; Data source: WHO,** http://apps.who.int/gho/data/node.main.A887?lang=en; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 2008.**

Cholesterol, particularly LDL cholesterol, is a major determinant of CVD risk which increases linearly as blood concentrations increase.[51,52] It 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.[53–55] The prevalence of elevated total cholesterol exceeds 50% in high-income countries including Europe compared with less than 30% in Africa and South East Asia.[56]

There has been no recent update of cholesterol statistics for ESC member countries and the section that follows, therefore, rehearses the section presented in the 2017 report.[1]

- *National statistics stratified by gender*: Data for 2009 showed that the median blood cholesterol concentration averaged across all

ESC member countries was 5.1 mmol/L in both females (IQR 4.9–5.2 mmol/L) and men (IQR 4.8–5.3 mmol/L), ranging from 4.5 to 4.4 mmol/L in females and males from Kyrgyzstan to 5.6 mmol/L in females and males from Iceland. The 2008 median age-standardized prevalence of hypercholesterolaemia (>6.2 mmol/L) averaged across member countries was 15.6% (IQR 12.1–18.9%) and 14.3% (IQR 9.6–18.6%) in females and males, ranging from <10% in Azerbaijan, Bosnia and Herzegovina, Republic of Georgia, Kyrgyzstan, Republic of Moldova, and Turkey to >20% in Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Norway, and UK (Supplementary material online, *Figure S4.1*).

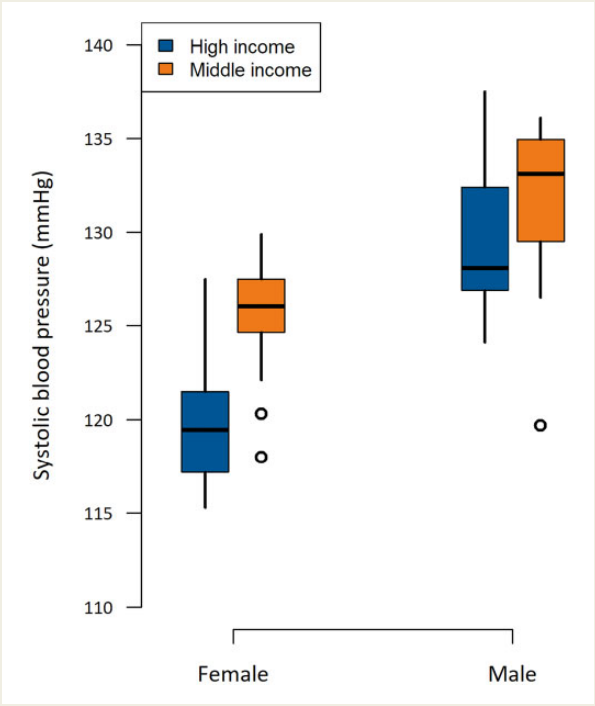

Figure 8 Mean systolic blood pressure in ESC member countries by sex and national income status (2015). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A882?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

- *Stratification by national income status*: The 2009 median, age-standardized blood cholesterol concentrations in females and males were 5.2 (IQR 5.1–5.3) mmol/L and 5.3 (5.1–5.4) mmol/L in high-income countries and 4.9 (IQR 4.8–4.9) mmol/L and 4.7 (IQR 4.6–4.9) mmol/L in middle-income countries. This difference between high- and middle-income countries was reflected in median age-standardized prevalence rates for hypercholesterolaemia (≥6.2 mmol/L) that were 18.8% (IQR 16.5–20.8%) and 18.1% (IQR 16.4–21.3%) in females and males from high-income countries and 11.8% (IQR 9.6–13%) and 8.7% (IQR 7.5–11.3%) in females and males from middle-income countries (*Figure 10*). Between 1980 and 2009, blood cholesterol concentration across high-income countries, changed from a median of 5.9 (IQR 5.6–6.0) mmol/L to 5.2 (IQR 5.1–5.3) mmol/L in females and from 5.9 (IQR 5.5–6.0) mmol/L to 5.3 (IQR 5.1–5.4) mmol/L in males. Quantitatively similar changes were recorded in females [5.3 (IQR 5.0–5.4) mmol/L to 4.9 (IQR 4.8–4.9) mmol/L] and males [5.2 (IQR 4.9–5.3) mmol/L to 4.7 (IQR 4.6–4.9) mmol/L] in middle-income countries.
- *Time series data*: Median blood cholesterol concentrations across ESC member countries declined from 5.5 (IQR 5.3–5.9) mmol/L to 5.1 (IQR 4.9–5.2) mmol/L in females and from 5.5 (IQR 5.2–5.9) mmol/L to 5.1 (IQR 4.8–5.3) mmol/L in males ≥25 years between 1980 and 2009 (*Figure 11*).

4.1.3 Diabetes

Data: Prevalence of diabetes (type 1 and type2); Data source: World Bank, https://data.worldbank.org/indicator/SH.STA.DIAB.ZS?view=chart; **Completeness: High-income countries 31/31 (100%), middle-income countries 24/25 (96%); Year of data: 2017.Data: Prevalence of diabetes (ICD10: E10-E14); Data source: WHO,** https://gateway.euro.who.int/en/indicators/hfa_379-2370-prevalence-of-diabetes-mellitus; **Completeness: High-**

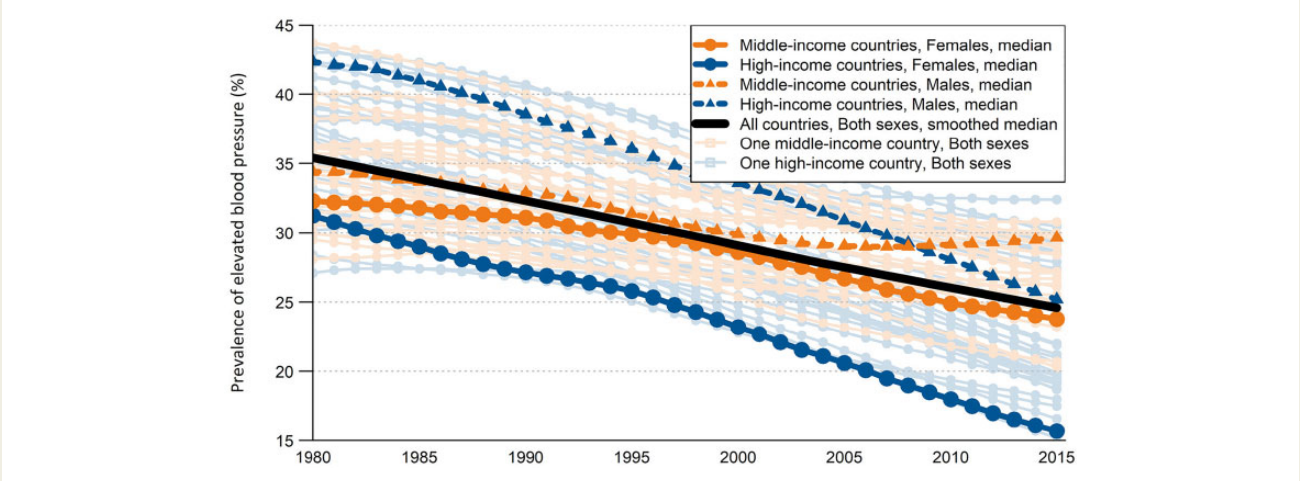

Figure 9 Prevalence of elevated blood pressure among adults (%) in ESC member countries (1980–2015). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A875STANDARD?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

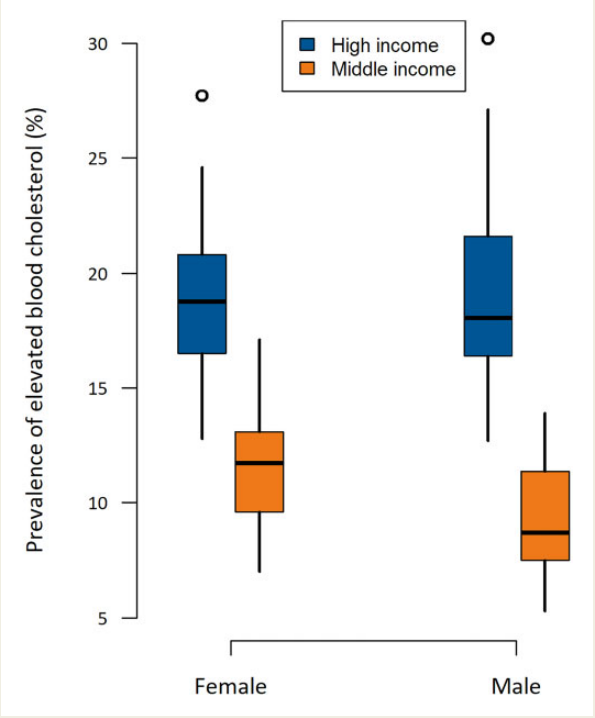

Figure 10 Age-standardized prevalence of elevated blood cholesterol (≥6.2 mmol/L) in adults aged ≥25 years in ESC member countries by sex and national income status (2008). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A887?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

income countries 22/31 (71%), middle-income countries 14/25 (56%); Year of data: 1980–2015.

The WHO reports 422 million people currently living with diabetes globally (mainly type 2), of whom over 60 million live in the European region. The prevalence of diabetes in males and females has risen dramatically over the last 30 years with no substantial worldwide difference between high-, middle-, or low-income countries.[57] This is largely attributed to the increasing number of people who are overweight and obese, which in turn is driven by excess dietary calories and physical inactivity. Diabetes doubles the risk of death compared with people without diabetes. At least half of these deaths are the result of CVD, usually IHD or stroke.[57]

- *National statistics*: The median prevalence of diabetes by 2017 estimates in females and males aged 20–79 years averaged 6.8% (IQR 5.3–8.4%) across ESC member countries, ranging from ≤4% in Estonia, Ireland, and Lithuania to ≥10 % in Albania, Bosnia and Herzegovina, Egypt, Lebanon, Libya, North Macedonia, Montenegro, Serbia, and Turkey (*Figure 12*).
- *Stratification by national income status*: The median prevalence of diabetes in people aged 20–79 years was greater in middle-income countries [7.7% (IQR 7.1–10.1%)] compared with high-income countries [5.6% (IQR 4.8–7.0%)], with prevalence greater than 12% in Egypt, Lebanon, and Turkey (*Figure 13*).
- *Time series data*: The proportion of people older than 15 with diabetes across those ESC member countries with data available increased from a median of 1.1% (IQR 0.8–1.5%) in 1990 to 3.9% (IQR 2.7–5.6%) in 2015 (*Figure 14*).
- *WHO non-communicable disease targets*: The WHO has called for a halt (with reference to 2010) to the rise in diabetes, to be achieved by 2025. However, analysis of paired 2010 and 2015 national data available for 26 countries, showed a sharp 28.5% increase in the median prevalence of diabetes from 3.2% (IQR 2.0–4.8%) to 4.2% (IQR 2.8–5.7%) during that period. This was particularly marked in middle-income countries where the prevalence of diabetes increased by 37.0% compared with 12.4% in high-income countries. These statistics suggest it is unlikely the WHO diabetes target will be met, particularly in middle-income countries, unless recent trends are reversed.

4.1.4 Obesity

Data: Prevalence of obesity, by gender and mean body mass index, by gender; Data source: WHO, http://apps.who.int/gho/data/node.main.BMIOBESITYA?lang=en **and** http://apps.who.int/gho/data/node.main.A904?lang=en, respectively; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1980–2016.**

The prevalence of overweight and obesity, defined by a body mass index (BMI) of ≥25 kg/m^2 and ≥30 kg/m^2, respectively, is increasing in both developed and developing countries. More people are now obese than are underweight both globally and in most regions of the world.[58] 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.[59] In 2016, the Global BMI Mortality Collaboration meta-analysis reported that for BMI ≥25.0 kg/m^2, the hazard ratio for every 5 kg/m^2 increase in BMI was 1.39 (1.34–1.43) among people living in the European region. The Collaboration concluded that the consequences of an increased BMI for all-cause mortality were severe and consistent across all regions of the world.[60]

- *National statistics*: Median age-standardized BMI across ESC member countries in 2016 was 26.6 (IQR 26.1–27.1) kg/m^2 and was similar for females [26.2 (IQR 25.5–26.9) kg/m^2] and males [27.0 (IQR 26.4–27.3) kg/m^2] (Supplementary material online, *Figure S4.2*). Mean BMIs among females ranged from 23.7 kg/m^2 in Switzerland to 31.4 kg/m^2 in Egypt and among males from 24.7 kg/m^2 in Algeria to 28.2 kg/m^2 in Hungary. Data for 2016 showed that, across ESC member countries, approximately one in five adult females and males were obese (≥30 kg/m^2), as reflected by prevalence rates of 22.8% (IQR 21.0–26.1%) and 22.3% (IQR 20.3–24.2%), respectively (*Figure 15*). Obesity among females was particularly common in Egypt and Libya, where it affected more than one in three females, while obesity among males was common in Malta, Hungary, Czech Republic, UK, and Lebanon, where it affected more than one in four males.
- *Stratification by national income status*: Median BMI in females and males averaged across ESC member countries in 2016 was 25.8 (IQR 25.2–26.3) kg/m^2 and 27.0 (IQR 26.6–27.5) kg/m^2 in high-income countries and 26.7 (IQR 26.3–27.5) kg/m^2 and 26.8 (26.1–27.1) kg/m^2 in middle-income countries. The prevalence of obesity in females and males was 21.4% (IQR 20.1–25.0%) and 23.7% (IQR 21.9–24.4%) in high-income countries and

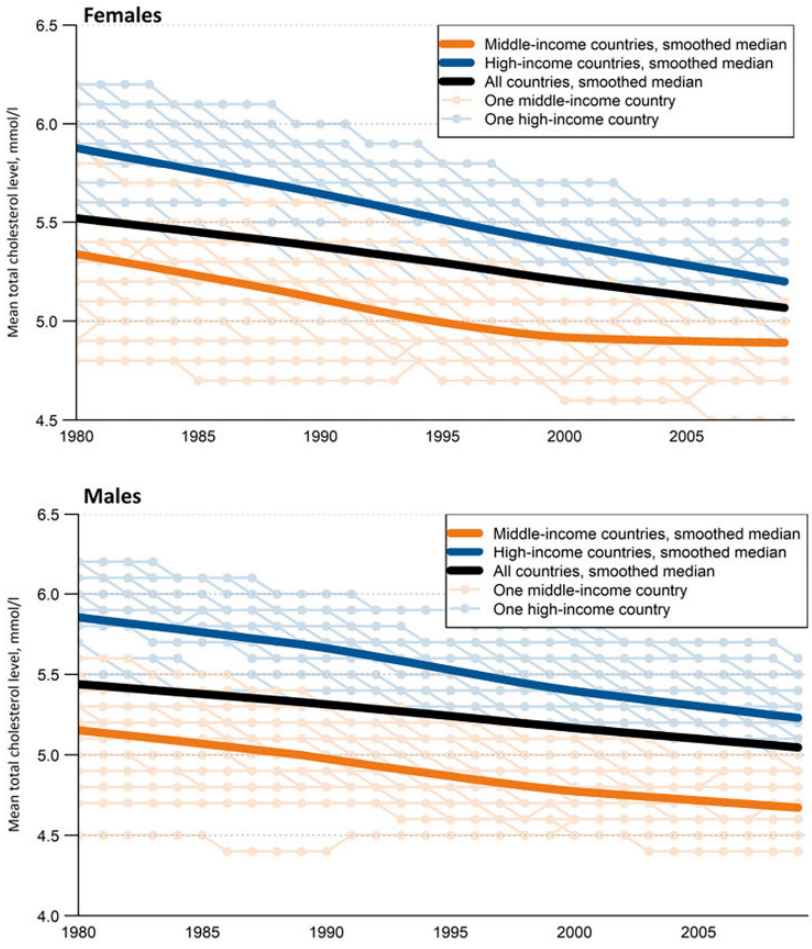

Figure 11 Mean blood cholesterol levels among females and males age ≥25 years in ESC member countries (1980–2009). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A891?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

24.1% (IQR 22.0–34.4%) and 21.0% (IQR 18.7–22.9%) in middle-income countries (*Figure 16*).

- *Time series data*: The median age-standardized prevalence of obesity across ESC member countries increased sharply between 1980 and 2016 from 9.6% (IQR 8.2–11.9%) to 22.6% (IQR 20.9–25.8%) (*Figure 17*). Increases in population obesity were similar in high-income and middle-income countries.
- *WHO non-communicable disease targets*: 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 18.9–24.8%) to 22.8% (IQR 21.0–26.1%) and males from 19.2% (IQR 17.1–21.1%) to 22.3% (IQR 20.3–24.2%). These statistics suggest it is unlikely the WHO obesity target will be met unless recent trends are reversed.

4.2 Health behaviours

4.2.1 Smoking

Data: Percentage of regular daily smokers, by gender; Data source: WHO, https://gateway.euro.who.int/en/indicators/hfa_421-3010-of-regular-daily-smokers-in-the-population-age-15+ **Completeness: High-income countries 31/31 (100%), middle-income countries 17/25 (68%); Year of data: 1995–2016**

Tobacco use has been described as, 'the single largest avoidable health risk in the European Union' by the European Commission's Directorate-General for Health and Food safety.[61] Tobacco use is linked to many forms of cancer and CVDs and is the major determinant of death for nearly 6 million people a year. Therefore, policy measures related to tobacco use and tobacco derivative commercialization have been promoted by the EU in the last 15 years. During this period, there has been continuous decline in the prevalence of smoking across Europe.[62]

- *National statistics*: In males and females aged ≥15 years, the median prevalence of regular daily smoking by 2014 estimates was 21% (IQR 18.2–25.7%), based on data from 29 ESC member countries. Prevalence ranged from 11.9% in Sweden to 36.1% in Latvia (*Figure 18*).
- *Stratification by gender*: Across ESC member countries, males smoked more than females with median 2014 prevalence

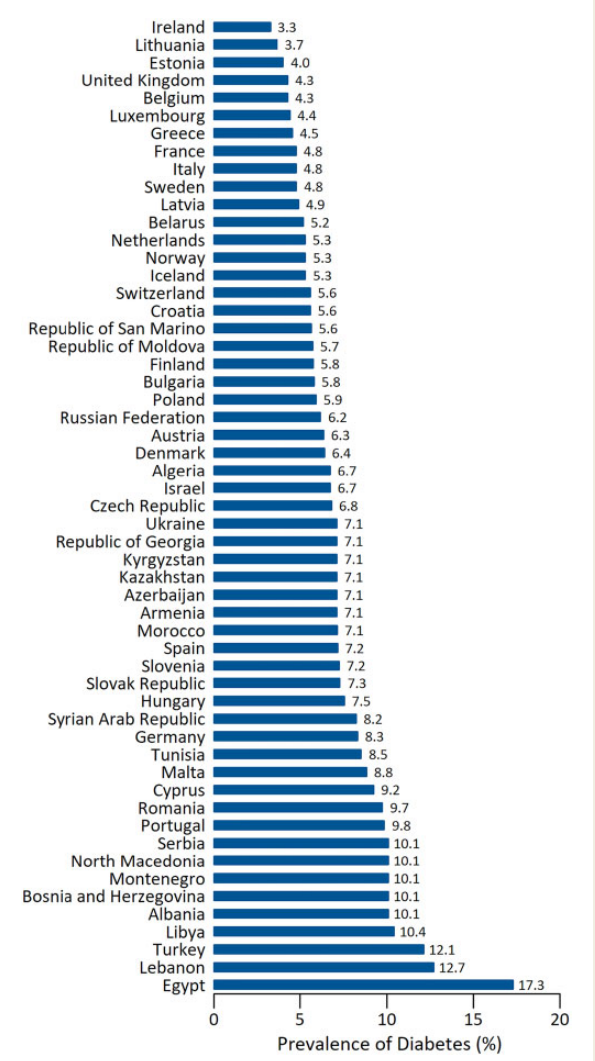

Figure 12 Prevalence of diabetes among adults aged 20–79 years in ESC member countries (2017). *Data source*: World Bank, https://data.worldbank.org/indicator/SH.STA.DIAB.ZS?view=chart. *Data not available*: Republic of Kosovo (Supplementary file: S4.xlsx).

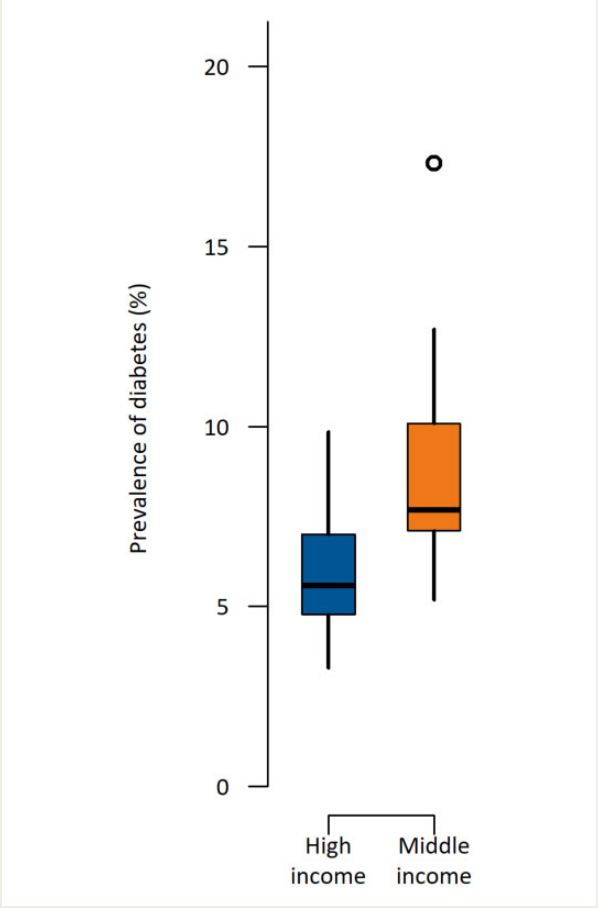

Figure 13 Prevalence of diabetes by national income status in ESC member countries (2017). *Data source*: World Bank, https://data.worldbank.org/indicator/SH.STA.DIAB.ZS?view=chart. *Data not available*: Republic of Kosovo (Supplementary file: S4.xlsx).

estimates of 26.5% (IQR 21.7–33.9%) compared with 15.0% (IQR 12.1–18.5%), respectively (*Figure 19*). Prevalence in males ranged from <15% in Sweden, Norway, and Iceland to ≥40% in Latvia, Albania, Armenia, Belarus, and Turkey. For females, prevalence ranged from <10% in Armenia, Albania, Azerbaijan, Lithuania, and Belarus to >20% in Hungary, Greece, France, Croatia, Latvia, and Austria.

- *Stratification by national income status*: Comparison of smoking prevalence in high- and middle-income ESC member countries showed inversed associations in females and males aged ≥15 years (*Figure 19*). Among females, 2014 smoking prevalence was higher in high-income countries [16.7% (IQR 13.9–19.7%)] compared with middle-income countries [8.7% (IQR 3.0–10.8)], but for males smoking prevalence was lower in high-income countries [26.0% (IQR 20.9–31.7%)] compared with middle-income countries [43.8% (IQR 37.4–48.0%)].
- *Time series data*: Between 1995 and 2014, the national prevalence of smoking across ESC member countries declined by 25% in people aged ≥15 years, from 28.0% (IQR 25.6–33.6%) to 21.0% (IQR 18.2–25.7%) (*Figure 20*). Declines were similar in females and males and in high-income and middle-income countries.
- *WHO non-communicable disease targets*: The WHO has called for a 30% relative reduction in prevalence of tobacco use in persons aged 15+ years, to be achieved by 2025 (reference to 2010). Paired prevalence data for daily smoking between 2010 and 2014–16 were available for only 15 high-income and 5 middle-income countries. During that period, the median prevalence of daily smoking reduced by 10.4% in females from 14.8% (IQR 13.5–19.3%) to 14.2% (10.7–16.8%) and by 14.8% in males from 28.3% (IQR 20.8–36.2%) to 24.1% (IQR 18.7–34.3%). Based on these data, the WHO smoking target appears feasible for ESC member countries, if current rates of decline continue.

4.2.2 Alcohol

Data: Alcohol consumption, by gender; Data source: WHO, http://apps.who.int/gho/data/node.main.A1036?lang=en; **Completeness: High-income countries 30/31 (97%),**

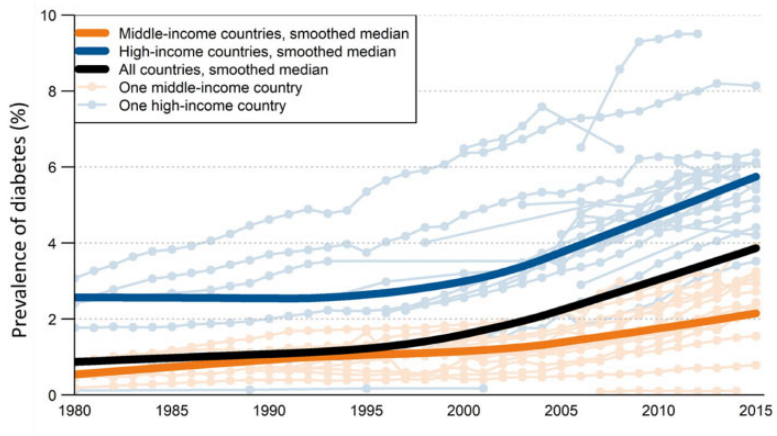

Figure 14 Prevalence of diabetes by national income status in ESC member countries (1990–2015). *Data source*: WHO, https://gateway.euro.who.int/en/indicators/hfa_379-2370-prevalence-of-diabetes-mellitus/. *Data not available for the following high-income countries*: Cyprus, Greece, Hungary, Ireland, Luxembourg, Norway, Poland, Sweden, Switzerland; *middle-income countries*: Algeria, Egypt, Lebanon, Libya, Montenegro, Morocco, Republic of Kosovo, Serbia, Syrian Arab Republic, Tunisia, and Turkey (Supplementary file: S4.xlsx).

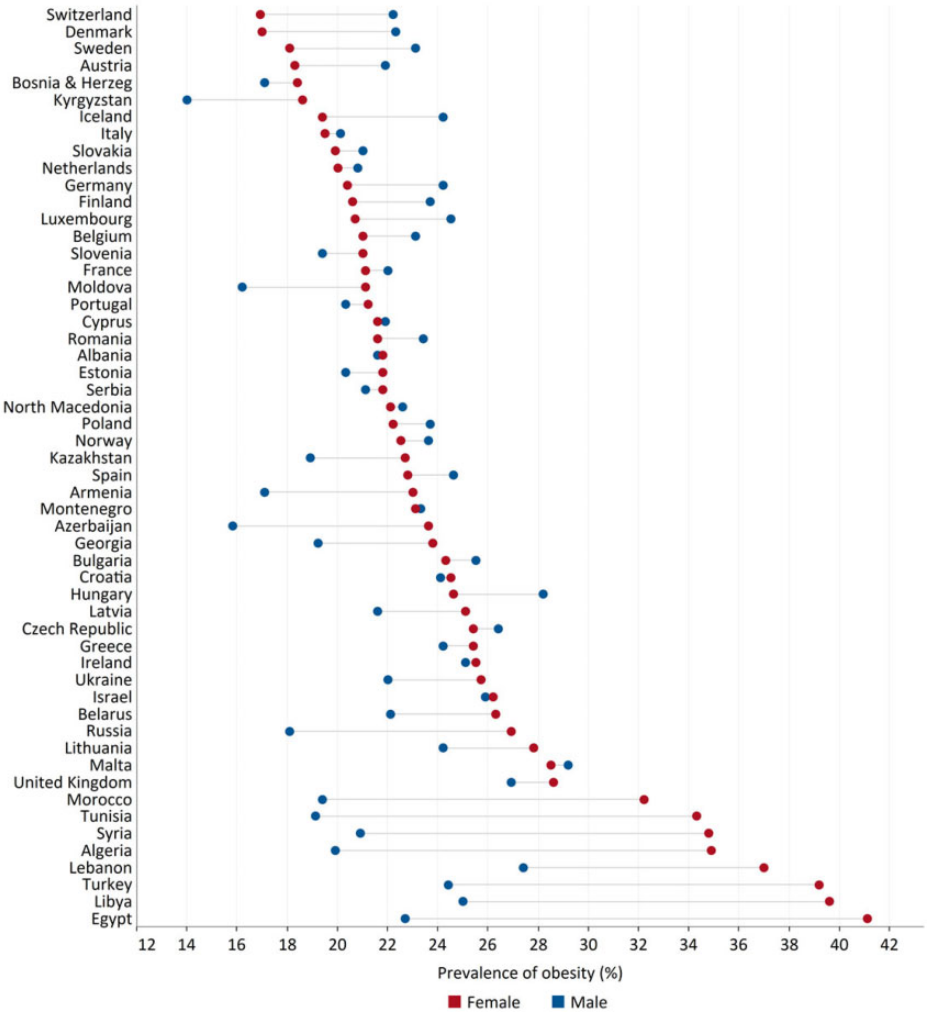

Figure 15 Prevalence of obesity (≥30 kg/m^2) by sex among adults in ESC member countries (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.BMIOBESITYA?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

middle-income countries 24/25 (96%); Year of data: 2010 and 2016.Data: Heavy episodic drinking, by gender; Data source: WHO, http://apps.who.int/gho/data/node.main.A1046?lang=en; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 2016.Data: Recommended limits for alcohol consumption; Data source: Health Promotion and Disease Prevention Knowledge Gateway,** https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/alcohol; **Completeness: High-income countries 21/31 (68%), middle-income countries 1/25 (4%); Year of data: 2019.**

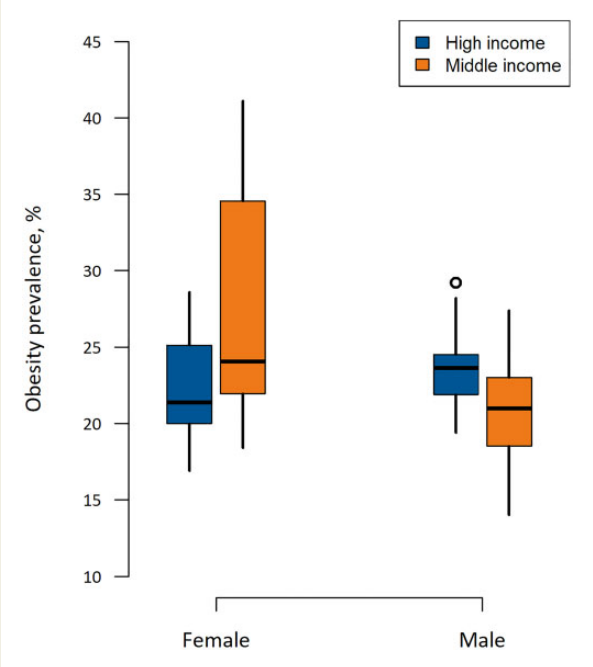

Figure 16 Prevalence of obesity (≥30 kg/m^2) among adults in ESC member countries by sex and national income status (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.BMIOBESITYA?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

Alcohol consumption is defined as the recorded amount (in litres) of pure alcohol consumed per adult (≥15 years) over a calendar year and is a European Core Health Indicator.[63] The indicator only takes into account the consumption that is recorded from production, import, export, and sales data, often via taxation. Recommended upper limits for alcohol consumption vary by country, perhaps reflecting uncertainty about precise risk thresholds (*Figure 21*).

Excessive alcohol consumption remains a leading cause of premature death in the USA where it is responsible for 1 in 10 deaths among working-age adults.[64] In the EU, harmful alcohol use is the third biggest cause of premature death after tobacco and hypertension with alcohol dependence estimated to be responsible for more than 60% of all alcohol-attributable mortality.[65]

- *National statistics*: Data for 2016 show that 66.6% (IQR 41.9–73.3%) of people aged ≥15 years living in ESC member countries had consumed alcohol in the previous 12 months, with a median consumption of 10.2 (IQR 7.5–11.7) L/capita/year (*Figure 22*). There were large differences between countries, with consumption ranging from <4 L/capita/year in Israel, Algeria, Azerbaijan, Egypt, Lebanon, Libya, Morocco, Syria, Tunisia, and Turkey, to >12 L/capita/year in Belgium, France, Germany, Latvia, Portugal, Slovenia, Bulgaria, Republic of Moldova, and Romania. Cultural and religious factors are likely to contribute to the very low alcohol consumption in many Middle East and North African countries.
- *Stratification by gender*: Across all ESC member countries, data for 2016 show that fewer females [55.1% (IQR 28.9–62.9%)] than males [79.4% (IQR 56.1–84.2%)] had consumed alcohol in the previous 12 months. Median consumption among females [4.1

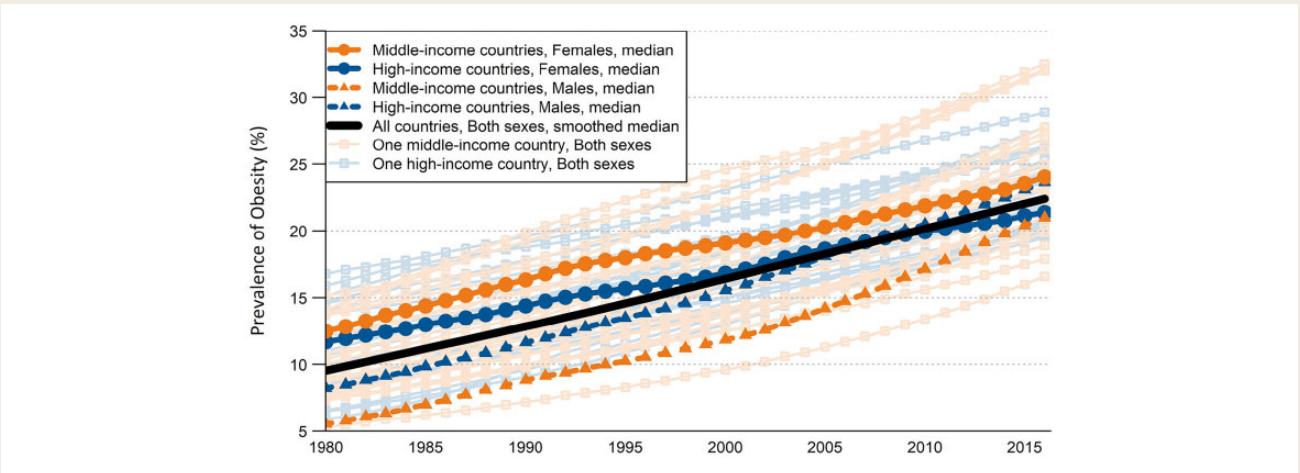

Figure 17 Prevalence of obesity (≥30 kg/m^2) among adults in ESC member countries 1980–2016. *Data source*: WHO, http://apps.who.int/gho/data/node.main.BMIOBESITYA?lang=en. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S4.xlsx).

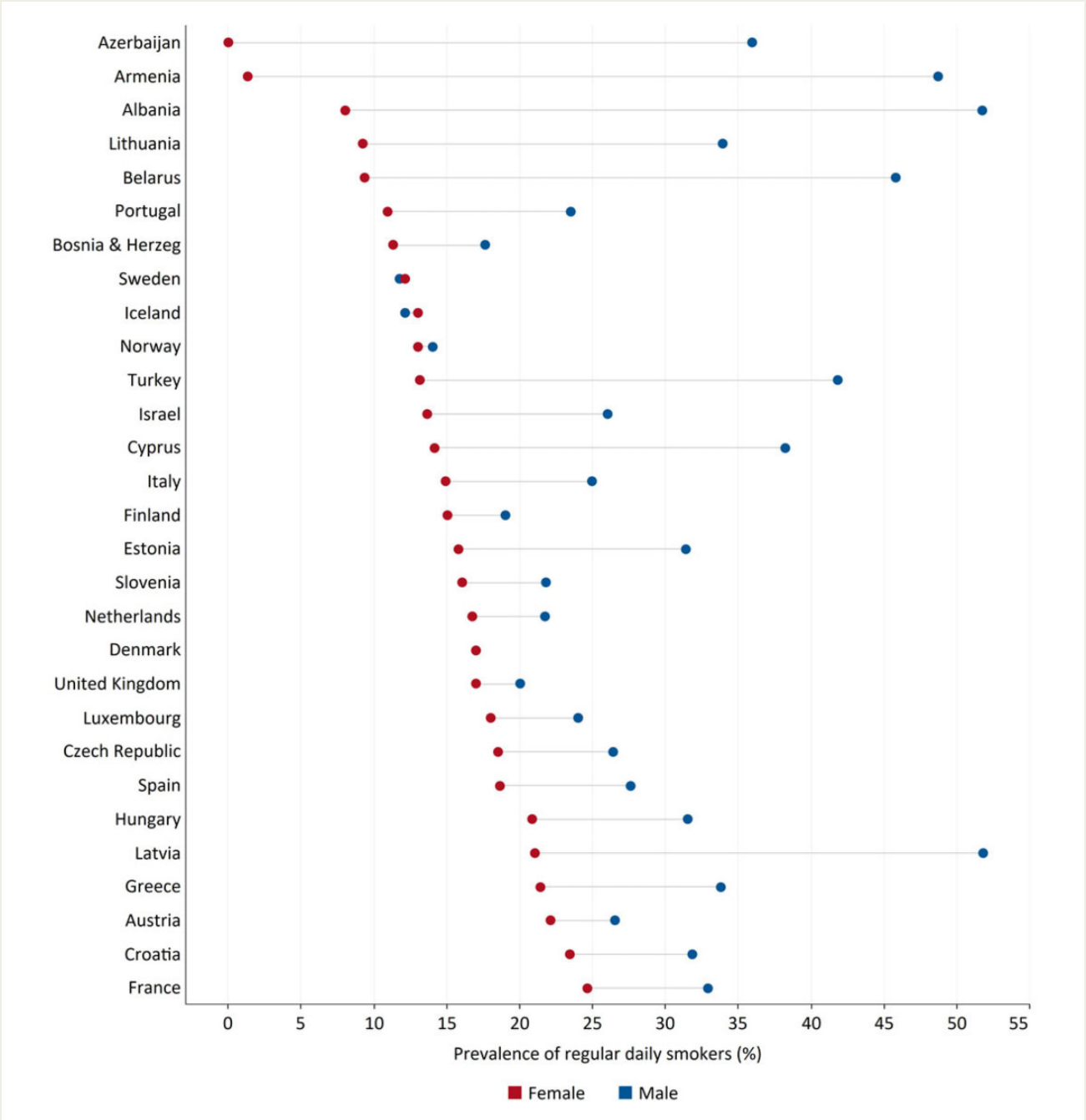

Figure 18 Prevalence of regular daily smokers aged ≥15 years in ESC member countries stratified by sex (2014). *Data source*: WHO, https://gateway.euro.who.int/en/indicators/hfa_421-3010-of-regular-daily-smokers-in-the-population-age-15plus/. *Data not available*: Algeria, Egypt, Lebanon, Libya, Morocco, Republic of Kosovo, Syrian Arab Republic, and Tunisia (Supplementary file: S4.xlsx).

(IQR 2.5–5.1) L/capita/year] was accordingly lower compared with males [16.8 (IQR 11.8–19.4) L/capita/year] and this was a consistent finding across nearly all ESC member countries (*Figure 23*). Age-standardized median prevalence rates for heavy episodic drinking (defined as consumption of at least 60 g of pure alcohol on at least one occasion in the past 30 days) were likewise lower in females [15.0% (IQR 7.8–20.1%)] compared with males [47.4% (IQR 32.0–55.9%)]. Rates ≥60% were recorded for males in Czech Republic, Estonia, Latvia, Lithuania, Luxembourg, and Slovenia. Rates tended to be high among females in these same countries and exceeded 30% for females in Latvia, Lithuania, and Luxembourg.

- *Stratification by national income status*: In 2016, the median prevalence of alcohol consumption in the previous 12 months was 72.7% (IQR 68.2–76.2%) in high-income countries, which was almost double the prevalence in middle-income countries (37.5%

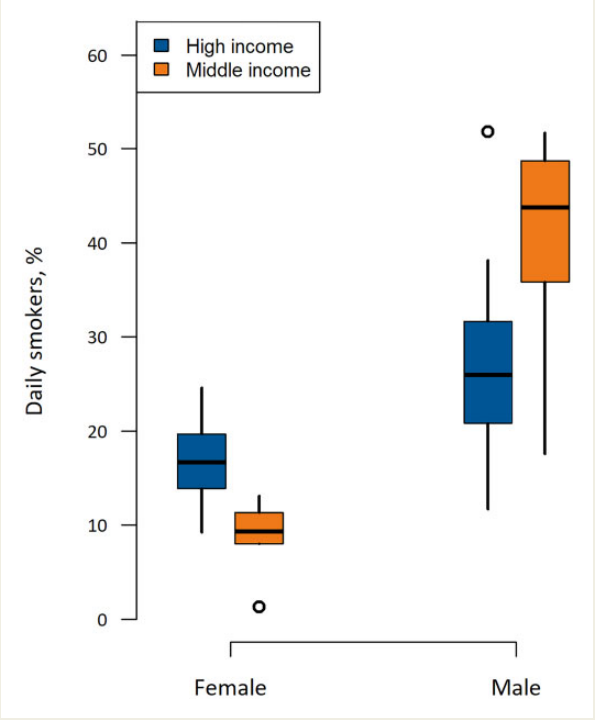

Figure 19 Prevalence of regular daily smokers aged ≥15 years in ESC member countries by sex and national income status (2014). *Data source*: WHO, https://gateway.euro.who.int/en/indicators/hfa_421-3010-of-regular-daily-smokers-in-the-population-age-15plus/. *Data not available*: Algeria, Egypt, Lebanon, Libya, Morocco, Republic of Kosovo, Syrian Arab Republic, and Tunisia (Supplementary file: S4.xlsx).

(IQR 5.9–58.6%). Accordingly, median alcohol consumption was higher in high-income [11.5 (9.4–12.5) L/capita/year] compared with middle-income countries [7.0 (1.4–10.1) L/capita/year] for both females and males (*Figure 23*). Nevertheless, there was considerable variation with consumption in high-income countries ranging from 3.8 L/capita/year in Israel to 15.0 L/capita/year in Lithuania and in middle-income countries from 0.3 L/capita/year in the Syrian Arab Republic to 15.2 L/capita/year in Republic of Moldova. Heavy episodic drinking showed a similar pattern with prevalence rates higher in high-income [35.7% (31.4–39.9%)] compared with middle-income [19.2% (1.3–27.2%)] countries for both females and males (Supplementary material online, *Figure S4.3*), although there was considerable variation by country.

- *WHO non-communicable disease targets*: The WHO has called for a 10% relative reduction in the harmful use of alcohol, to be achieved by 2025 (reference to 2010). Paired 2010/2016 data show that median alcohol consumption across ESC member countries has declined by 8.9% from 11.2 (IQR 7.1–12.3) L/capita/year to 10.2 (IQR 7.5–11.7) L/capita/year. The decline was limited almost exclusively to middle-income countries where consumption declined by 8.6% compared with an increase of 0.4% in high-income countries. These data suggest that if current trends continue the WHO alcohol target is feasible, particularly for middle-income countries.

4.2.3 Vegetable and fruit consumption

Data: Vegetable consumption, by gender and fruit consumption, by gender; Data source: OECD, https://stats.oecd.org/viewhtml.aspx?datasetcode=HEALTH_LVNG&lang=en; **Completeness: High-income countries 26/31 (84%),**

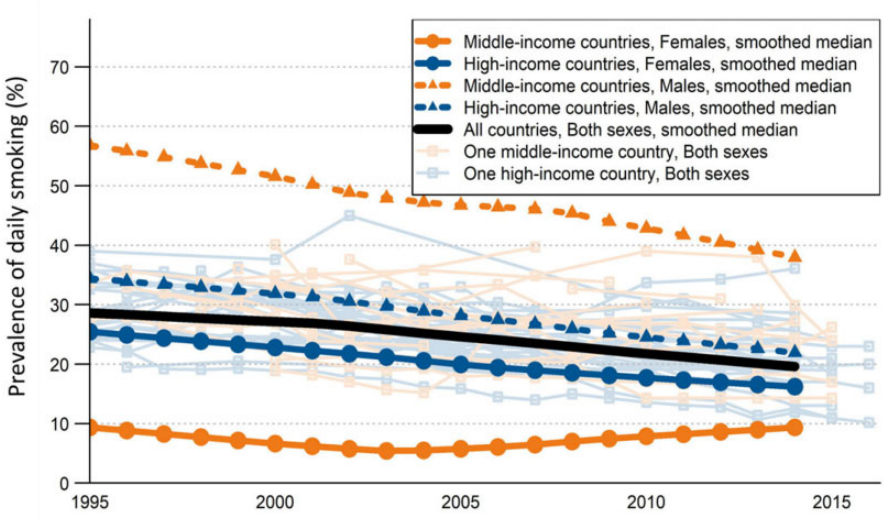

Figure 20 Prevalence (%) of regular daily smokers aged ≥15 years in ESC member countries (1995–2014). *Data source*: WHO, https://gateway.euro.who.int/en/indicators/hfa_421-3010-of-regular-daily-smokers-in-the-population-age-15plus/. *Data not available*: Algeria, Egypt, Lebanon, Libya, Morocco, Republic of Kosovo, Syrian Arab Republic, and Tunisia (Supplementary file: S4.xlsx).

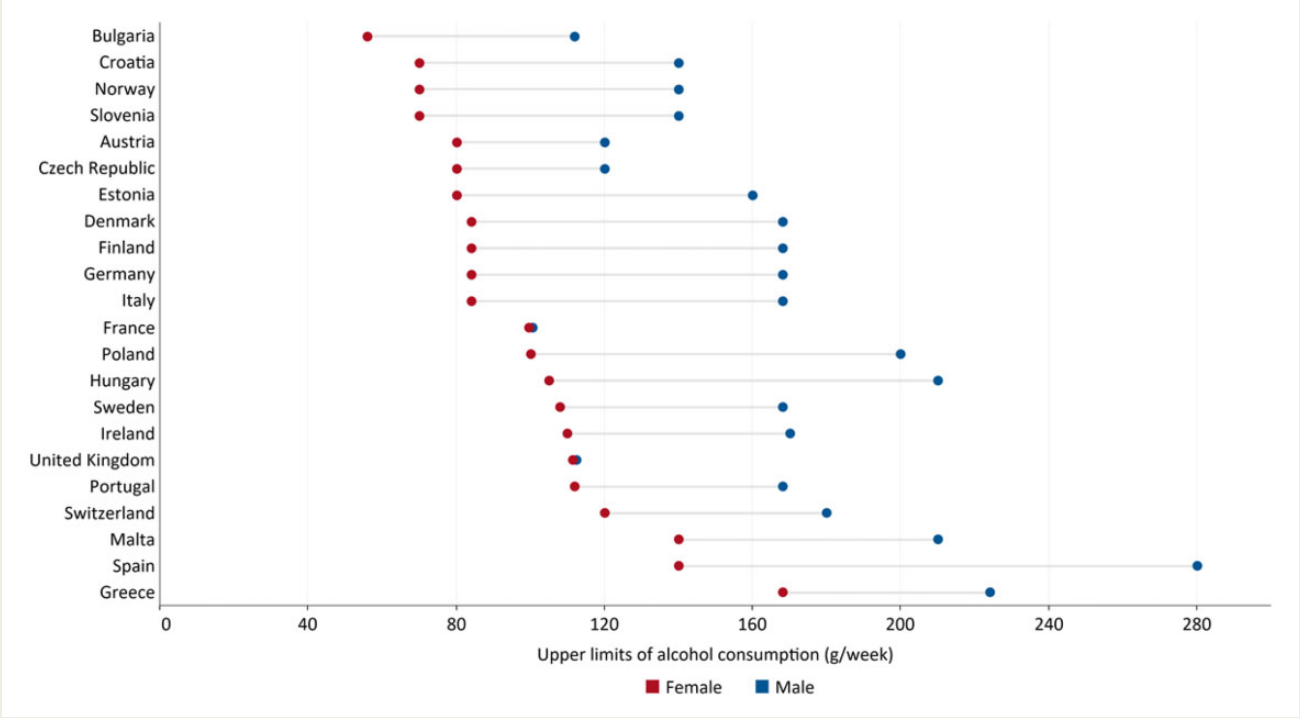

Figure 21 Alcohol consumption: recommended upper limits in females and males (g/week). *Data source*: Health Promotion and Disease Prevention Knowledge Gateway, https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/alcohol. *Data not available*: Albania, Algeria, Armenia, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Cyprus, Egypt, Iceland, Israel, Kazakhstan, Kyrgyzstan, Latvia, Lebanon, Libya, Lithuania, Luxembourg, Montenegro, Morocco, Netherlands, North Macedonia, Republic of Georgia, Republic of Kosovo, Republic of Moldova, Republic of San Marino, Romania, Russian Federation, Serbia, Slovak Republic, Syrian Arab Republic, Tunisia, Turkey, and Ukraine (Supplementary file: S4.xlsx).

middle-income countries 1/25 (4%); Year of data: 2005–2017.

Low fruit and vegetable intake are recognized risk factors for NCDs, such as cancer and coronary heart disease.[66,67] In a systematic review and dose–response meta-analysis of 95 prospective studies, 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, whereas for total cancer no further reductions in risk were observed above 600 g/day.[68] Like all studies examining relations between nutrition and disease cautious interpretation is necessary, partly because of confounding by healthy lifestyle that makes nutritional contributions to risk reduction hard to ascertain and partly because of variable lack of precision in the dietary measurement. Similar caution needs exercising in interpreting the dietary data recorded in the ESC Atlas.

- *National statistics*: The most recent available estimates for vegetable and fruit consumption were obtained in 2014 for people aged ≥15 years and were limited to 22 high-income countries and one middle-income country (Turkey). Across these 23 ESC member countries, 52.2% (IQR 44.1–60.5%) of people consumed at least one portion of vegetables per day and 55.0% (IQR 47.4–60.9%) consumed at least one portion of fruit per day. Vegetable consumption was greatest in Israel where 81.0% of the population consumed at least one portion per day compared with <35% of the populations of Netherlands and Germany. Fruit consumption was greatest in Italy and Israel where >70% of the populations consumed at least one portion per day compared with only 20.2% in Latvia.
- *Stratification by gender*: Across the ESC member countries, a greater proportion of females [61.2% (IQR 55.8–68.3%)] consumed at least one portion of fruit per day compared with males [45.9% (IQR 39.6–52.7%)]. The proportion of females consuming at least one portion of vegetables per day [59.5% (IQR 50.1–64.5%)] was also greater compared with males [43.4% (IQR 36.1–55.3%)].
- *Time series data*: Paired 2010/2014 data were available for just seven high-income countries plus Turkey. During this period, Latvia and Iceland showed a substantial increase in both fruit and vegetable consumption, while Germany showed a marked decline.

4.2.4 Physical activity

Data: Prevalence of insufficient physical activity, by gender; Data source: WHO, http://apps.who.int/gho/data/node.main.A893?lang=en; **Completeness: High-income countries 28/31 (90%), middle-income countries 19/25 (76%); Year of data: 2016.**

Insufficient physical activity is defined as the proportion of the population attaining less than 150 min of moderate-intensity physical activity per week or less than 75 min of vigorous-intensity physical

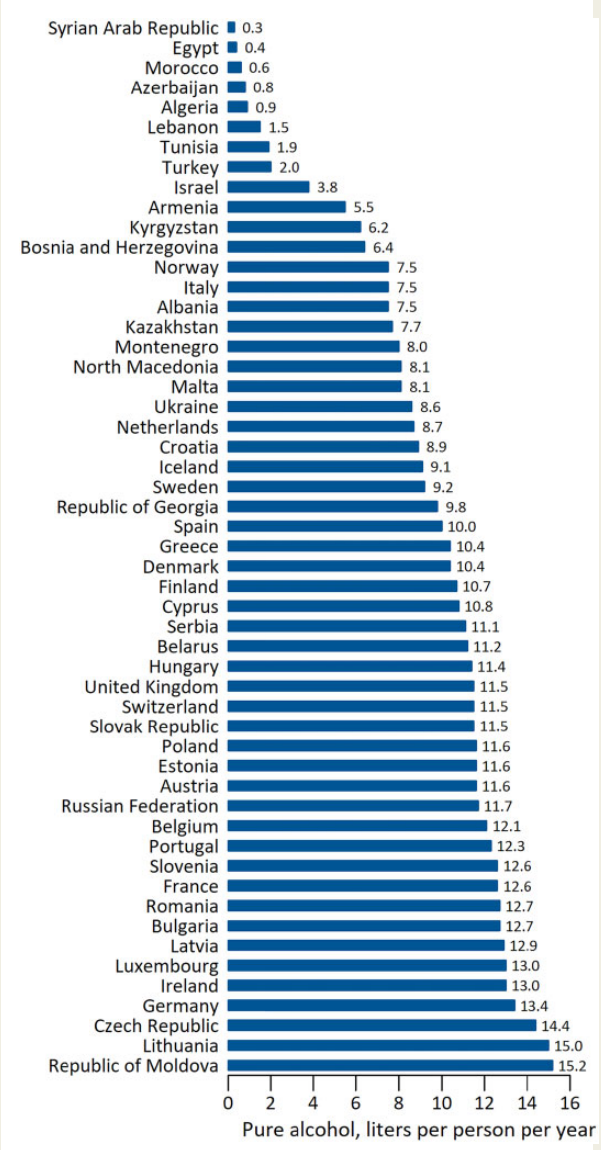

Figure 22 Alcohol consumption per calendar year by persons aged ≥15 years in ESC member countries (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A1046?lang=en. *Data not available*: Libya, Republic of Kosovo, and Republic of San Marino (Supplementary file: S4.xlsx).

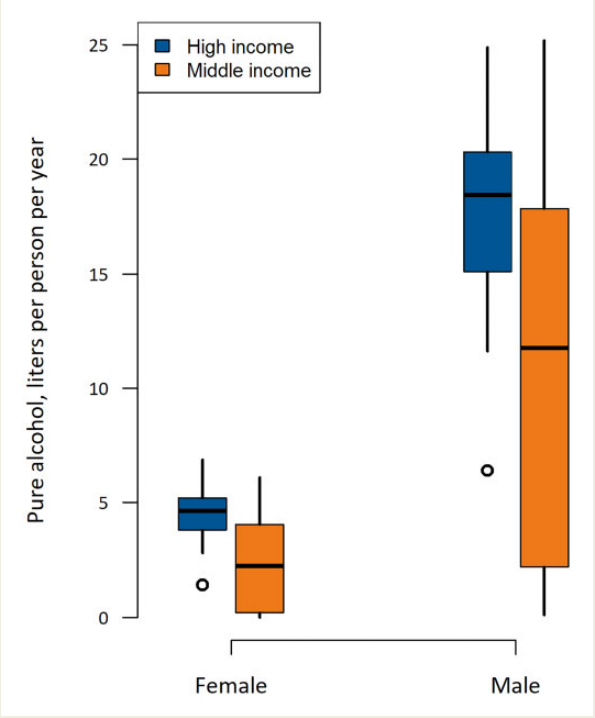

Figure 23 Alcohol consumption per calendar year by sex and national income status among persons aged ≥15 years in ESC member countries (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A1046?lang=en. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Republic of Kosovo (Supplementary file: S4.xlsx).

activity per week. 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.[69] Promotion of leisure time exercise has consistently been shown to promote cardiovascular health.[70]

- *National statistics by gender*: In 2016, the median age-standardized prevalence of self-reported insufficient physical activity was 31% (IQR 26.4–35.8%) among adults aged ≥18 years across the ESC member countries (*Figure 24*). The prevalence tended to be higher in females [33.9% (IQR 28.9–40.1%)] than males [26.4% (IQR 22.9–31.5%)] with >43% of females in Cyprus, Germany, Italy, Malta, and Portugal reporting insufficient physical activity compared with ≥35% of males in the same countries.
- *Stratification by national income status*: Median prevalence rates of insufficiently active females and males were higher in high-income countries [34.3% (IQR 31.0–40.7%)] and 28.2% (IQR 25.4% to 31.9%)) compared with middle-income countries [31.4% (IQR 19.5–38.8%)] and 23.2% (IQR 18.0–29.1%)) (*Figure 25*).

4.3 Summary

- 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, but current rates of decline do not appear sufficient to meet the WHO NCD target for 2025.
- Age-standardized data for 2009 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 concentrations across all of the ESC member countries have shown a small downward trend the last 30 years.
- Across all of the ESC member countries, approximately one in 15 adults had diabetes by 2017 estimates. The prevalence of

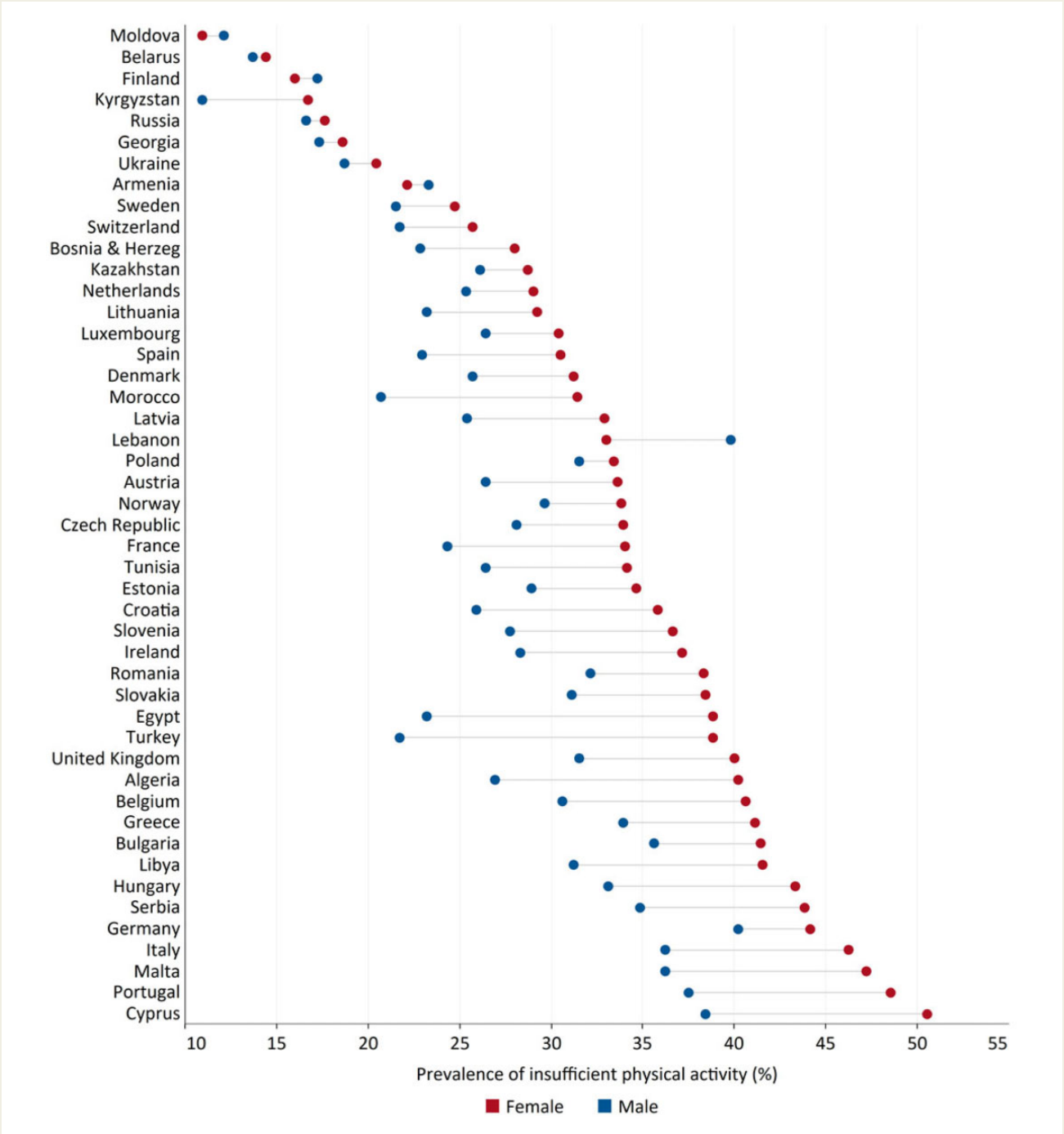

Figure 24 Age-standardized prevalence of insufficient physical activity by sex among adults aged ≥18 years in ESC member countries (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A893?lang=en. *Data not available*: Albania, Azerbaijan, Iceland, Israel, Montenegro, North Macedonia, Republic of Kosovo, Republic of San Marino, and Syrian Arab Republic (Supplementary file: S4.xlsx).

diabetes was lower in high-income compared with middle-income countries where it often exceeded 10%. Across all of the ESC member countries, the prevalence of diabetes has increased more than three-fold in the last 25 years.

- Age-standardized data for 2016 showed that, across ESC member countries, approximately one in four adult females and males were obese. The prevalence was a little higher in high-income compared with middle-income countries and has increased more than two-fold the last 36 years across all countries. The WHO NCD target for a halt to the rise in obesity by 2025 is unlikely to be met unless current increases are reversed.
- More than one in five adults across ESC member countries were smokers by 2014 estimates. Smoking was more common among males than females, particularly in middle-income

countries where 43.8% of males smoked compared with 10.8% of females. Across all countries, smoking has declined by 25% in the last 19 years. The WHO NCD target for a 30% reduction in tobacco use by 2025 appears feasible if current trends continue.

- Alcohol consumption by 2016 estimates was more than three times higher in males compared with females across ESC member countries and almost twice as high in high-income compared with middle-income countries. Consumption since 2010 appears to be declining, particularly in middle-income countries where the WHO NCD target for a 10% relative reduction in the harmful use of alcohol by 2025 appears feasible if current trends continue.
- Physical activity by self-reported data in 2016 was graded insufficient in one in three adults living in ESC member countries. Rates of inactivity were somewhat higher in females compared with males and in high-income compared with middle-income countries.

4.4 Comment

The ESC Atlas data repository of risk factors and health behaviours provides a broad overview of the challenges confronting ESC member countries in the development of policies to reduce the burden of CVD. These challenges are particularly relevant in middle-income countries where disease burden is high, no doubt reflecting increased rates of hypertension, diabetes, and smoking compared with high-income countries. The relative paucity of contemporary treatment facilities in many of these middle-income countries completes the paradox of inferior healthcare provision where need is greatest that is enshrined in the inverse care law.[12] While the expense of modern cardiovascular technology is hard to prioritize in many countries, steps to tackle key risk factors represent a more realistic strategy for reducing CVD burden in middle-income countries as they are more dependent on organizational change than large financial investment. 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 reversed.

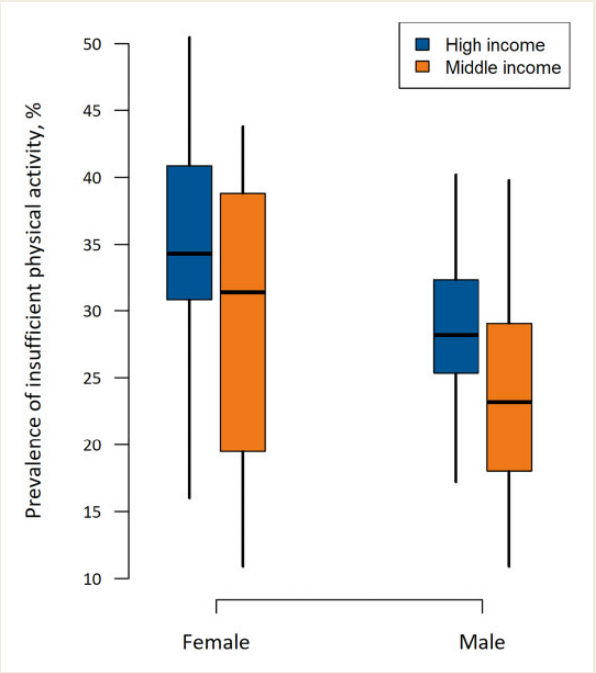

Figure 25 Age-standardized prevalence of insufficient physical activity by sex and national income status among adults aged ≥18 years in ESC member countries (2016). *Data source*: WHO, http://apps.who.int/gho/data/node.main.A893?lang=en. *Data not available for the following high-income countries*: Iceland, Israel, Republic of San Marino; *middle-income countries*: Albania, Azerbaijan, Montenegro, North Macedonia, Republic of Kosovo, and Syrian Arab Republic (Supplementary file: S4.xlsx).

5 Cardiovascular disease morbidity

Measures of morbidity play an important role in describing the epidemiology of a disease, as they represent the number of people who are suffering from it within a population.[71]

Prevalence measures describe the number of individuals who currently have a particular disease in a given population. In the case of acute cardiovascular events, such as myocardial infarction or stroke, they signify the number of people living in the population, who have ever suffered such an event. Incidence defines the number of new cases in a population over a given time, providing a measure of disease occurrence.

Even for conditions with a relatively high case fatality, such as stroke and AMI, morbidity is an important measure alongside mortality, as the disability caused by suffering such events can be high in those who survive and there is some burden in treating individuals irrespective of their level of recovery.

Compared with collecting mortality data, however, which involves aggregating the number of registered deaths, collecting morbidity data is more challenging. Despite the proliferation of electronic record systems within health services in most countries, few utilize such systems to report accurate records of morbidity. We must, therefore, rely on other sources for morbidity statistics.

Throughout this chapter, we present data from the GBD study, which models morbidity estimates for countries using data from health surveys, prospective cohorts, health system administrative data and registries.[72,73] Such estimates are invaluable in allowing morbidity comparisons between countries and over time.

It must be remembered, however, that the strength of the original data source is key to the accuracy of the final modelled estimate[74,75] and countries should be encouraged to develop more comprehensive and systematic means of collecting morbidity data for all conditions, including CVD.

In this section, data concerning CVD morbidity are presented for a maximum of 54 contributing ESC member countries, or fewer

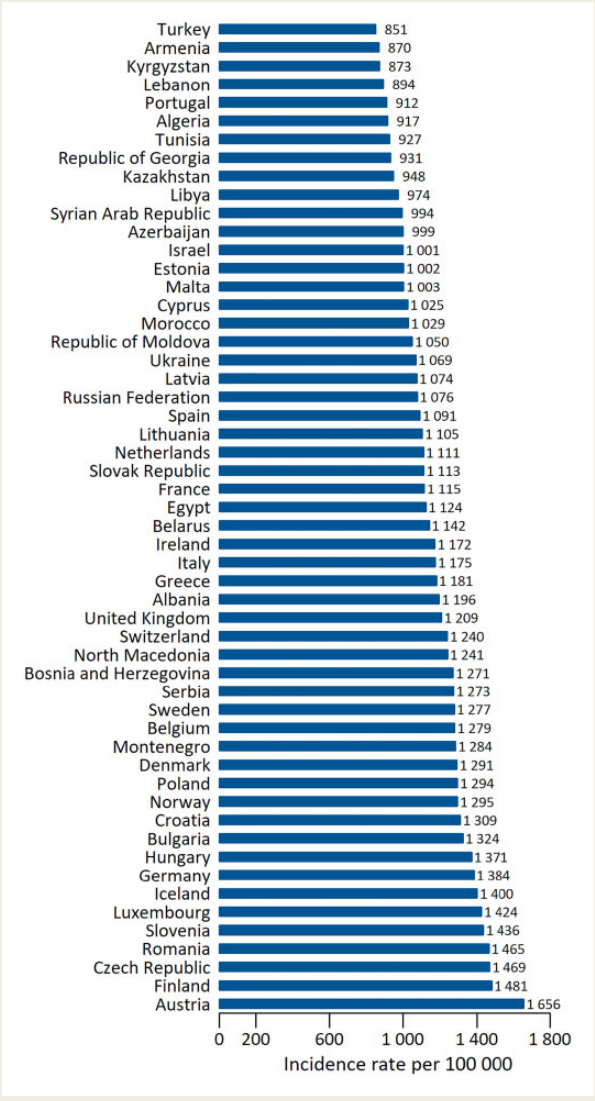

Figure 26 Age-standardized incidence of cardiovascular disease in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

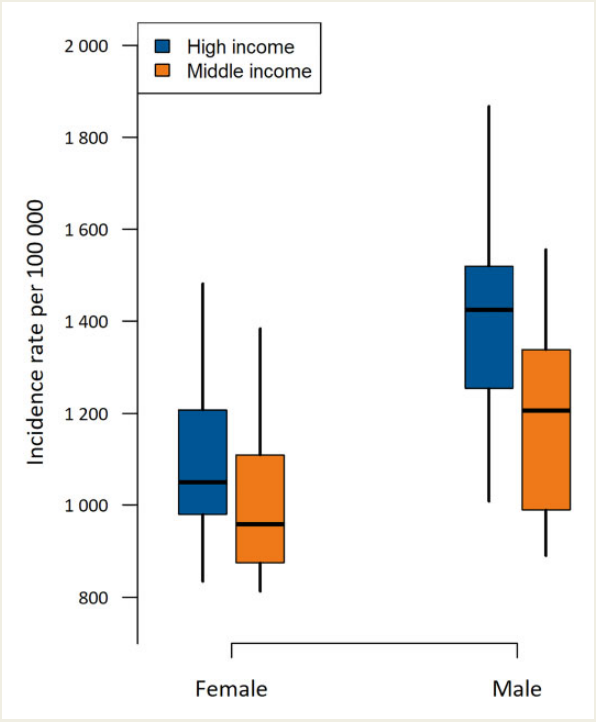

Figure 27 Age-standardized incidence of cardiovascular disease in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

depending upon how complete are the morbidity statistics of interest. There are no data for Republic of Kosovo or Republic of San Marino.

5.1 Incidence of cardiovascular disease

Data: Incidence of cardiovascular disease, ischaemic heart disease, stroke, peripheral vascular disease and atrial fibrillation, by gender; Data source: Global Burden of Disease Study 2017, http://ghdx.healthdata.org/gbd-results-tool; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1990–2017.**

- *National statistics*: In 2017, there were 19.9 million new cases of CVD in the 54 ESC member countries with data available. National contributions were in part determined by population size, with Germany and Russian Federation each contributing about 2.5 million new cases and Iceland and Malta contributing <10 000. The median, age-standardized incidence of CVD was 1133 (IQR 1002–1289) per 100 000 inhabitants of each member country, ranging from <900 in Turkey, Armenia, Kyrgyzstan, and Lebanon to >1400 in Austria, Czech Republic, Finland, Luxembourg, Romania, and Slovenia (*Figure 26*).
- *Stratification by gender*: Females accounted for more new cases of CVD across ESC member countries compared with males (10.3 million vs. 9.6 million) but after age-standardization median rates per 100 000 people were lower in females than in males (1006 vs. 1291) (Supplementary material online, *Figures S5.1* and *S5.2*).
- *Stratification by national income status*: The median age-standardized incidence of CVD per 100 000 inhabitants was lower in middle-income countries compared with high-income countries [1039 (IQR 930–1207) vs. 1224 (IQR 1106–1356)] for both females and males (*Figure 27*). In middle-income countries, rates peaked at >1300 per 100 000 people in Romania and Bulgaria, but in high-income countries rates were yet higher peaking at >1400 per 100 000 people in Austria, Czech Republic, Finland, Iceland, Luxembourg, Romania and Slovenia.
- *Time series data*: The median age-standardized incidence of CVD per 100 000 inhabitants changed from 1186 (IQR 1078–1340) in 1990–1133 (IQR 1002–1289) in 2017 (*Figure 28*). Declines in median incidence rates per 100 000 inhabitants registered in 43

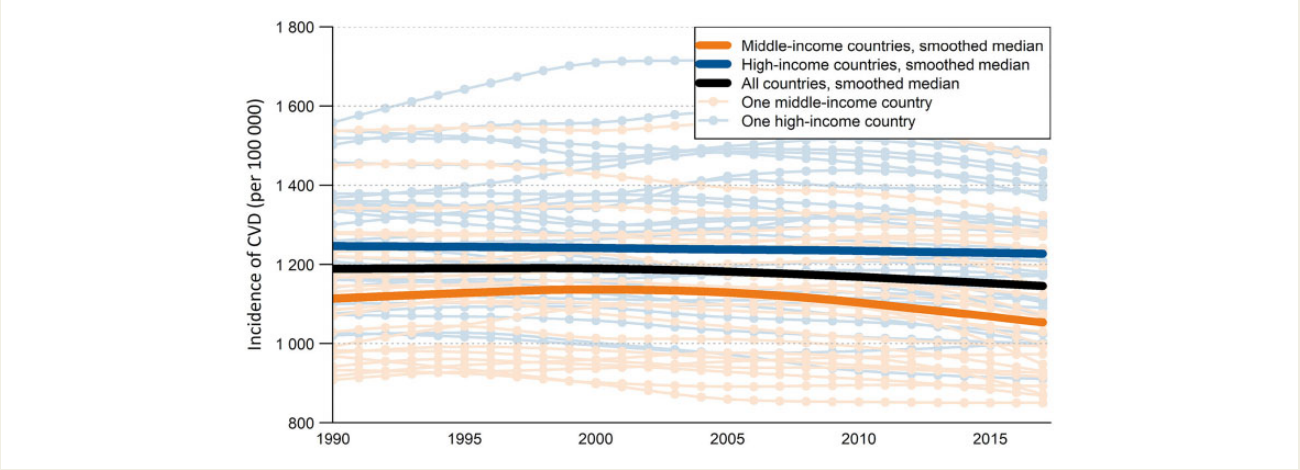

Figure 28 Age-standardized incidence of cardiovascular disease in ESC member countries (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

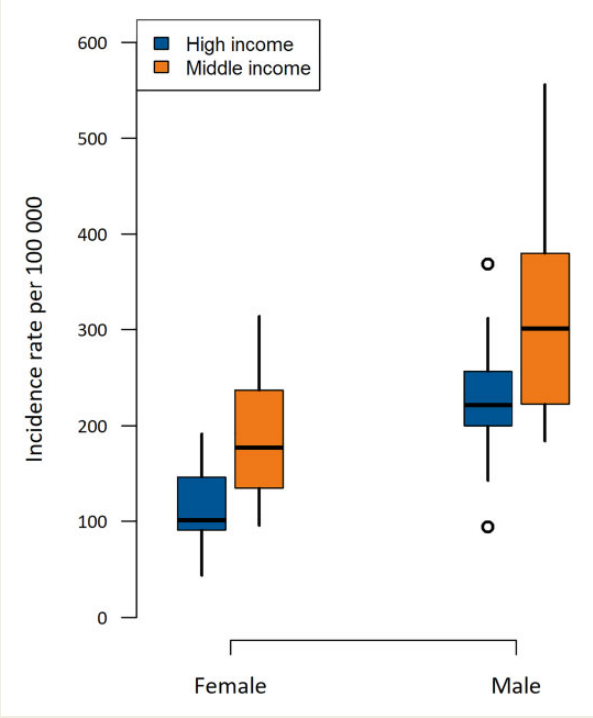

Figure 29 Age-standardized incidence of ischaemic heart disease in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

countries were generally small with 11 countries registering an increase. Moldova and Estonia registered the greatest declines (>13%), but in those countries registering an increase it never exceeded 7.0%.

5.1.1 Incidence of ischaemic heart disease

- *National statistics*: In 2017, IHD was the most common manifestation of incident CVD with 3.6 million new cases in the 54 ESC member countries with data available. The median age-standardized rate per 100 000 inhabitants of each member country was 176.3 (IQR 150.0–238.0) and in both females and males rates were lowest in Portugal, Cyprus, Malta, Spain and Luxembourg and highest in Egypt, Morocco and Belarus in females and in Azerbaijan, Belarus and Egypt in males (Supplementary material online, *Figures S5.3 and S5.4*).
- *Stratification by gender*: Females accounted for fewer new cases of IHD compared with males (1.6 million vs. 2.0million), and after age-standardization, median rates per 100 000 inhabitants of ESC member countries were substantially lower in females than males [132.0 (IQR 98.2–174.6) vs. 235.9 (IQR 208.8–310.0)] (*Figure 29*).
- *Stratification by national income status*: The median age-standardized incidence of IHD per 100 000 inhabitants was higher in middle-income countries compared with high-income countries [243.0 (IQR 175.7–282.3) vs. 160.5 (IQR 140.0–193.5)] (*Figure 29*). In middle-income countries, the incidence rate per 100 000 people varied between 142.9 and 421.0 in Albania and Egypt, while in high-income countries it varied between 66.3 and 267.2 in Portugal and Lithuania.
- *Time series data*: Between 1990 and 2017, the median age-standardized incidence of IHD per 100 000 inhabitants of ESC member countries declined from 273.0 (IQR 201.6–335.5) to 176.3 (IQR 150.0–238.0) (*Figure 30*). Declines exceeded 45% in Poland, Portugal and Romania and only in Libya was an increase recorded from 268.1 per 100 000 people in 1990 to 289.2 per 100 000 people in 2017.

5.1.2 Incidence of stroke

- *National statistics*: In 2017, there were 2.3 million new cases of stroke in the 54 ESC member countries with data available. The median age-standardized number of new cases per 100 000

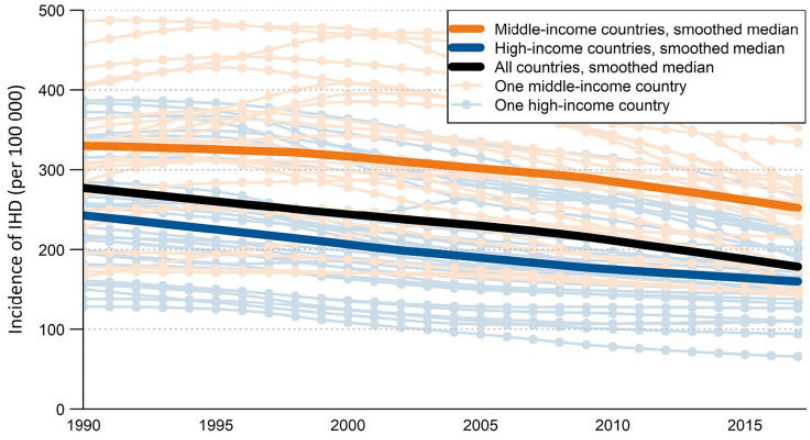

Figure 30 Age-standardized incidence of ischaemic heart disease in ESC member countries (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

inhabitants of each member country was 143.4 (IQR 100.5–180.5). Stroke numbers for females and males were greatest across Eastern European and North African ESC countries (*Figure 31*), ranging from 82.8 per 100 000 inhabitants in Italy to 213.4 per 100 000 inhabitants in Egypt (Supplementary material online, *Figure S5.5*).

- *Stratification by gender*: New cases of stroke across ESC member countries were shared almost equally between females and males (1.2 million vs. 1.1 million). However, the median age-standardized rate per 100 000 people was lower in females than males [130.3 (IQR 90.5–166.4) vs. 159.9 (IQR 111.0–190.7)] (Supplementary material online, *Figure S5.5*).
- *Stratification by national income status*: The median age-standardized incidence of stroke per 100 000 people was higher in middle-income countries compared with high-income countries [179.7 (IQR 161.8–190.7) vs. 101.8 (IQR 94.4–131.9)] for both females and males (*Figure 32*). In middle-income countries, the incidence per 100 000 people ranged from <150 in Armenia and Kyrgyzstan to >200 in Romania and Egypt, while in high-income countries it ranged from <85 in Switzerland and Italy to >190 in Latvia and Lithuania.
- *Time series data*: Between 1990 and 2017, the median age-standardized incidence of stroke per 100 000 inhabitants of ESC member countries declined from 172.9 (IQR 133.8–211.3) in 1990 to 143.4 (IQR 100.5–180.5) in 2017 (*Figure 33*). This was reflected in national data which showed variable declines in age-standardized stroke rates for all ESC member countries except Libya, Lithuania and Egypt. In Portugal, the 52% decline in stroke rate exceeded that of all other ESC member countries.

5.1.3 Incidence of peripheral vascular disease

- *National statistics*: In 2017, there were 2.2 million new cases of peripheral vascular disease (PVD) in the 54 ESC member countries with data available. The median age-standardized number of new cases per 100 000 inhabitants of each member country was 132.2 (IQR 126.2–136.2), with incidence rates lowest in Norway and highest in Denmark.
- *Stratification by gender*: New cases of PVD were distributed evenly between the sexes with females and males each contributing 1.1 million cases in 2017. After age-standardization, however, the median incidence per 100 000 people was lower in females compared with males [124.4 (IQR 110.6–133.6) vs. 135.9 (IQR 123.7–157.9)] (Supplementary material online, *Figures S5.6 and S5.7*).
- *Stratification by national income status*: The median age-standardized incidence of PVD per 100 000 people was similar in middle-income and high-income countries [133.1 (IQR 127.3–135.9) vs. 130.6 (IQR 125.8–136.4)] (Supplementary material online, *Figure S5.7*). In middle-income countries, the incidence per 100 000 people ranged from 118.8 in Albania to 141.0 in Libya, while in high-income countries it ranged from 89.8 in Norway to 177.7 in Denmark.
- *Time series data*: Between 1990 and 2017, the median age-standardized incidence of PVD per 100 000 people remained relatively stable at 136.8 (IQR 130.8–154.5) in 1990 and 132.2 (IQR 126.2–136.2) in 2017 (Supplementary material online, *Figure S5.8*). However, in 43 of the 54 countries, there was a variable increase in the age-standardized incidence of PVD, greatest in the UK which experienced an increase of 32%.

5.1.4 Incidence of atrial fibrillation

- *National statistics*: In 2017, there were 0.75 million new cases of atrial fibrillation (AF) in the 54 ESC member countries with data available. The median age-standardized number of new cases per 100 000 inhabitants of each member country was 44.3 (IQR 39.7–47.5).
- *Stratification by gender*: In 2017, females and males accounted for similar numbers of new cases of AF (0.35 million vs. 0.40 million), but median age-standardized rates per 100 000 people were lower for females compared with males [35.0 (IQR 32.8–38.4) vs. 54.3 (IQR 49.3–59.4)] (*Figure 34*).
- *Stratification by national income status*: The median age-standardized incidence of AF per 100 000 people was lower in middle-income countries compared with high-income countries [40.7

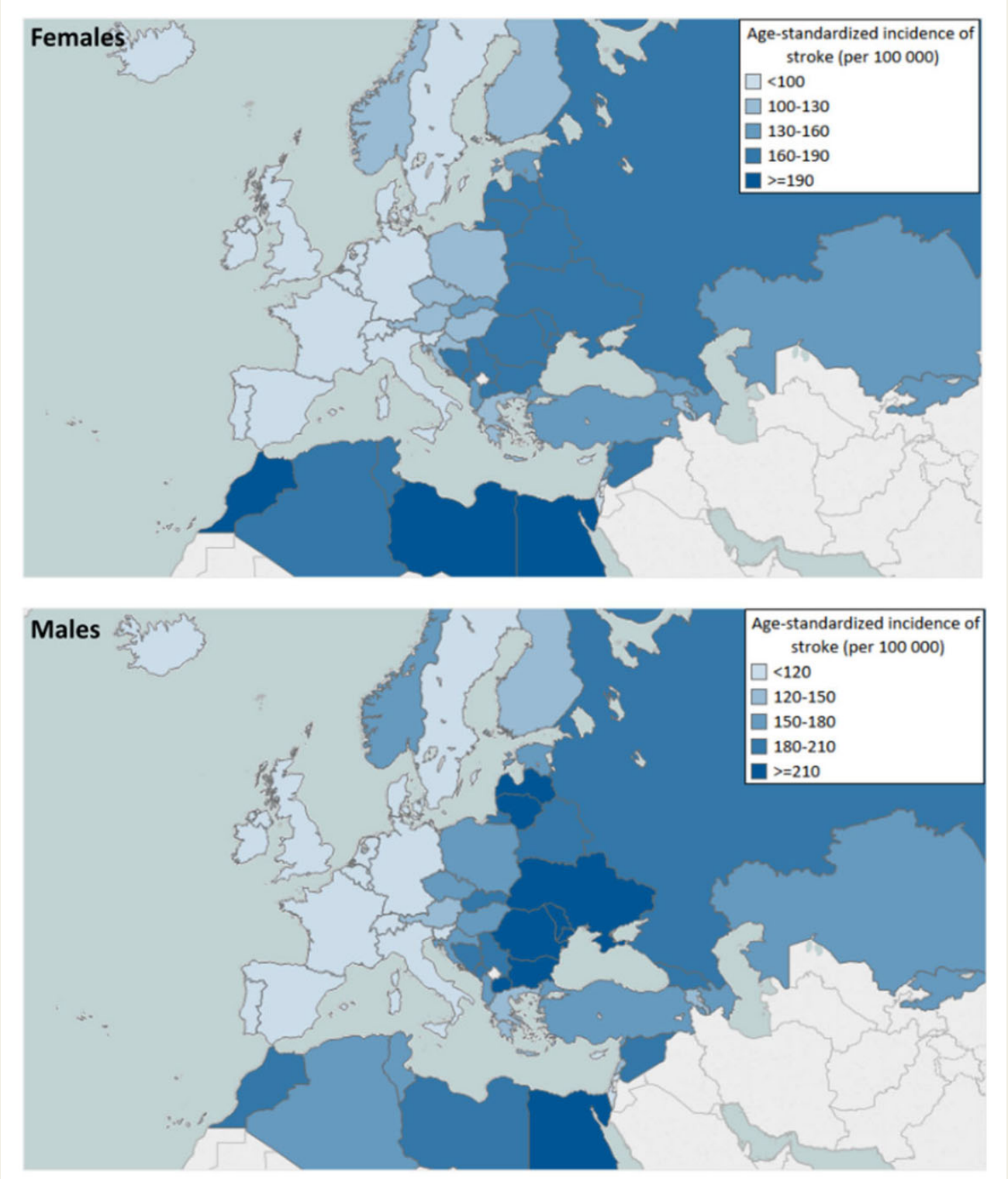

Figure 31 Age-standardized incidence of stroke in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

(IQR 27.1–42.4) vs. 47.3 (IQR 45.7–52.4)] (*Figure 35*). The age-standardized incidence per 100 000 people in middle-income countries ranged from 22.1 in Turkey to 45.1 in Ukraine, and in high-income countries from 33.5 in Portugal to 63.9 in Sweden.

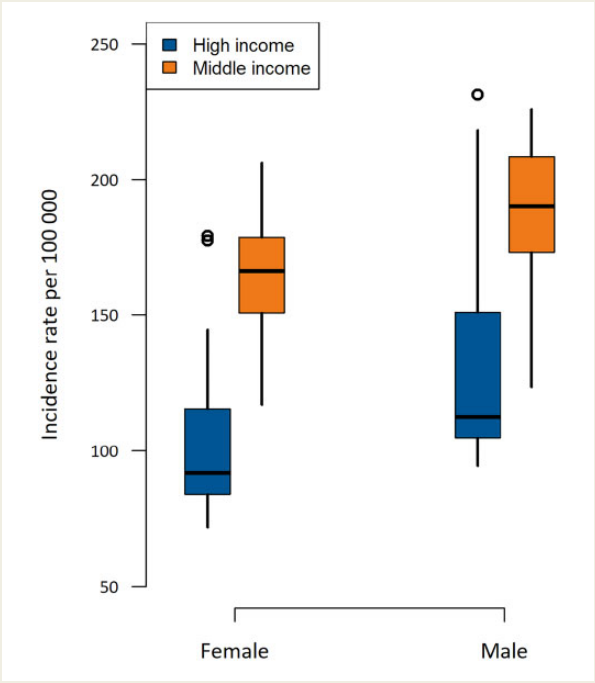

Figure 32 Age-standardized incidence of stroke in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

- *Time series data*: Between 1990 and 2017, the median age-standardized incidence of AF per 100 000 people remained relatively stable at 44.7 (IQR 39.9–51.5) in 1990 and 44.3 (IQR 39.7–47.5) in 2017 (Supplementary material online, *Figure S5.9*). In just over half of the ESC member countries a variable, usually small, increase in the age-standardized incidence of AF was recorded, greatest for Portugal where the incidence increased by 45%.

5.2 Prevalence of cardiovascular disease

Data: Prevalence of cardiovascular disease, ischaemic heart disease, stroke, peripheral vascular disease, and atrial fibrillation, by gender; Data source: Global Burden of Disease Study 2017, http://ghdx.healthdata.org/gbd-results-tool; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1990–2017.**

- *National statistics*: In 2017, there were 108.7 million people living with CVD in the 54 ESC member countries with data available. The median age-standardized prevalence per 100 000 inhabitants of each member country was 6595 (IQR 6184–7108), ranging from 5254 in Norway to 8766 in Bulgaria (*Figure 36*).
- *Stratification by gender*: There were more females than males living with CVD across ESC member countries (55.7 million vs. 52.9 million). The median age-standardized prevalence rates per 100 000 people were lower for females compared with males [6190 (IQR 5529–6842) vs. 7250 (IQR 6661–7793)] (Supplementary material online, *Figures S5.10* and *S5.11*). Rates per 100 000 for females ranged from 4421 in Norway to 8128 in Czech Republic and for males from 6156 in Cyprus to 9674 in Bulgaria.
- *Stratification by national income status*: The median age-standardized prevalence of CVD per 100 000 inhabitants was higher in

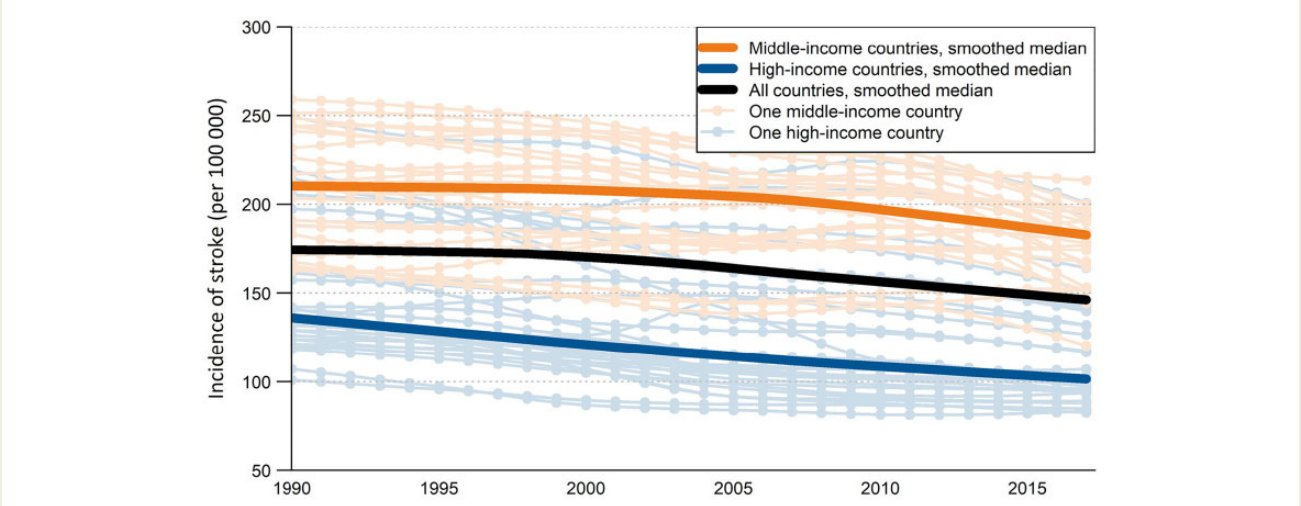

Figure 33 Age-standardized incidence of stroke in ESC member countries (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

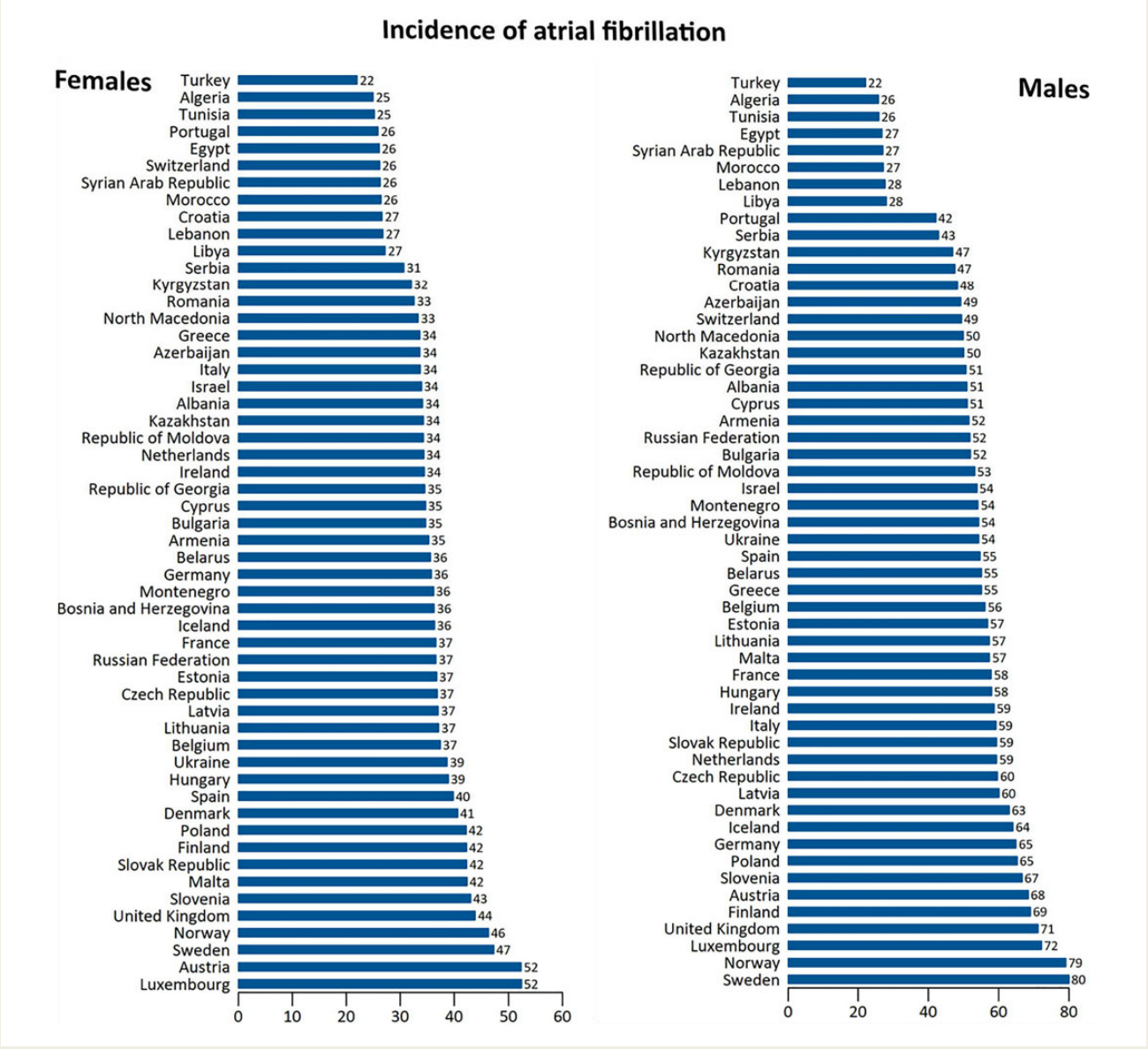

Figure 34 Age-standardized incidence of atrial fibrillation/flutter in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

middle-income countries compared with high-income countries [7022 (IQR 6562–7354) vs. 6245 (IQR 5785–6911)] for both females and males (*Figure 37*). The age-standardized prevalence per 100 000 people in middle-income countries ranged from 5976 in Moldova to 8766 in Bulgaria, and in high-income countries from 5254 in Norway to 8457 in Czech Republic.

- *Time series data*: Between 1990 and 2017, the median age-standardized prevalence of CVD per 100 000 people remained relatively stable at 7155 (IQR 6672–7652) in 1990 vs. 6595 (IQR 6184–7108) in 2017 (*Figure 38*). Modest increases in prevalence were seen in all but seven countries (Libya, Egypt, Georgia, Russian Federation, Lithuania, Azerbaijan, Bosnia and Herzegovina) peaking in Portugal where the prevalence increased by 27% over the 27-year period.

5.2.1 Prevalence of ischaemic heart disease

- *National statistics*: In 2017, there were 34.9 million people living with IHD in the 54 ESC member countries with data available. The median age-standardized prevalence per 100 000 inhabitants of each member country was 2270 (IQR 1508–2565) ranging from 1156 in Portugal to 3000 in Egypt. In both females and males, prevalence was higher in Eastern European and North African countries compared with Western European countries. (*Figure 39*).
- *Stratification by gender*: There were fewer females living with IHD in ESC member countries compared with males (16.2 million vs. 18.7 million). Median age-standardized prevalence rates per 100 000 people were lower for females compared with males [1895 (IQR 1049–2127) vs. 2665 (IQR 2018–3068)]

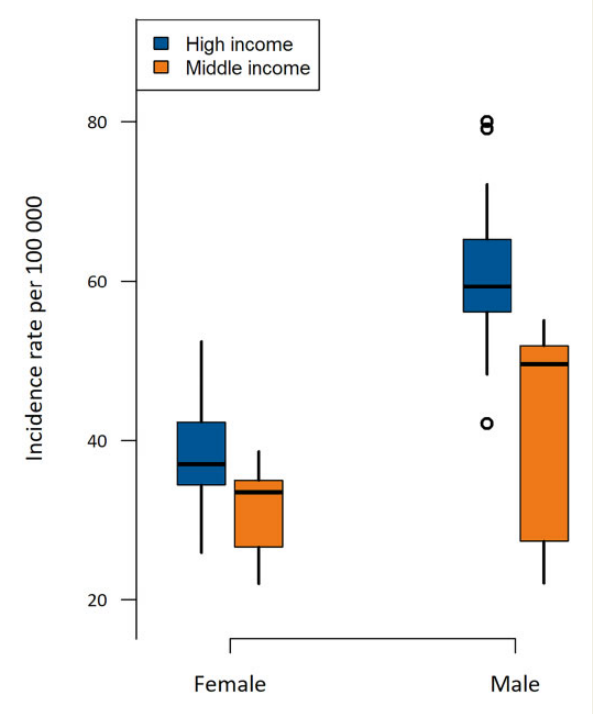

Figure 35 Age-standardized incidence of atrial fibrillation/flutter in ESC member countries by sex and national income level (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

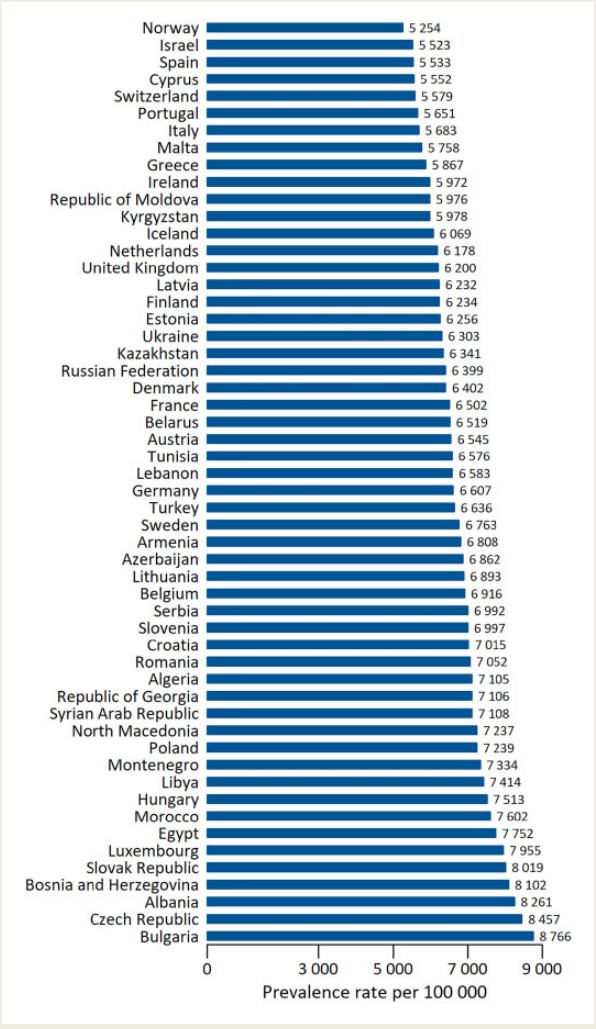

Figure 36 Age-standardized prevalence of cardiovascular diseases in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

(Supplementary material online, *Figure S5.12*). Rates per 100 000 for females ranged from 873 in Portugal to 2499 in Morocco and for males from 1507 in Portugal to 3677 in Belarus.

- *Stratification by national income status*: The median age-standardized prevalence of IHD per 100 000 inhabitants was higher in middle-income countries compared with high-income countries [2503 (IQR 2270–2640) vs. 1527 (IQR 1396–2387)] in both females and males (*Figure 40*). In middle-income countries, age-standardized prevalence per 100 000 inhabitants ranged from 1679 in Kyrgyzstan to 3000 in Egypt, and in high-income countries from 1156 in Portugal to 2837 in Hungary.
- *Time series data*: Between 1990 and 2017, the median age-standardized prevalence of IHD per 100 000 people showed a small decline from 2482 (IQR 1869–2811) in 1990 to 2270 (IQR 1508–2565) in 2017 (*Figure 41*). Variable, usually small, declines in the age-standardized prevalence of IHD per 100 000 people were recorded in all ESC member countries, except Libya and Syrian Arab Republic.

5.2.2 Prevalence of stroke

- *National statistics*: In 2017, there were 20.4 million people living with stroke in the 54 ESC member countries with data available. The median age-standardized prevalence of stroke per 100 000 inhabitants of each member country was 1276 (IQR 917–1552), ranging from 570 in Italy to 1869 in Latvia. In both females and males, prevalence was higher in Eastern European and North African countries compared with Western European countries (*Figure 42*).
- *Stratification by gender*: There were more females than males living with stroke (11.4 million vs. 9.06 million) across ESC member countries. With age-standardization, however, median prevalence rates per 100 000 people were lower for females compared with males [1272 (IQR 878–1505) vs. 1322 (IQR 971–1639)] (Supplementary material online, *Figure S5.13*). Rates for females ranged from 540 in Italy to 1890 in Egypt and for males from 607 in Italy to 2022 in Latvia.
- *Stratification by national income status*: The median age-standardized prevalence of stroke per 100 000 people, was higher in middle-income countries compared with high-income countries [1542 (IQR 1364–1728) vs. 942 (IQR 874–1255)] for both females and males (*Figure 43*). In middle-income countries, age-

standardized prevalence per 100 000 inhabitants ranged from 1166 in Armenia to 1798 in Serbia, and in high-income countries from 570 in Italy to 1869 in Latvia.

- *Time series data*: Between 1990 and 2017, the median age-standardized prevalence of stroke per 100 000 people showed a small decline from 1405 (IQR 1028–1706) in 1990 to 1276 (IQR 917–1552) in 2017 (*Figure 44*). Declines in the prevalence of stroke occurred in all except 15 ESC member countries and exceeded 35% in Estonia and Portugal. In Azerbaijan and Bosnia and Herzegovina, however, prevalence increased by over 15%.

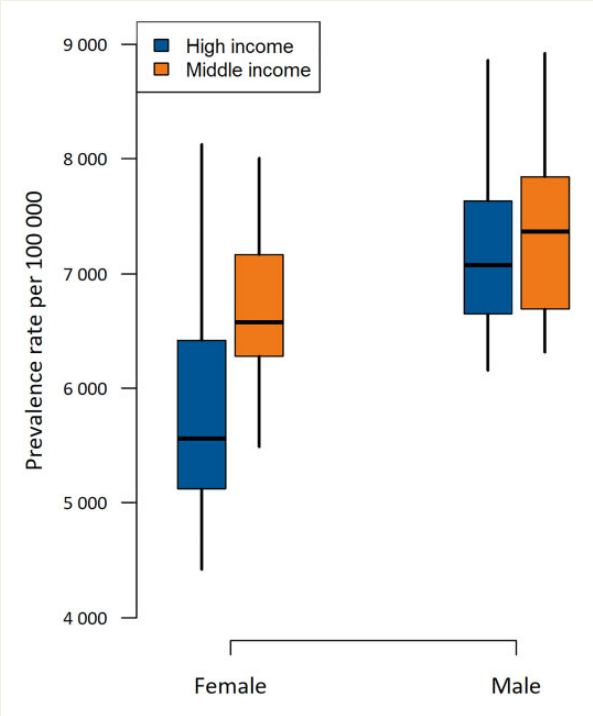

Figure 37 Age-standardized prevalence of cardiovascular diseases in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

5.2.3 Prevalence of peripheral vascular disease

- *National statistics*: In 2017, there were 25.8 million people living with PVD in the 54 ESC member countries with data available. The median age-standardized prevalence of PVD per 100 000 inhabitants of each member country was 1460 (IQR 1366–1573), ranging from 1061 in Norway to 2204 in Denmark.
- *Stratification by gender*: There were more females than males living with PVD (13.8 million vs. 12.0 million) across ESC member countries. However, median age-standardized prevalence rates for PVD per 100 000 people were similar for females and males [1415 (IQR 1347–1481) vs. 1456 (IQR 1299–1845)] (Supplementary material online, *Figure S5.14*). Rates per 100 000 for females ranged from 880 in Norway to 1856 in Denmark and for males from 1184 in Russian Federation to 2609 in Denmark.
- *Stratification by national income status*: The median age-standardized prevalence of PVD per 100 000 people, was 1417 (IQR 1363–1461) in middle-income countries compared with 1552 (IQR 1397–1639) in high-income countries. In middle-income countries, age-standardized prevalence per 100 000 inhabitants ranged from 1250 in Kyrgyzstan to 1529 in Libya, and in high-income countries from 1061 in Norway to 2204 in Denmark.
- *Time series data*: Between 1990 and 2017, the median age-standardized prevalence of PVD per 100 000 inhabitants of ESC member countries was stable at 1468 (IQR 1381–1869) in 1990 and 1460 (IQR 1365–1572) in 2017. A total of 37 countries recorded small declines in the age-standardized prevalence of PVD which exceeded 20% in UK, Italy and Norway. Increases in

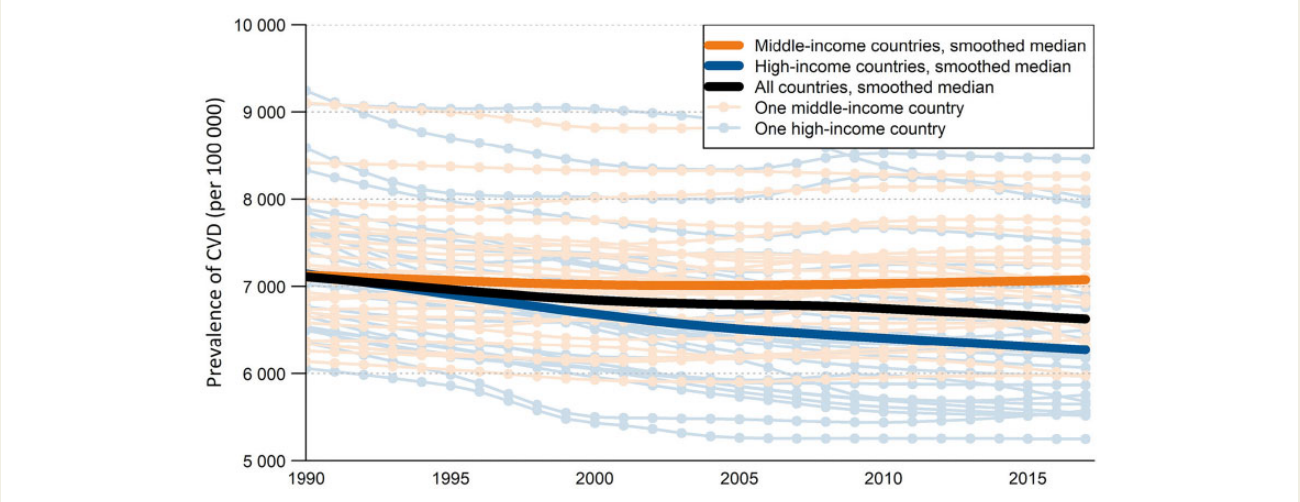

Figure 38 Age-standardized prevalence of cardiovascular diseases in ESC member countries by national income status (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

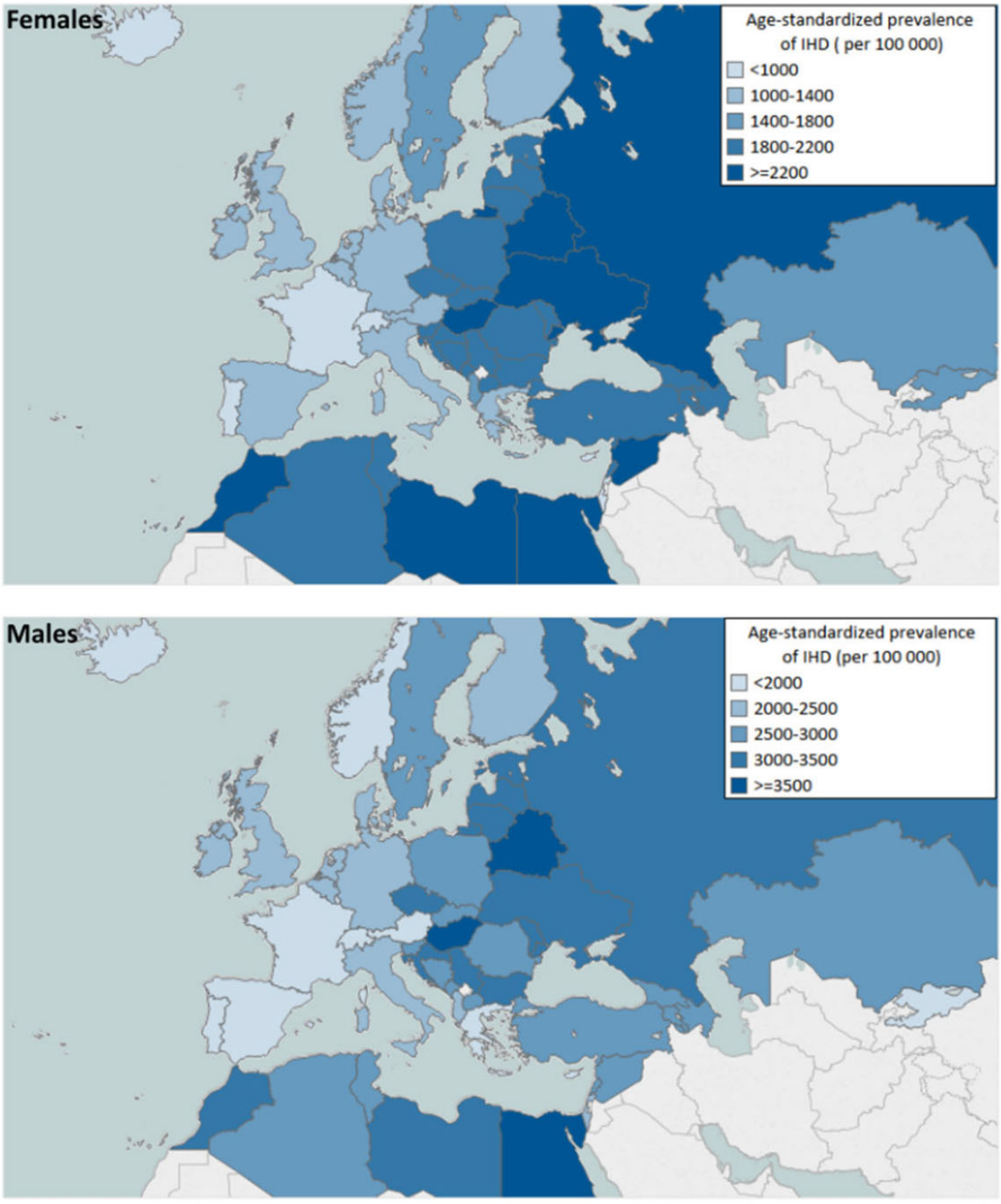

Figure 39 Age-standardized prevalence of ischaemic heart disease in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

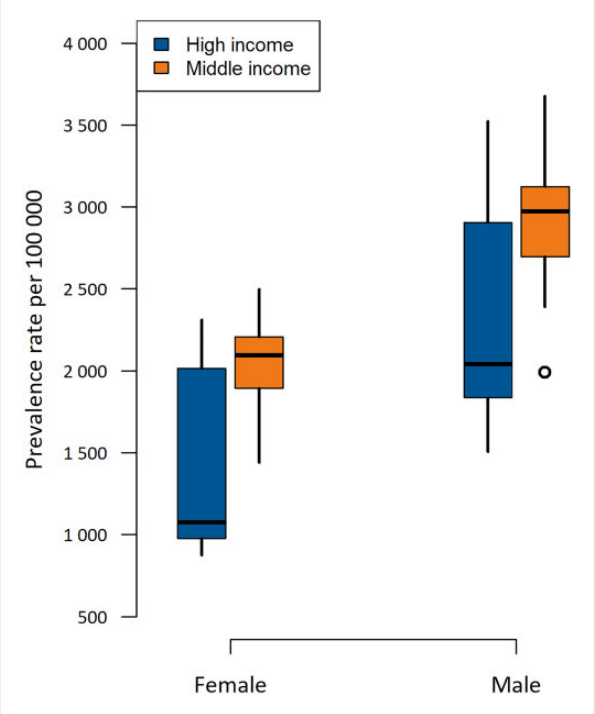

Figure 40 Age-standardized prevalence of ischaemic heart disease in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

prevalence seen in 17 countries were always small, never exceeding 8% (Supplementary material online, *Figure S5.15*).

5.2.4 Prevalence of atrial fibrillation

- *National statistics*: In 2017, there were 10.0 million people living with AF in the 54 ESC member countries with data available. Across all ESC member countries, the age-standardized median prevalence of AF per 100 000 inhabitants was 571.8 (IQR 510.8–622.7), ranging from 265.7 in Turkey to 806.1 in Sweden.
- *Stratification by gender*: There were fewer females than males living with AF (4.6 million vs. 5.4 million) across ESC member countries. Median age-standardized prevalence rates for AF per 100 000 people were lower for females than males [436.8 (IQR 380.6–479.6) vs. 752.5 (IQR 670.4–832.3)] (*Figure 45*). Rates for females ranged from 262.9 in Turkey to 637.6 in Austria and for males from 269.8 in Turkey to 1108 in Sweden.
- *Stratification by national income status*: Across all ESC member countries, the median age-standardized prevalence of AF per 100 000 people was lower in middle-income countries compared with high-income countries [531.3 (IQR 332.0–565.4) vs. 608.7 (IQR 572.6–690.9)] in both females and males (*Figure 46*). In middle-income countries, age-standardized prevalence per 100 000 people ranged from 265.7 in Turkey to 603.7 in Ukraine, and in high-income countries from 405.9 in Portugal to 806.1 in Sweden.
- *Time series data*: Between 1990 and 2017, the median age-standardized prevalence of AF per 100 000 inhabitants of ESC member countries was stable at 589.5 (IQR 525.5–640.5) in 1990 and 571.75 (IQR 510.8–622.7) in 2017 (Supplementary material online, *Figure S5.16*). Declines in age-standardized prevalence of

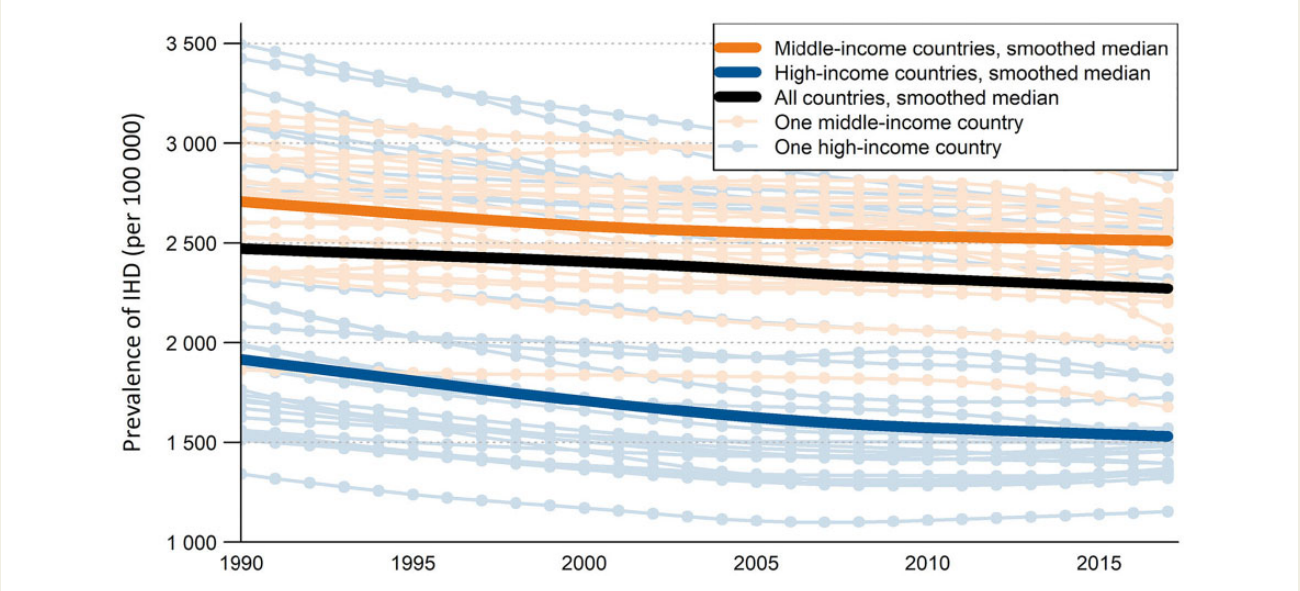

Figure 41 Age-standardized prevalence of ischaemic heart disease in ESC member countries by national income status (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

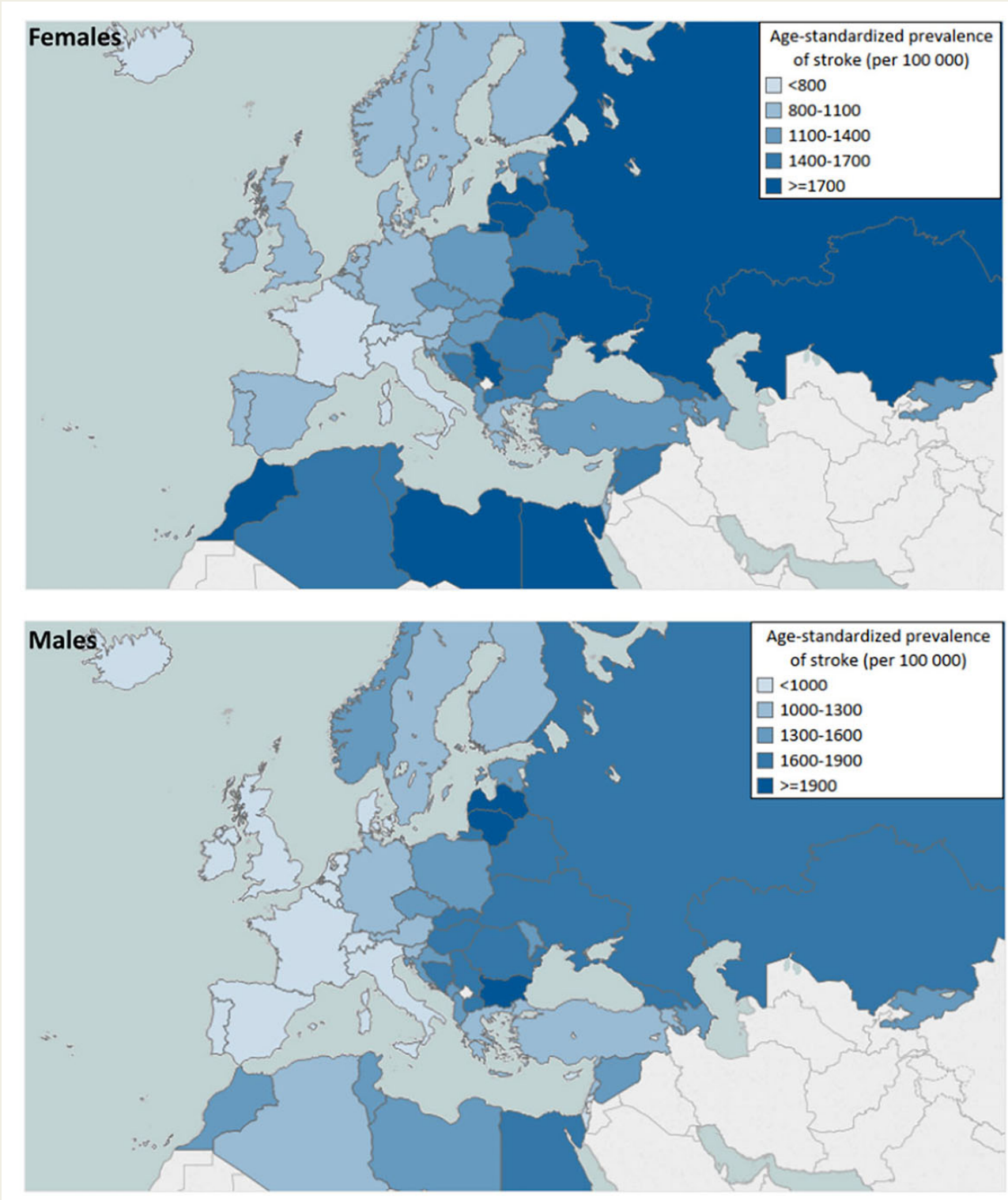

Figure 42 Age-standardized prevalence of stroke in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

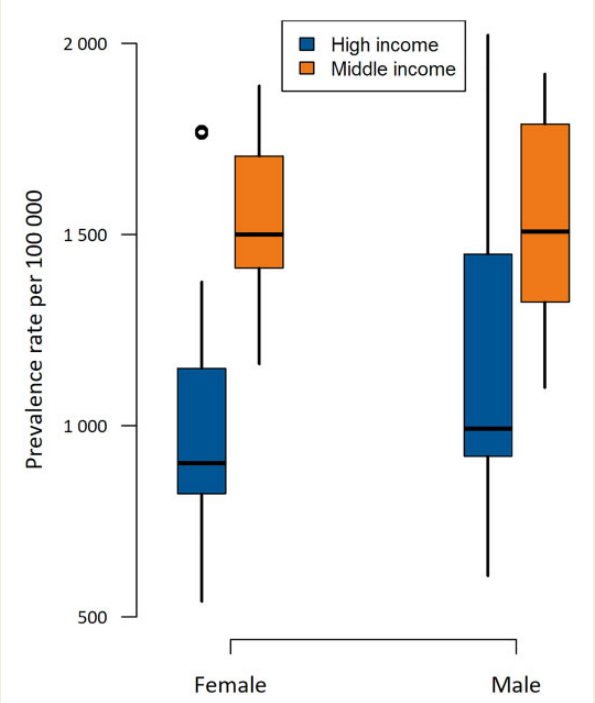

Figure 43 Age-standardized prevalence of stroke in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

AF, recorded in 26 countries, exceeded 20% in Italy and Portugal, while increases, recorded in 28 countries, exceeded 15% in Luxembourg, Austria, and Latvia.

5.3 Disability-adjusted life years due to cardiovascular disease

Data: DALYs due to cardiovascular disease, ischaemic heart disease, and stroke, by gender;
Data source: Global Burden of Disease Study 2017, http://ghdx.healthdata.org/gbd-results-tool; **Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 1990–2017.**

Disability-adjusted life years 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.[76] One DALY can be thought of as one lost year of 'healthy' life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. It allows comparison of the overall health and life expectancy of different countries.[76]

- *National statistics*: In 2017, the median number of age-standardized DALYs due to CVD, was 4530 (IQR 2179–6463) per 100 000 inhabitants of ESC member countries, ranging from <1600 in Switzerland, Israel, and France to >10 000 in Ukraine and Egypt (*Figure 47*, Supplementary material online, *Figure S5.17*). Ischaemic heart disease and stroke were the major contributors to DALYs due to CVD, accounting for 54% and 27%,

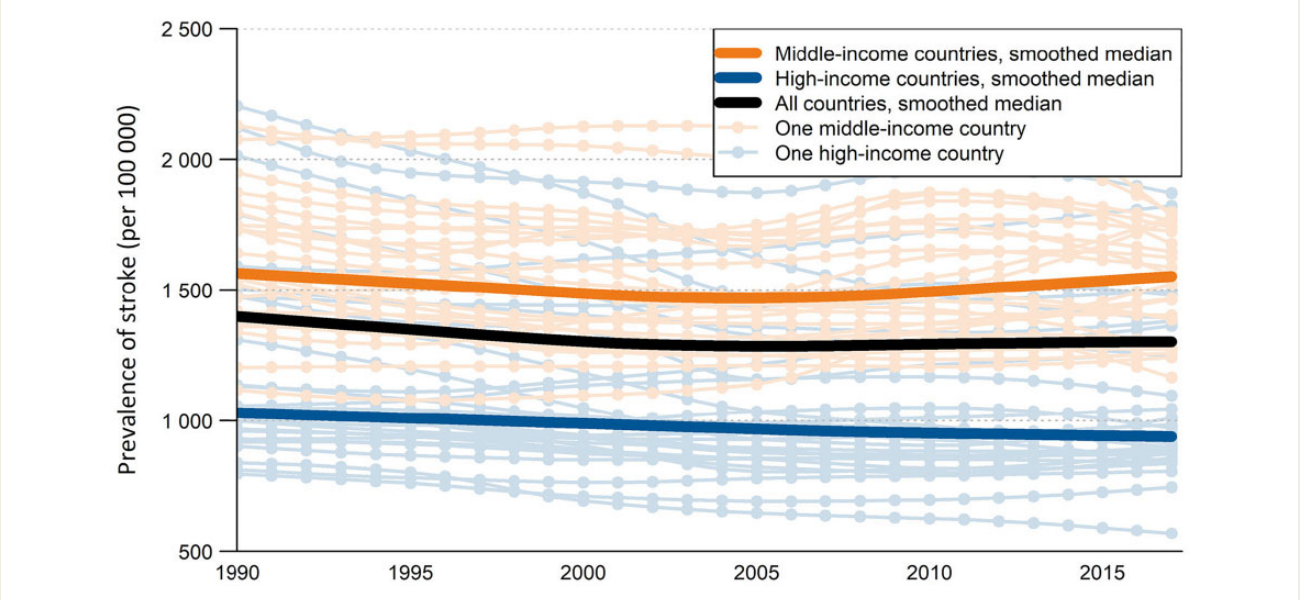

Figure 44 Age-standardized prevalence of stroke in ESC member countries by national income status (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

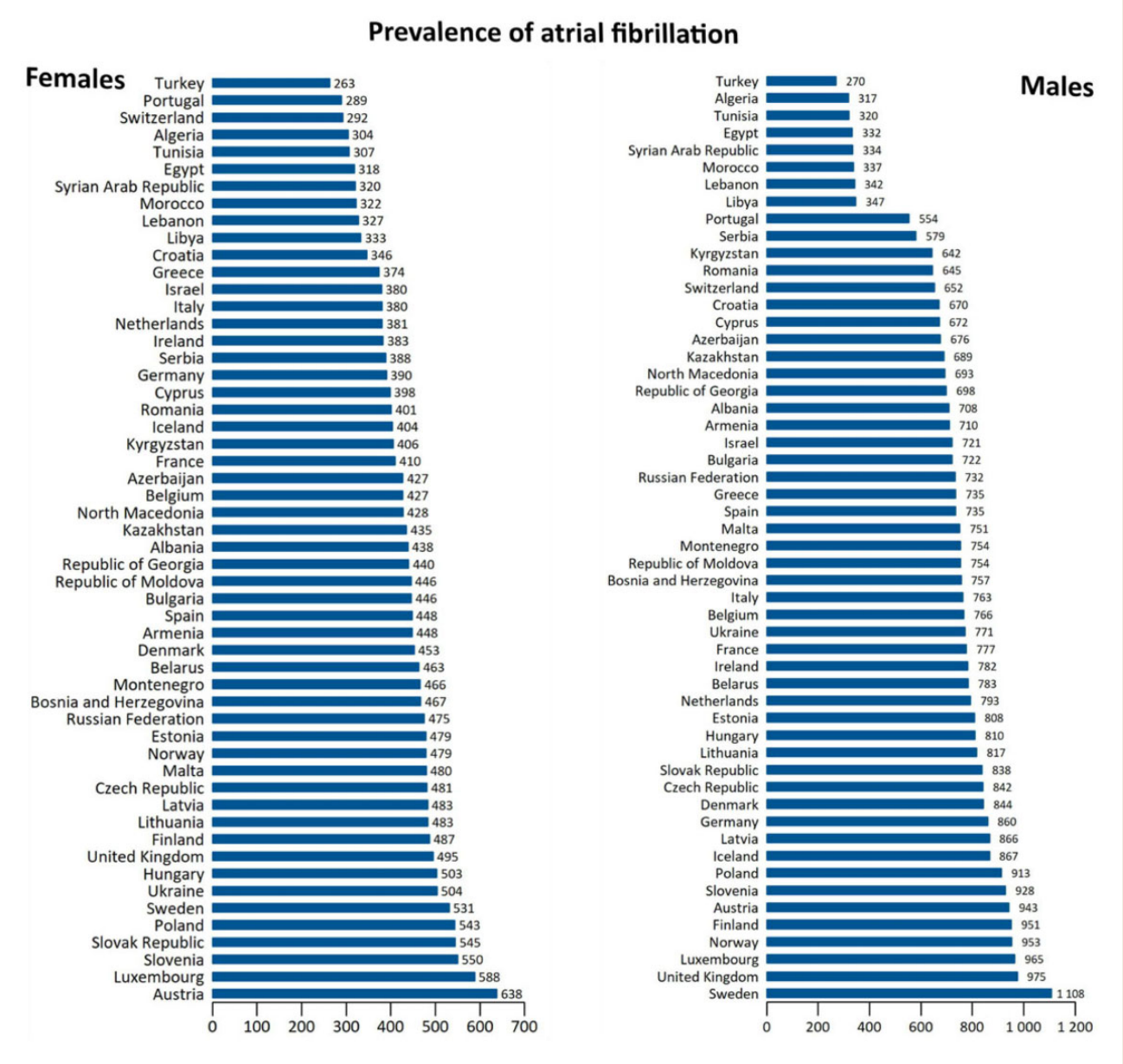

Figure 45 Age-standardized prevalence of atrial fibrillation/flutter in ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

respectively. Peripheral vascular disease and AF together accounted for less than 3% of DALYs due to CVD.

- *Stratification by gender*: Median age-standardized DALYs per 100 000 people due to CVD were 3219 (IQR 1597–5324) for females, ranging from 1114 in France to 7657 in Morocco. For males, the median number of DALYs per 100 000 people due to CVD was almost twice as high [5925 (IQR 2810–8124)] ranging from 1938 in Switzerland to 15 077 in Ukraine (Supplementary material online, *Figure S5.18*). Ischaemic heart disease was the major contributor to the difference between females and males with a nearly three-fold difference in median values for DALYs: 1384 (IQR 615–2423) vs. 3145 (IQR 1513–5261) per 100 000 people, respectively. For stroke, however, DALYs per 100 000 people were more comparable between the sexes at 951 (IQR 481–1730) for females vs. 1255 (IQR 612–2426) for males.
- *Stratification by national income status*: The median number of age-standardized DALYs per 100 000 people due to CVD was considerably higher in middle-income countries compared with high-income countries [7160 (IQR 5655–8115) vs. 2235 (IQR 1896–3602)] (*Figure 48*). Median age-standardized DALYs due to IHD were 3910 (IQR 2788–4771) per 100 000 inhabitants of middle-income countries compared with 1042 (IQR 797–1910)

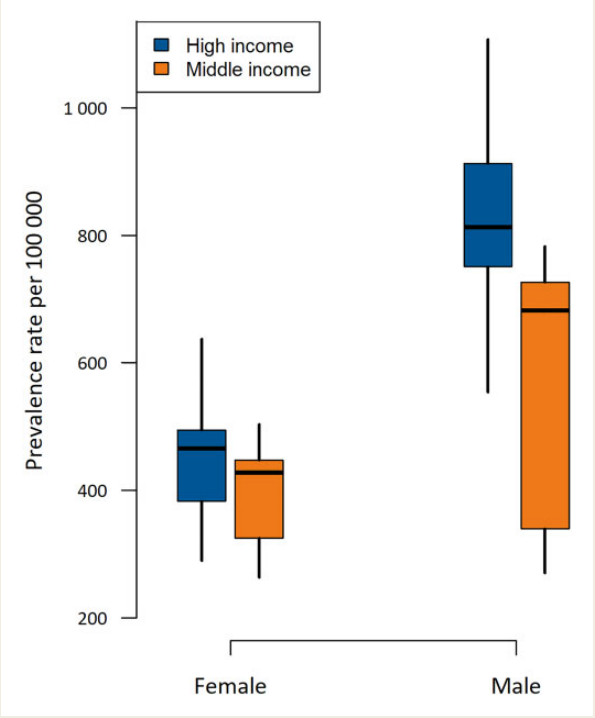

Figure 46 Age-standardized prevalence of atrial fibrillation/flutter in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

per 100 000 inhabitants of high-income countries. For stroke, the difference was 2183 (IQR 1517–2491) DALYs per 100 000 people in middle-income countries compared with 546 (IQR 489–855) in high-income countries.

- *Time series data*: Between 1990 and 2017, age-standardized DALYs due to CVD per 100 000 inhabitants of ESC member countries declined, from 7542 (IQR 5244–9278) to 4530 (IQR 2179–6463) (*Figure 49*). Declines were >60% in Ireland, Portugal, Denmark, Norway and Israel with only Azerbaijan and Belarus recording an increase. Ischaemic heart disease and stroke contributed importantly to the declines in DALYs due to CVD, with median age-standardized values for IHD falling from 4069 (IQR 2843–5237) to 2186 (IQR 1032–3667) per 100 000 inhabitants of ESC member countries. Data for stroke were similar with age-standardized DALYs falling from a median value of 2035 (IQR 1223–3000) to 1141 (IQR 537–2011) per 100 000 inhabitants. Only Ukraine, Azerbaijan, Kyrgyzstan, Libya and Belarus recorded an increase in age-standardized DALYs due to IHD and only Azerbaijan an increase in DALYs due to stroke.

5.4 Summary

- Declines in the age-standardized incidence of CVD during the last 27 years have been small and, in 11 ESC member countries, non-existent.
- The age-standardized incidence of CVD's major components, IHD and stroke, have both shown a downward trend during the last 27 years. Downward trends in their prevalence have been smaller.
- Differences between females and males in the crude incidence and prevalence of IHD and stroke were small but after age-standardization rates were consistently lower in females.

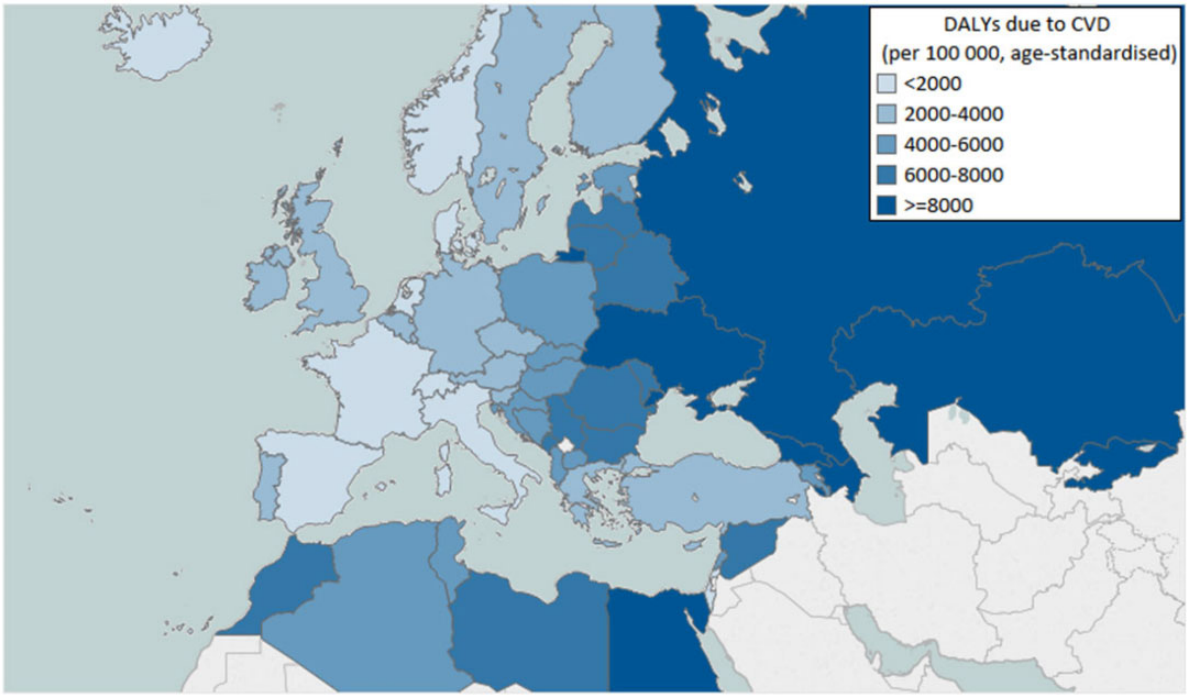

Figure 47 Age-standardized disability-adjusted life years due to cardiovascular diseases in inhabitants of ESC member countries (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

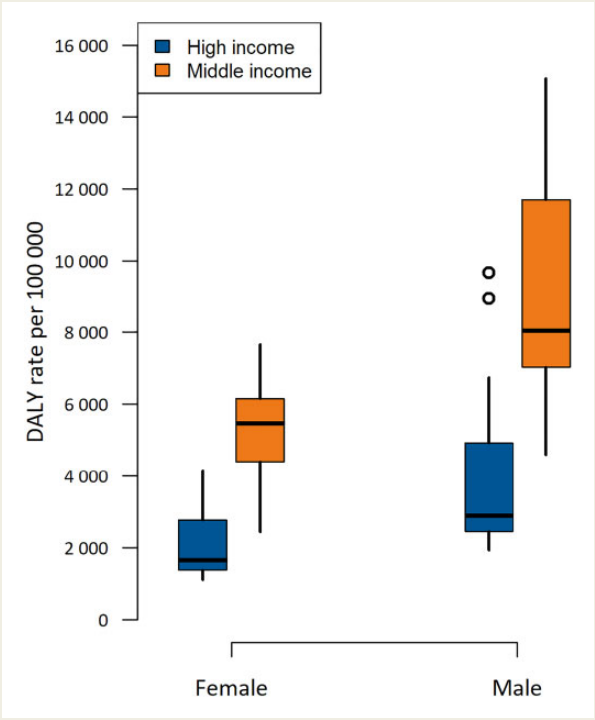

Figure 48 Age-standardized disability-adjusted life years due to cardiovascular disease in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

- The age-standardized incidence and prevalence of IHD and stroke were higher in middle-income compared with high-income ESC member countries.
- Ischaemic heart disease and stroke accounted for 82% of DALYs due to CVD in ESC member countries.
- Age-standardized DALYs due to CVD have been in steep decline the last 27 years, with just two middle-income countries recording an increase.
- Disability-adjusted life years due to CVD were almost twice as high in males compared with females and three times as high in middle-income compared with high-income ESC member countries.
- The age-standardized incidence and prevalence of AF tended to be lower in females compared with males and in middle-income compared with high-income ESC member countries. Data for PVD were mixed with only small differences by gender and national income status.
- Across all ESC member countries, age-standardized incidence and prevalence rates of AF and PVD have remained stable during the last 27 years.

5.5 Comment

In the current 2019 iteration of CVD statistics, granularity of disease burden has been enhanced by inclusion of data on key CVD phenotypes including IHD, stroke, PVD, and AF. The data show small but welcome declines in the age-standardized incidence and prevalence rates of IHD and stroke during the last 27 years although rates for PVD and AF were more stable. Less welcome were the persisting inequalities in disease burden by gender and national income status. These inequalities were vividly reflected in the DALYs due to CVD

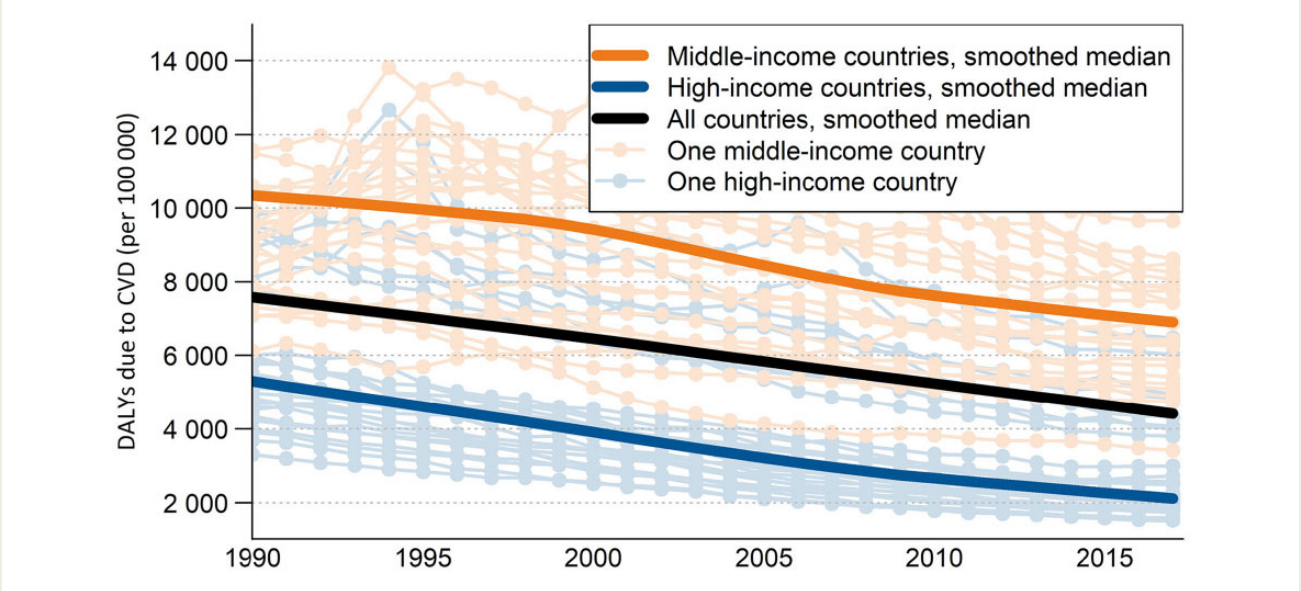

Figure 49 Age-standardized disability-adjusted life years lost to cardiovascular diseases among inhabitants of ESC member countries by national income status (1990–2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available*: Republic of Kosovo and Republic of San Marino (Supplementary file: S5.xlsx).

which in 2017 were almost twice as high in males compared with females and three times as high in middle-income compared with high-income ESC member countries. The negative effects of IHD and stroke on absenteeism, lost productivity, and life expectancy must impact substantially on family welfare and national prosperity. The ESC Atlas shows how impact falls hardest on middle-income countries that can least afford the loss of agricultural and industrial manpower. These same countries are often further disadvantaged in their ability to meet the costs of contemporary cardiovascular care such that healthcare delivery is variably undermined by inadequate staffing levels and limited infrastructure. Prevention of CVD is perhaps less affected by these resource constraints yet plays as important a role as the treatment of established disease in reducing both its prevalence and socioeconomic impact.[77,78] The same primary and secondary prevention strategies that have guideline indications[79] need concerted application across all ESC member countries.

The AF and PVD data included in the current report need cautious interpretation. Under-diagnosis of these disorders is commonplace,[80] particularly when the availability of electrocardiogram monitoring and non-invasive imaging technology is limited. This may account for the prevalence of both disorders being lower in middle-income than high-income countries. Addressing under-diagnosis of AF and PVD in middle-income countries provides a potentially important means of reducing the high stroke rate by targeting individuals for antithrombotic treatment and other strategies that protect against adverse cerebrovascular outcomes.

6 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, particularly for chronic conditions, such as CVD.

In addition, death is one of the most reliably ascertained outcomes. Death reporting is often a mandatory part of a country's vital statistics system. In most countries, health authorities require that each death in the population be reported, including a record of cause of death. These records can then be compiled in order to produce mortality measures for the population, including absolute number of deaths and rates that adjust for population size and distribution.[81]

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 fairly accurate. However, in many less-developed countries, health record systems can be incomplete. Many deaths may go unreported, particularly if they occur outside of the health system.[82,83]

The WHO consider 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.[17] 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 52 contributing ESC member countries, or fewer depending upon how complete are the mortality statistics of interest. There are no data for Algeria, Lebanon, Libya, or Republic of Kosovo.

6.1 Number of deaths

Data: Total numbers of deaths by cause, by gender, latest available year; Data source: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en; **Completeness: High-income countries 31/31 (100%), middle-income countries 21/25 (84%); Year of data: Latest available between 2007 and 2017, median 2015.**

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.[84–86] In some individual countries, however, improvements in CVD prevention and treatment have led to cancer becoming the most common cause of death.[86]

- *National statistics stratified by gender*: Cardiovascular disease remains the most common cause of death within ESC member countries, accounting for 2.2 million deaths in females and 1.9 million deaths in males, in the most recent year of available data (*Figure 50*). These equate to 47% and 39% of all deaths in females and males, respectively. Ischaemic heart disease accounts for 38% of 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.
- *Cardiovascular disease vs. cancer*: Although the total number of CVD deaths across ESC member countries far exceeds the number of cancer deaths for both sexes (females 887 688, males 1.1 million), cancer now causes more deaths than CVD in several individual countries. These countries include Denmark, Israel, Netherlands, Republic of San Marino and the UK for females along with Belgium, Denmark, France, Ireland, Israel, Luxembourg, Netherlands, Norway, Portugal, Republic of San Marino, Slovenia, Spain, Switzerland and the UK for males.
- *National income status*: In both females and males, a greater proportion of deaths are caused by CVD in middle-income countries compared with high-income countries (*Figure 51*). All countries where cancer has become the most common cause of death are high-income, with this reflected in the higher median proportion of all deaths caused by CVD in middle-income countries (males 47%, females 57%) than high-income countries (males 33%, females 35%).

6.2 Premature cardiovascular disease mortality

Data: Number of deaths under 70 years by cause, by gender; Data source: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en; **Completeness: High-income countries 31/31 (100%), middle-income countries 21/25 (84%); Year of data: Latest available between 2005 and 2017, median 2015.**

The risk of CVDs increases with age and as populations live longer, we expect such ageing-associated, or age-related, diseases to increase.[87] Individuals dying prematurely from CVD are of greater concern, as we know that CVD is often preventable at younger ages.

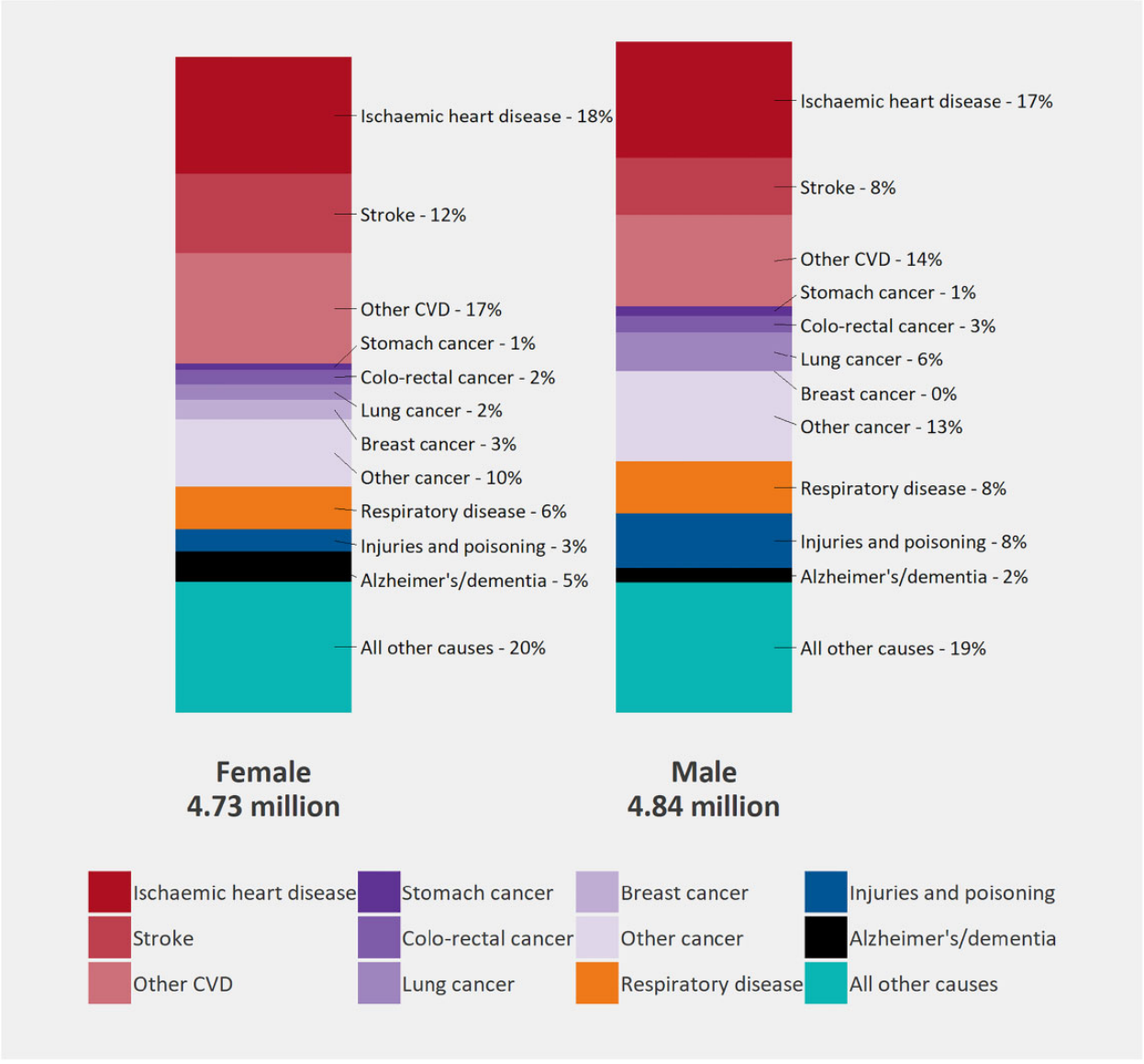

Figure 50 Deaths by cause for all ages in ESC member countries (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Lebanon, Libya, and Republic of Kosovo (Supplementary file: S6.xlsx).

Premature CVD mortality is an important metric of unfulfilled life expectancy and represents an opportunity for increased prevention efforts.[88]

Although there is not a standard definition of premature death, it is usually applied to deaths occurring in people younger than 65 or 75 years.[89] Here, we define it as death occurring before the age of 70 years to align with WHO targets presented later in this section.[90]

- *National statistics stratified by gender*: Compared with deaths for all ages within the ESC region, CVD accounts for a smaller proportion of premature deaths (<70 years) in both females (30%) and males (33%). This equates to about 323 000 deaths among females and 699 000 deaths among males (*Figure 52*).
- *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 = 359 504) than any other disease. However, the number of males dying from cancer before the age of 70 (n = 506 343) is higher than for females reflecting the lower risk of overall and CVD-specific premature mortality among females.
- *National income status*: Disparities between high- and middle-income countries in the proportion of premature deaths caused by CVD are greater for females, with a median of 37% of all premature deaths caused by CVD in middle-income countries, compared with 16% for high-income countries for females; whereas a

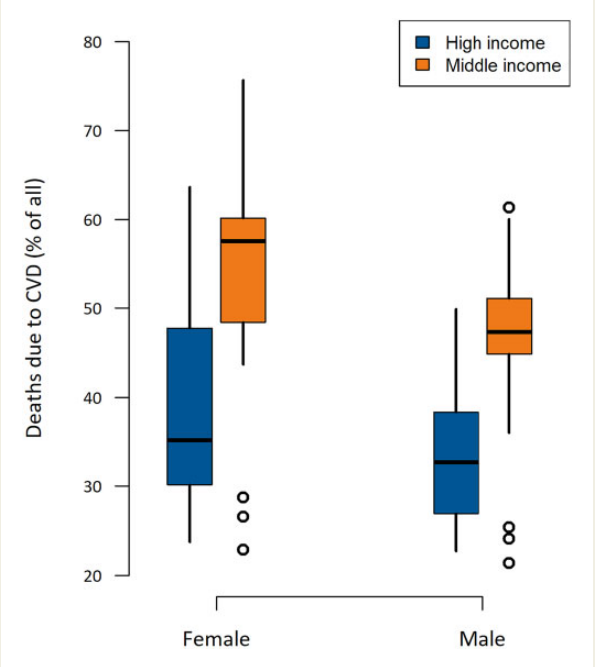

Figure 51 Deaths from cardiovascular disease as a percentage of all deaths in ESC member countries by sex and national income status (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available for the following middle-income countries*: Algeria, Lebanon, Libya, and Republic of Kosovo (Supplementary file: S6.xlsx).

median of 36% of all premature deaths in males are caused by CVD in middle-income countries compared with 24% in high-income countries (*Figure 53*).

6.3 Potential years of life lost due cardiovascular disease

Data: Potential years of life lost (PYLL) due to cardiovascular disease and cancer, by sex; Data source: Global Burden of Disease Study 2017, http://ghdx.healthdata.org/gbd-results-tool; Completeness: High-income countries 30/31 (97%), middle-income countries 24/25 (96%); Year of data: 2017.

Potential years of life lost (PYLL), is a summary measure of premature mortality. PYLL estimates the years of potential life lost due to premature death. Potential years of life lost takes into account the age at which the death occurs, giving greater weight to deaths at a younger age and lower weight to deaths at older age.[91]

Potential years of life losts are calculated by multiplying the number of deaths by the standard life expectancy at the age at which the death occurs. This allows measurement of the proportion of total PYLL in a population caused by a specific disease.[91]

- *National statistics stratified by gender*: Cardiovascular disease accounted for 28 million and 38 million PYLLs within ESC member countries among females and males, respectively, making up 37% of all years lost for females and 34% for males. In comparison, cancer accounted for 25% of PYLLs in females and 22% of PYLLs in males, equivalent to 18.7 million and 25.5 million PYLLs, respectively.
- *Stratification by national income status*: On average, CVD accounted for a greater proportion of PYLLs in middle-income compared with high-income countries in females (43% vs. 28%) and males (39% vs. 28%) (*Figure 54*). The reverse is true for cancer, where the median proportion of PYLLs was lower in middle-income compared with high-income countries in females (19% vs. 34%) and males (18% vs. 35%). Large variations are seen between the different countries, with the lowest proportion of country specific CVD PYLLs similar between high- and middle-income countries. Eight middle-income countries (33%) had more than 40% of total PYLLs caused by CVD in males compared with only one high-income country (Latvia). For females, five middle-income countries (21%) but no high-income countries had more than half of total PYLLs caused by CVD.

6.4 Cardiovascular disease crude mortality rates

Data: Crude mortality rates from cardiovascular disease, by sex, all ages and under 70 years old;
Data source: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en; **Completeness: High-income countries 31/31 (100%), middle-income countries 20/25 (80%); Year of data: 1979–2017.**

Using absolute mortality measures, such as number of deaths or total PYLLs, may be misleading as they do not account for population size. Comparisons between countries and over time should show us the crude rate which considers differences and changes in populations. Crude rates are calculated by dividing the total number of deaths (or PYLLs) by population size, commonly expressed as per 100 000 individuals within the population.[71]

- *National statistics stratified by gender*: Data for 2017 show that median crude mortality rates for CVD per 100 000 people were higher for females than males in both high-income (332 vs. 303) and middle-income countries (531 vs. 488). Premature CVD mortality decreases from east to west across Europe for females and males (*Figure 55*). 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 (Supplementary material online, *Figures S6.1* and *S6.2*).
- *Stratification by national income status*: Crude CVD mortality tended to be higher in middle-income compared with high-income countries, but there was considerable heterogeneity.
  - *Mortality in males*: Of the 19 middle-income countries with data available, Kazakhstan, Kyrgyzstan, Syrian Arab Republic, Tunisia and Turkey had crude CVD mortality rates for males below 303 deaths per 100 000 individuals equivalent to the median crude death rate for high-income countries. Conversely, of 30 high-income countries with data available, Croatia, Estonia, Hungary, Latvia and Lithuania reported crude CVD deaths rates for males

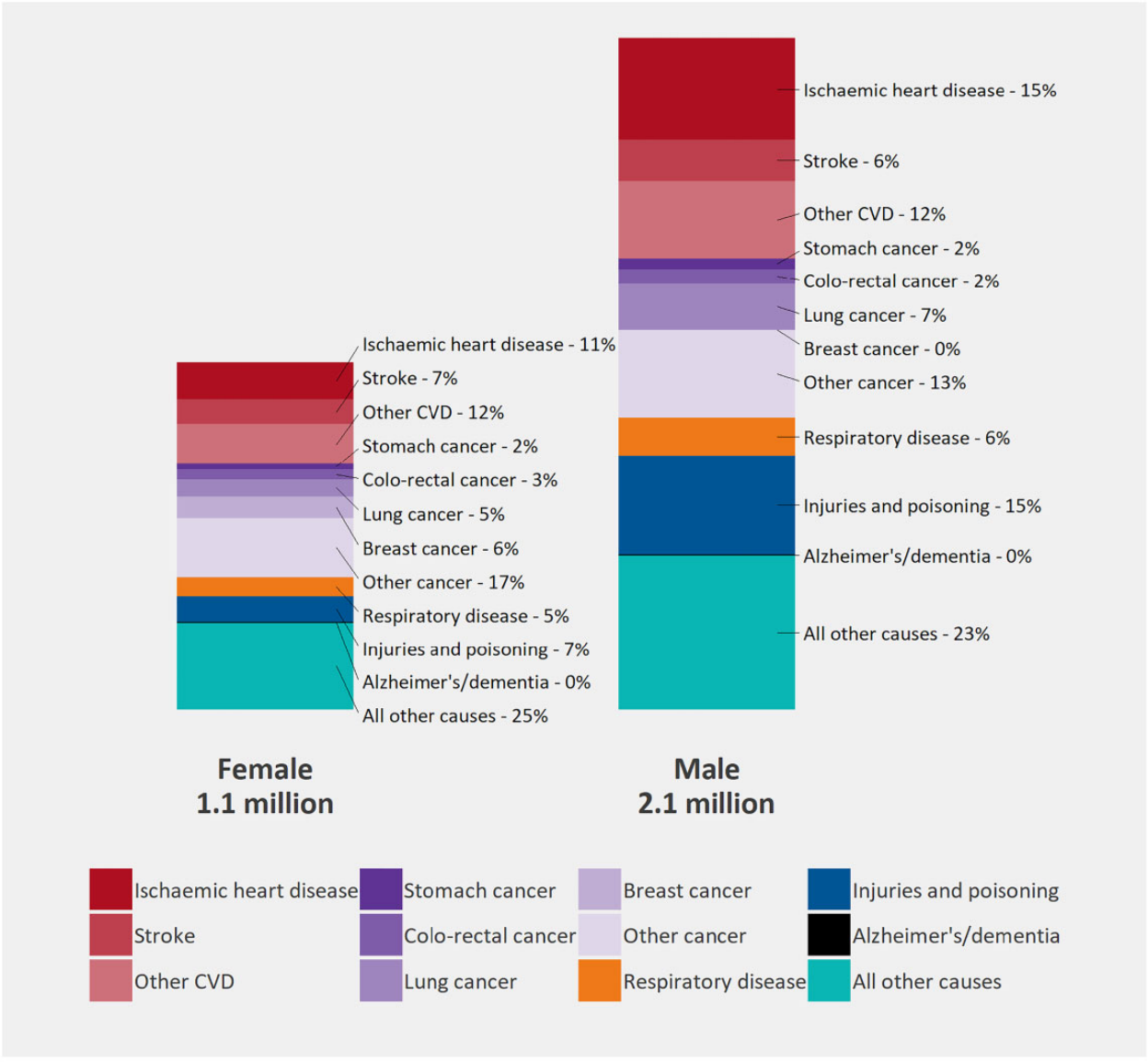

Figure 52 Premature deaths by cause for all ages in ESC member countries (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Lebanon, Libya, Republic of Kosovo, and Republic of San Marino (Supplementary file: S6.xlsx).

above the middle-income median of 488/100 000 (Supplementary material online, *Figure S6.3*). These differences were more apparent when crude rates for premature mortality were considered. Among males in middle-income countries, only Tunisia reported a crude rate below the high-income median of 70/100 000 and in high-income countries only Hungary, Latvia, and Lithuania reported a crude rate greater than the middle-income country median of 193/100 000 (*Figure 56*).

- *Mortality in females*: Disparities among females showed a similar pattern, with crude mortality rates in five high-income countries (Croatia, Estonia, Hungary, Latvia and Lithuania) above the middle-income median of 531/100 000, while seven middle-income countries (Azerbaijan, Egypt, Kazakhstan, Kyrgyzstan, Syrian Arab Republic, Tunisia and Turkey) had crude mortality rates below the high-income median (332/100 000). For premature mortality (<70 years), differences by national income status were more apparent with Latvia the only high-income country demonstrating crude CVD mortality rates for females <70 years, higher than the middle-income median of 102/100 000 and Tunisia the only middle-income country reporting a crude CVD mortality rate lower than the high-income median of 27/100 000.
- *Mortality in both sexes*: Among both sexes, associations were found between premature CVD crude mortality rates (≤70 years) and

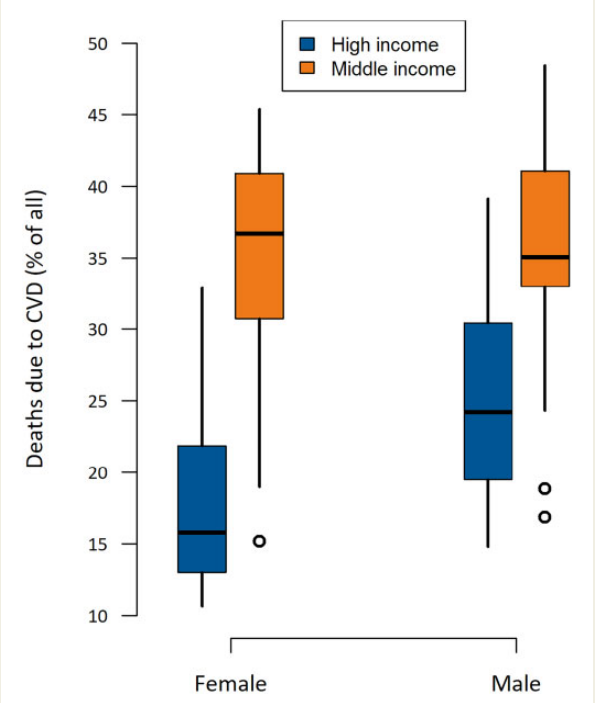

Figure 53 Proportion of all premature deaths (<70 years old) caused by cardiovascular diseases in ESC member countries by sex and national income status (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Algeria, Lebanon, Libya, and Republic of Kosovo (Supplementary file: S6.xlsx).

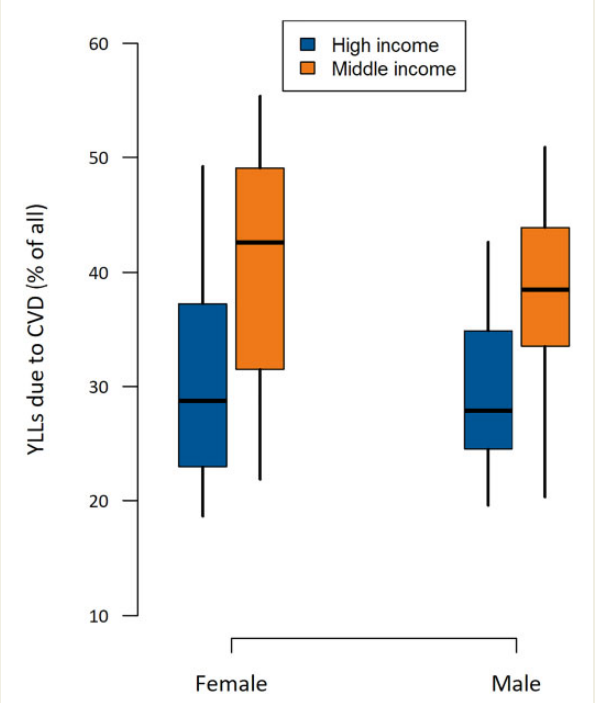

Figure 54 Potential years of life lost to cardiovascular disease in ESC member countries by sex and national income status (2017). *Data source*: Global Burden of Disease Study 2017, Institute for Health Metrics and Evaluation, http://ghdx.healthdata.org/gbd-results-tool. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Republic of Kosovo (Supplementary file: S6.xlsx).

both GDP and CHE (Supplementary material online, *Figures S6.4 and S6.5*).

- *Time series data—crude mortality (all ages)*: Although median crude mortality rates in ESC member countries declined in both males (absolute decrease of -72/100 000; relative decrease of -18%) and females (absolute decrease of -59/100 000; relative decrease of -12%) between 1990 (or closest year of data) and 2017 (or the most recent year of data) differences by national income status were more apparent. During this period, increases in crude CVD mortality rates among females and males were recorded in 15 and 16 of the 18 middle-income countries with data available, respectively. Kazakhstan and Serbia were the only middle-income countries showing a decrease in crude rates for males and Egypt, Kazakhstan and Kyrgyzstan were the only middle-income countries showing decreases for females. Of the 30 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 with Italy. In those countries with a net increase in crude CVD mortality between 1990 and 2017, fluctuating values were often observed with no consistent trend over time (*Figure 57*).
- *Time series data—premature mortality (<70 years)*: Long-term trends in crude premature mortality were more reassuring than the trends for all ages and in females none of the ESC member countries recorded an increase in mortality between 1990 and 2017 (or closest years available). In males too none of the high-income ESC member countries recorded an increase in crude premature mortality between 1990 and 2017 (or closest years available) but in 8 of 16 middle-income countries an increase occurred. Absolute and relative median decreases in premature mortality were greater in high-income countries for both sexes (females: absolute decrease of -42/100 000, relative decrease of -56%; males: absolute decrease of -71/100 000, relative decrease of -46%) than in middle-income countries (females: absolute decrease of -24/100 000, relative decrease of -17%; males: absolute decrease of -0.4/100 000, relative decrease of -0.2%) (*Figure 58*).

6.5 Cardiovascular disease age-standardized mortality rates

Data: Age-standardized mortality rates from cardiovascular disease, by sex; Data source: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en; **Completeness: High-income countries 31/31 (100%), middle-income countries 20/25 (80%); Year of data: 1979–2017.**

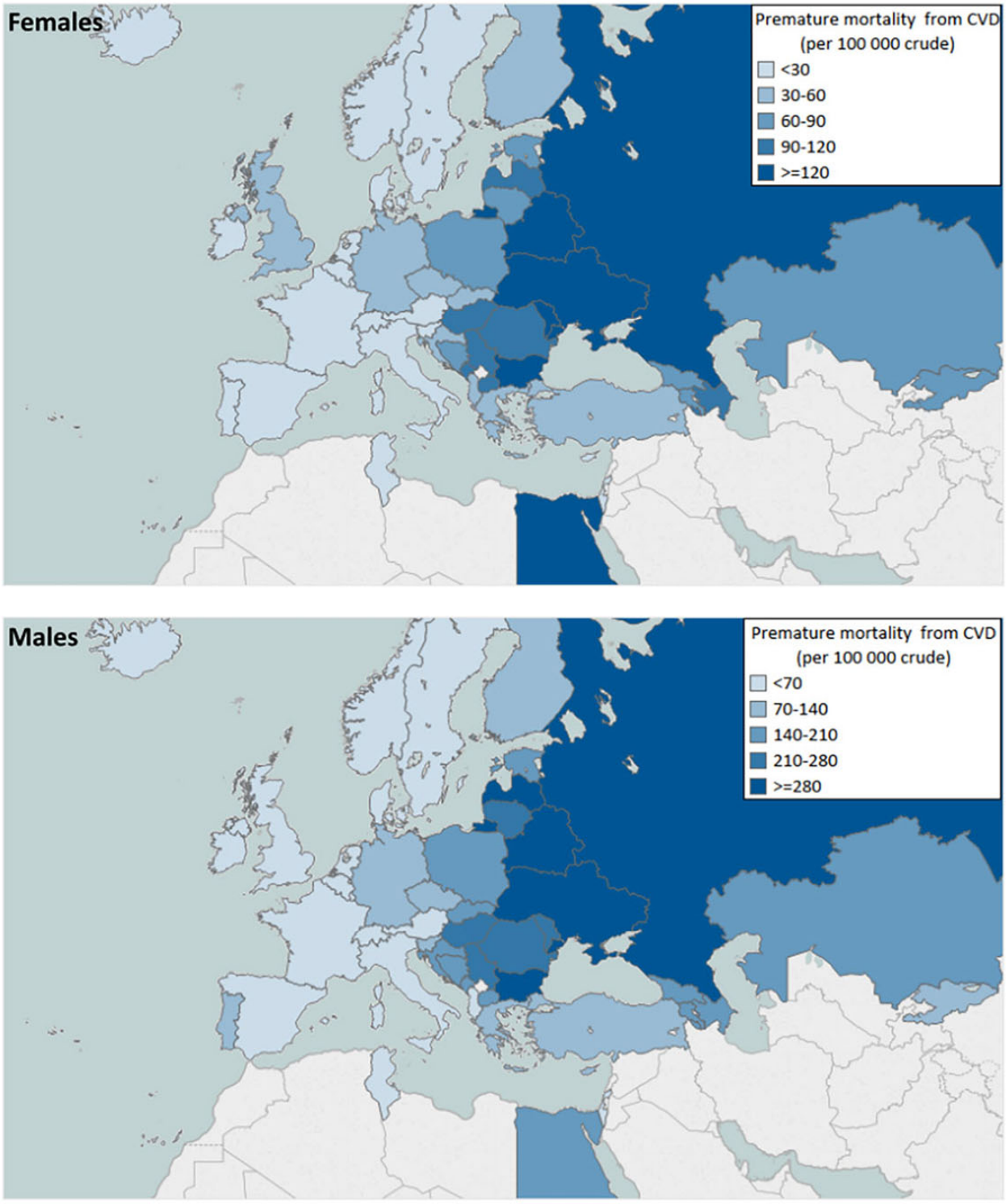

Figure 55 Cardiovascular disease crude premature mortality rate among females and males aged <70 years in ESC member countries (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Lebanon, Libya, Morocco, Republic of Kosovo, and Syrian Arab Republic (Supplementary file: S6.xlsx).

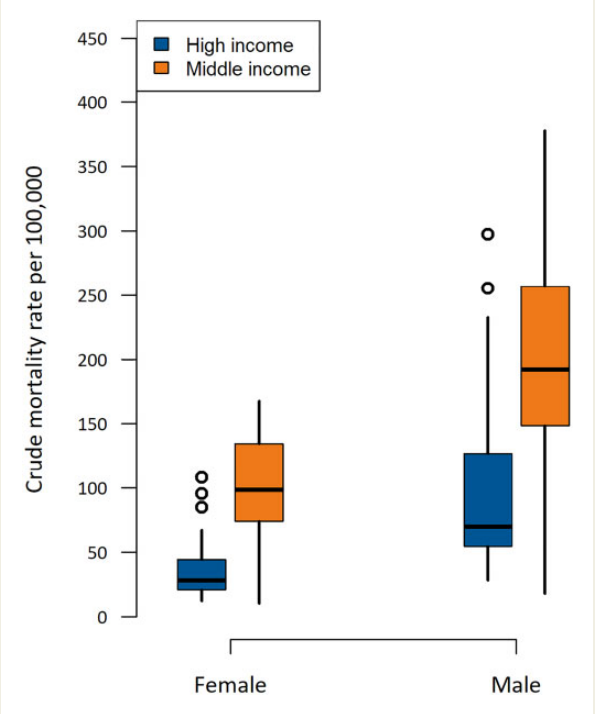

Figure 56 Cardiovascular disease crude premature (age <70 years) mortality rate by sex and national income status in ESC member countries (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available for the following middle-income countries*: Algeria, Lebanon, Libya, Morocco, Republic of Kosovo, and Syrian Arab Republic (Supplementary file: S6.xlsx).

For ageing-associated diseases such as CVD, the number of deaths per 100 000 population is influenced by the age distribution of the population. A population with a greater distribution of older individuals would be expected to experience a greater number of CVD deaths. In order to make comparisons between populations by calculating crude rates to adjust for population size, it is often necessary to calculate age-standardized rates which adjust for population distribution as well.[71]

Age-standardized mortality rates (ASMRs) adjust for differences in the age distribution of populations by applying the observed age-specific mortality rates for each population to a standard population.[71] 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 by large amounts.[92]

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 ESP.[92,93]

- 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 (283 vs. 410) and middle-income countries (790 vs. 1019) (*Figure 59*).
- In both females and males, ASMRs for CVD are higher in middle-income countries compared with high-income countries (*Figure 59*). Age-standardized mortality rates are closely correlated with GDP and CHE, with those countries with low GBD or low CHE demonstrating higher ASMRs (*Figures 60 and 61*). There is some suggestion of plateauing of ASMRs with increasing GDP and CHE, with those countries above median values of both measures demonstrating much less variation in ASMRs than those countries below the median.
- Decreases in ASMRs were seen between 1990 (or the closet year of data) and 2017 (or the most recent year of data) in both females and males for countries with suitable data available (*Figure 62*). Although median absolute rate decreases were lower in females (decrease of 297/100 000) than males (decrease of 400/100 000) over this period, relative decreases were similar at around 47%. However, differences were apparent by national income status with a median relative decrease of more than 50% in females and males in high-income countries compared to a 19% decrease in ASMRs in females and a 14% decrease in males in middle-income countries. Although a number of middle-income countries showed increases in ASMRs over this time (Azerbaijan, Egypt and Syrian Arab Republic in females only; Belarus, in males only; Kyrgyzstan, North Macedonia, Moldova, and Ukraine in both sexes) fluctuating trends and increases in ASMRs after 1990 meant that most experienced decreases in later decades.

6.6 Achieving global mortality targets

Target 1 of the NCD's global action plan relates to mortality and requires countries to achieve a 25% relative reduction in the overall mortality from CVD, cancer, diabetes, and chronic respiratory disease.[90] The emphasis is on premature mortality with a focus on deaths under the age of 70 years.

- High-income countries have demonstrated relative reductions in median crude mortality rates for those aged under 70 years, of 9% for females and 11% for males since 2010, or the nearest available year of data. Declines among females in middle-income countries (8%) are similar but a much lower median decline is found in middle-income countries for males (2%) making it unlikely that the 25% WHO target will be attained (Supplementary material online, *Figure S6.6*).
- It is alarming to note, however, that crude premature CVD mortality rates have increased in a number of high-income countries since 2010, both for females (Israel, Italy, Malta, Poland, Portugal and Spain) and for males (Greece, Italy, Malta, Poland, Portugal and Spain) (*Figure 63*).
- Four of the 13 middle-income countries demonstrated an increase in crude premature mortality rates from 2010 to the most recent year of data in females (Bulgaria, Egypt, Republic of Georgia and Turkey) and six did so in males (Bulgaria, Egypt, Republic of Georgia, Romania, Serbia and Turkey) (*Figure 64*).
- Although a relationship can be seen between decreasing relative reductions in crude mortality rates for those under 70 years and both increasing GDP and increasing CHE, there is wide variation in mortality outcomes amongst those countries with lower GDP and CHE (*Figures 63* and *64*). For example,

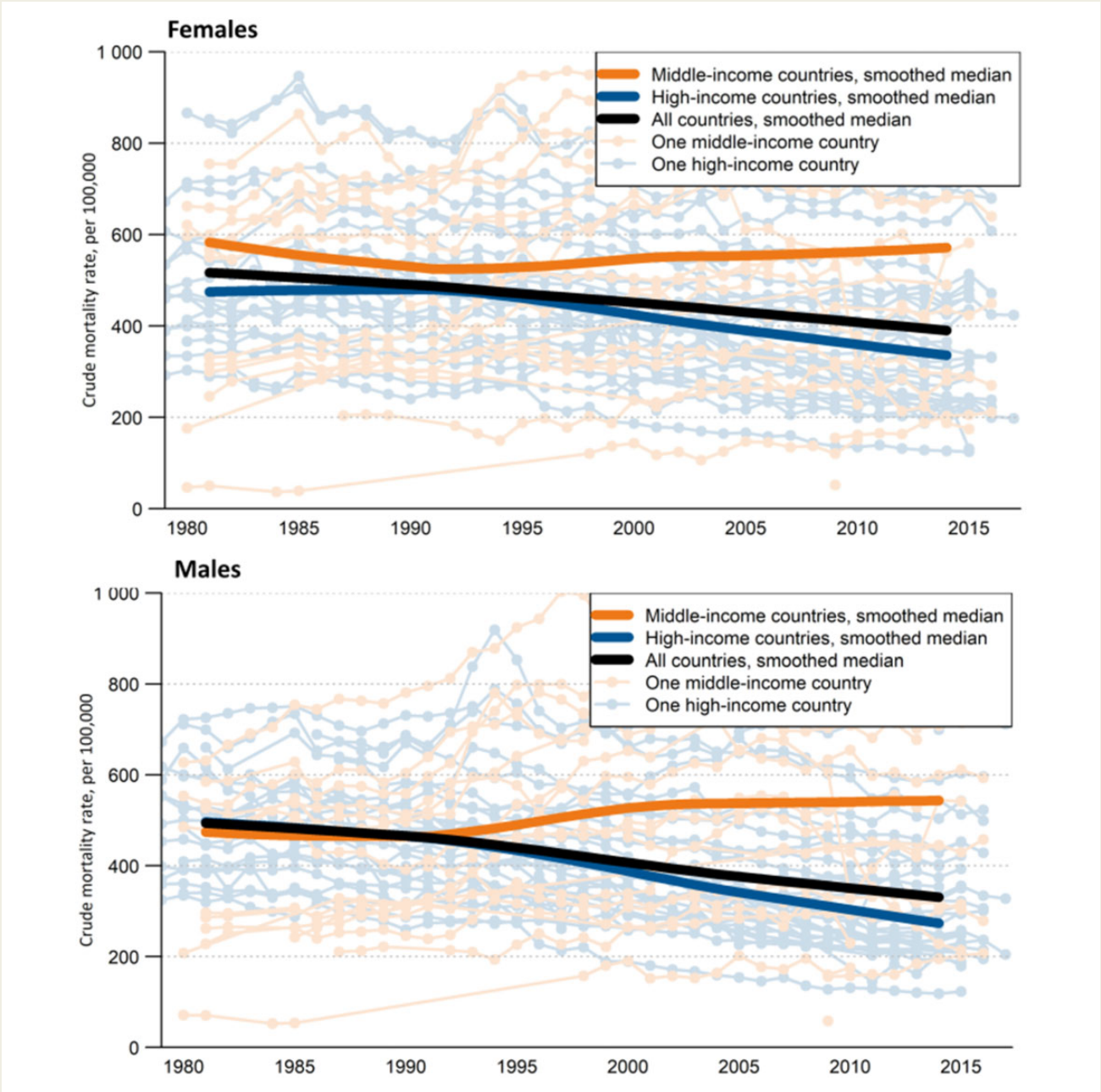

Figure 57 Crude cardiovascular disease mortality in females and males living in ESC member countries (1990–2017). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Kosovo, Lebanon, Libya, and Morocco (Supplementary file: S6.xlsx).

the country with the greatest relative decrease in crude mortality rates since 2010 (Kazakhstan: females -50%, males -45%,) and the country with the greatest increase (Republic of Georgia: females 40%, males 43%) are both middle-income countries with similar GDPs and CHEs.

- Using PYLLs, adjusted for population size, we find a median decrease in high-income countries of just over 6% for both females and males, whereas middle-income countries demonstrate a median decrease of 2.4% for females and a 2.2% increase for males (Supplementary material online, *Figure S6.7*).
- Five high-income countries (17%) demonstrated an increase of PYLLs in males (Germany, Greece, Iceland, Lithuania, and Malta) with Greece, Lithuania, and Malta also doing so for females. This compared with 14 out of 24 middle-income countries that demonstrated an increase in PYLLs in males and eight for females.
- As with crude premature mortality rates, greater variation in change in PYLL is found at the lower levels of both GDP and CHE, with countries with the highest and lowest percentage changes in PYLL found for those in the lower half of both measures.

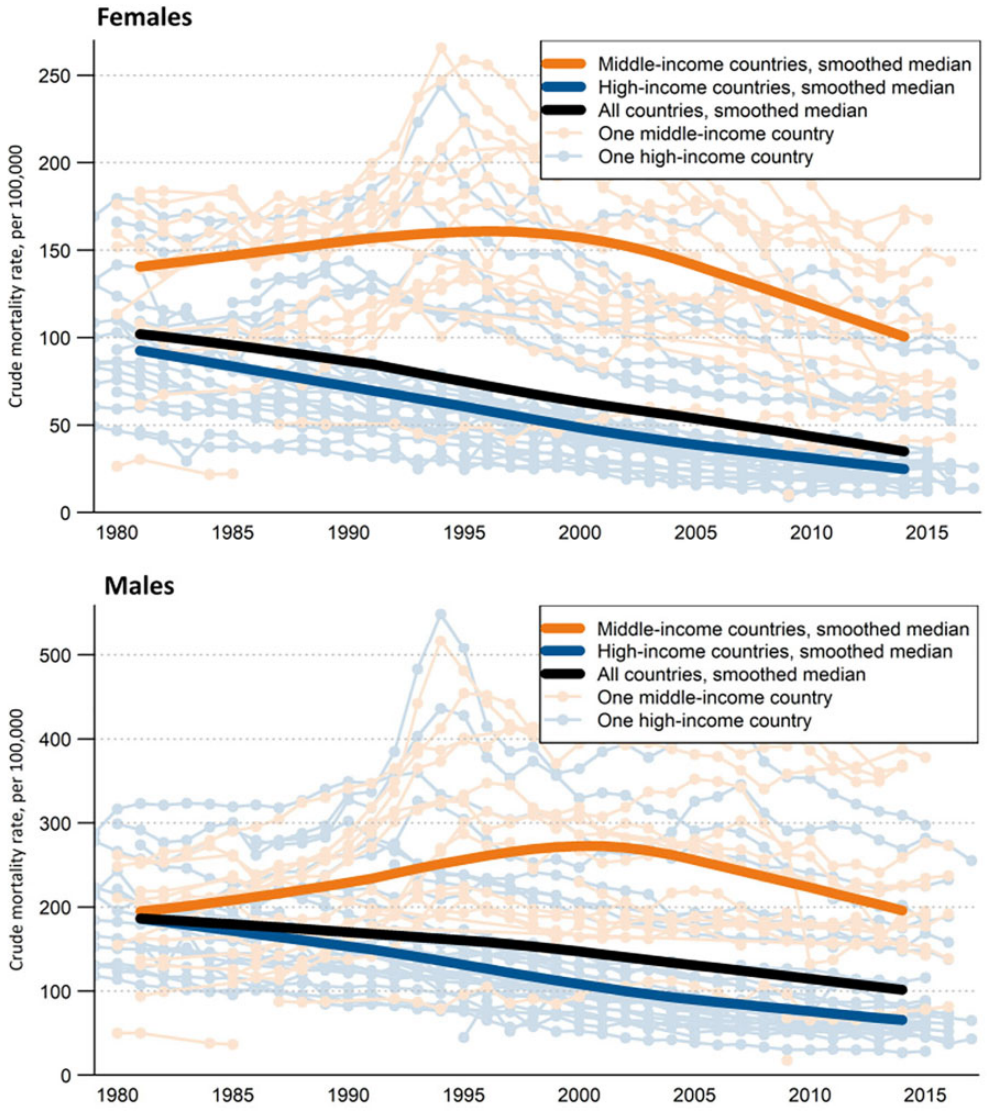

Figure 58 Premature cardiovascular disease mortality (age <70 years) in females and males living in ESC member countries (1990–2017). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Kosovo, Lebanon, Libya, and Morocco (Supplementary file: S6.xlsx).

6.7 Summary

- Despite sustained declines in CVD mortality in many countries across Europe, it remains the most common cause of death within the region.
- Ischaemic heart disease accounts for 38% of CVD deaths in females and 44% in males.
- Cardiovascular disease is also the most common cause of premature (age <70 years) death in the region amongst males, but this is not the case for females among whom cancer kills more individuals than any other disease.
- There are large disparities between high- and middle-income countries in the proportion of premature deaths caused by CVD. For females, in middle-income countries, a median of 35% of all premature deaths are caused by CVD compared with 16% in high-income countries. For males, the respective rates are 36% in middle-income countries compared with 24% in high-income countries.
- Cardiovascular disease accounts for 37% of PYLLs for females and 34% of PYLLs for males. In comparison, cancer accounts for 25% of PYLLs in females and 22% in males.
- Cardiovascular disease accounts for a greater proportion of PYLLs in middle-income than high-income countries for both males and females, but the opposite is true for cancer for which the proportion of PYLLs from cancer was higher than from CVD in high-income compared with middle-income countries.
- In contrast to crude rates per million people, ASMRs, that adjust for both population size and distribution, are lower for females than males in both high-income and middle-income countries.

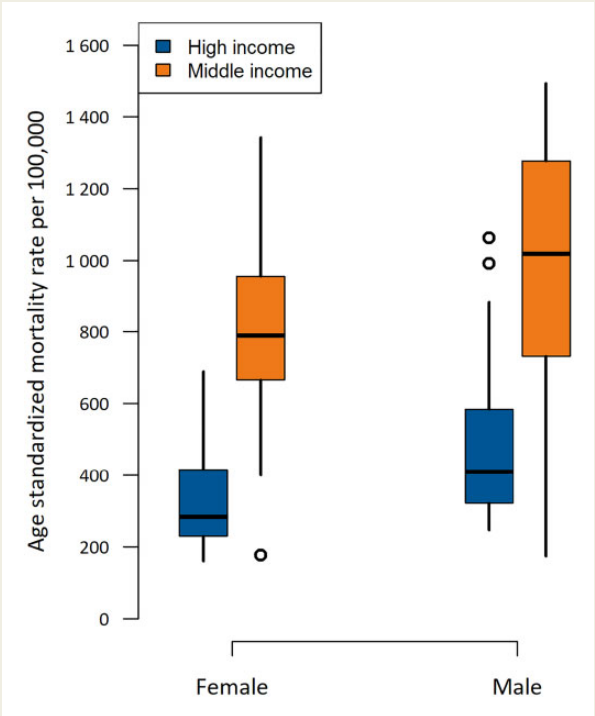

Figure 59 Cardiovascular disease age-standardized mortality rate by sex and national income status in ESC member countries (latest year available). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available for the following middle-income countries*: Algeria, Lebanon, Libya, Morocco, and Republic of Kosovo (Supplementary file: S6.xlsx).

- The WHO Target 1 is for a 25% reduction in CVD mortality by 2025 with reference to 2010. During this period, crude mortality per million people in high-income countries has fallen by 9% in females and 11% in males. Reassuring as this is, an alarming increase in crude CVD mortality has been recorded in a number of countries in both females (Israel, Italy, Malta, Poland, Portugal and Spain) and males (Greece, Italy, Malta, Poland, Portugal and Spain). In middle-income countries, females have shown an 8% reduction in mortality during the same period, but in males, the reduction has been only 2%, making unlikely the 25% WHO target will be attained.

6.8 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 amongst males suggest that females are dying at older ages from CVD. Although females may experience some physiological protection from CVD, particularly up until menopause,[94] 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[84,85] most likely due to both improved prevention and treatment.[95] However, large inequalities in mortality across the ESC members and recent worrying trends in both high- and middle-income countries give cause for concern.

Not only do we find large variation in current measures for mortality, but recent trends in premature mortality differ between the ESC member countries. In large parts of the world mortality from CVD is on the increase[96] and worryingly crude premature mortality rates and population adjusted PYLLs are once again on the increase in a number of high- and middle-income ESC member countries, suggesting that they may struggle to obtain WHO targets of 25% reductions in premature mortality between 2010 and 2025.

Further work should be undertaken to understand why these inequalities exist. This should include improved and standardized surveillance on mortality and other epidemiological measures related to CVD within countries, as well investigation into the challenges countries face in implementing recommended preventive and treatment approaches.

7 Cardiovascular healthcare delivery

Strategies for treatment of CVD have complemented disease prevention strategies and lifestyle changes in delivering the declines in cardiovascular mortality that have been recorded in Western societies during the last 50 years.[77,78] Increasingly, it has been technological interventions that have come to dominate contemporary treatment strategies and this trend is on a steep upward trajectory, bringing with it a financial burden that many countries can ill afford. Already the healthcare budget exceeds 10% of GDP in many Western countries[97] and recent predictions are that novel medical technologies will be a more significant factor than population ageing in driving up healthcare costs during the next 50 years.[98] Documenting human and capital resource statistics as they affect cardiovascular healthcare delivery in ESC member countries is, therefore, an important exercise for identifying where the shortfalls lie and determining what corrective action might be needed.

In this section, CVD healthcare delivery data are presented for a maximum of 47 contributing ESC member countries, or fewer depending upon how complete are the statistics of interest. There are no data for Algeria, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Republic of San Marino, Syrian Arab Republic, or Tunisia.

7.1 Cardiological specialists

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Total number of cardiologists; Completeness: High-income countries 28/31 (90%), middle-income countries 16/25 (64%); Year of data: Latest available between 2011 and 2017, median 2016.

Data: Percentage of female cardiologists; Completeness: High-income countries 26/31 (84%), middle-income countries 9/25 (36%); Year of data: Latest available between 2014 and 2017, median 2016.

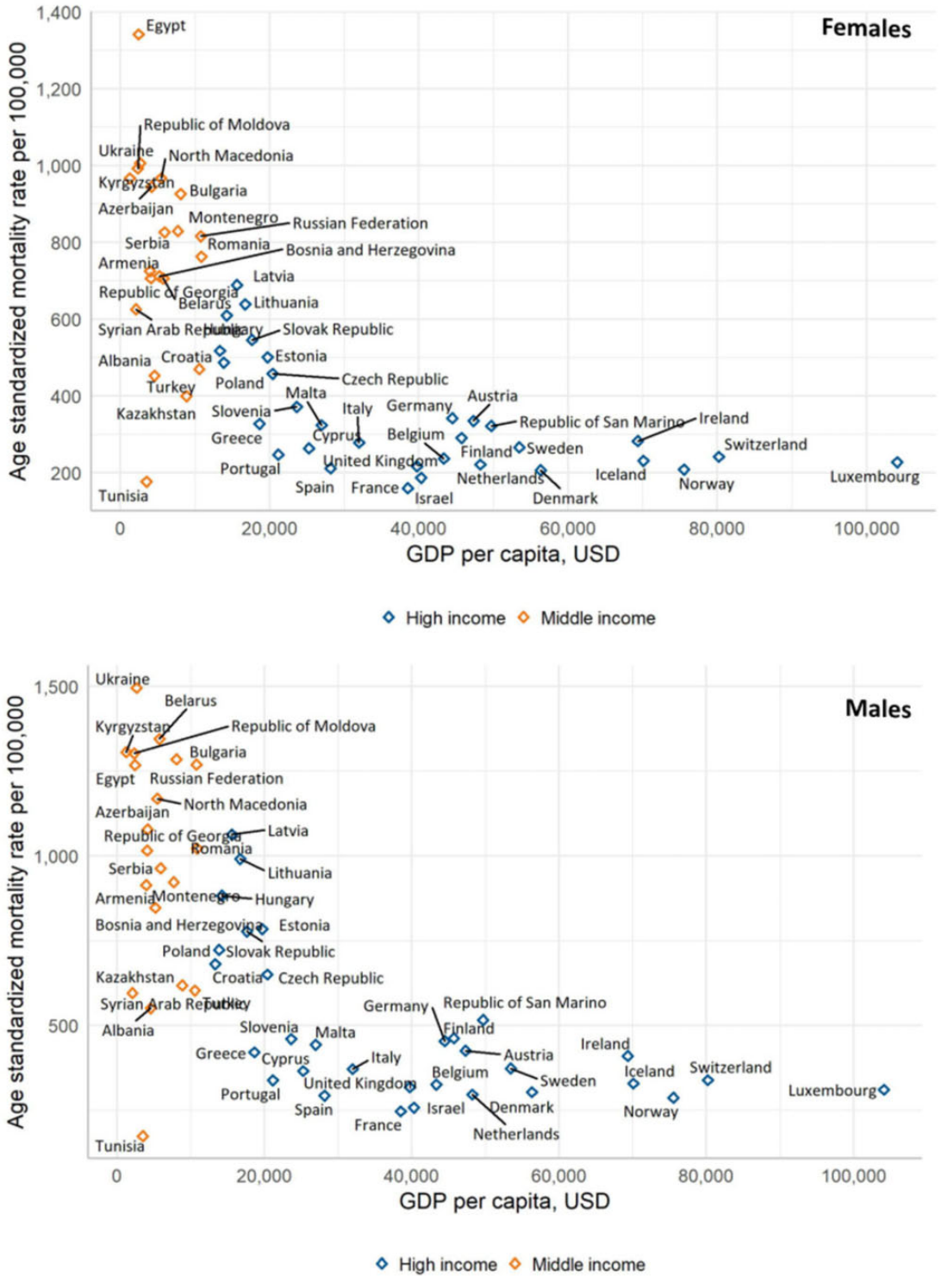

Figure 60 Cardiovascular disease age-standardized mortality rate among females and males vs. gross domestic product per capita in US$ (2017). *Data not available*: Algeria, Lebanon, Libya, Morocco, and Republic of Kosovo.

- *Human resource*: Across all ESC member countries in the 2018/19 survey, there was a median of 80.9 (IQR 59.7–108.9) cardiologists per million people, with numbers ranging from <30 per million in UK, Ireland and Turkey to >250 per million in Italy, Greece and Republic of Georgia (*Figure 65*, Supplementary material online, *Figure S7.1*).
- *Females in cardiology*: Females comprised 28% of all cardiologists working in ESC member countries. Under-representation of

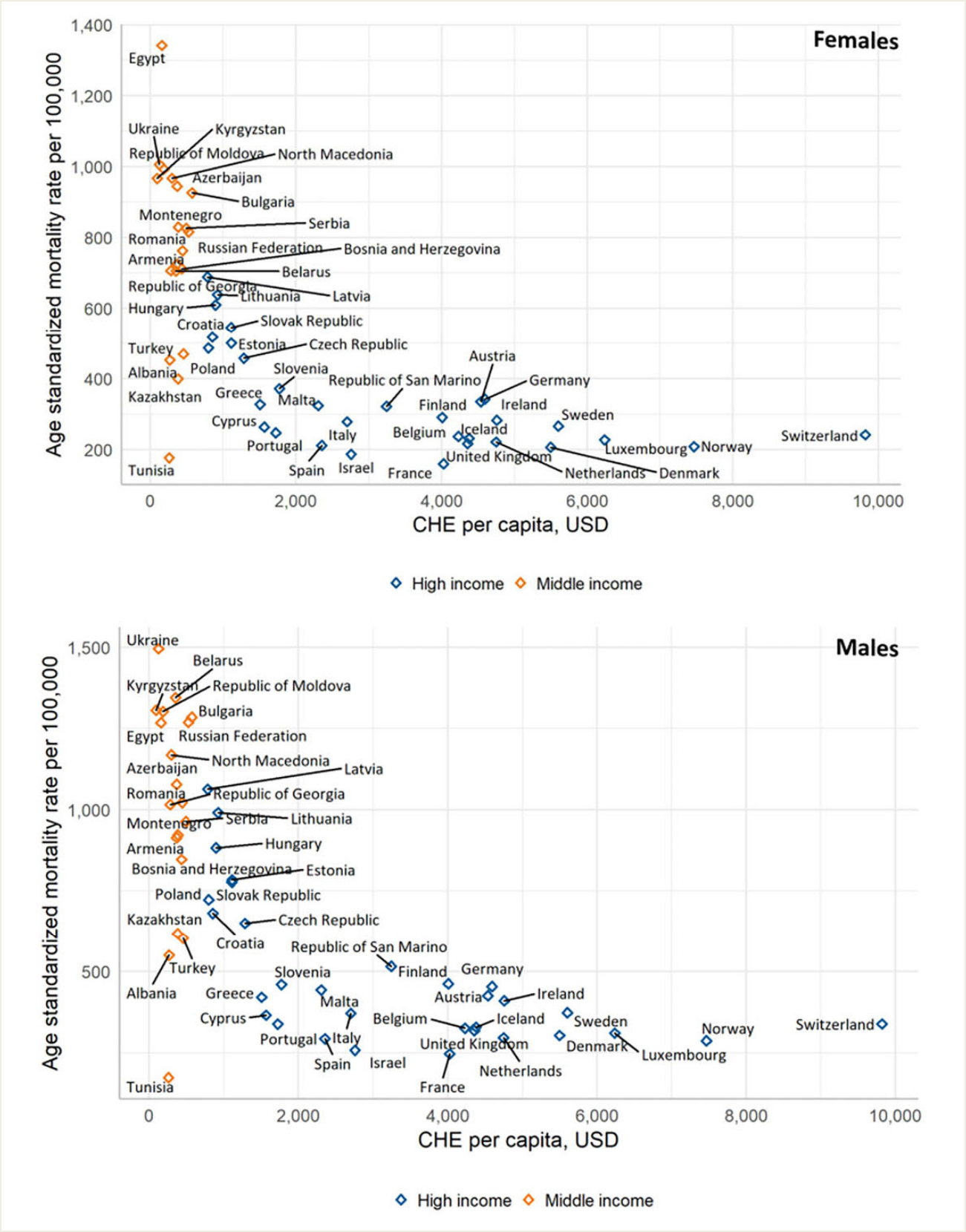

Figure 61 Cardiovascular disease age-standardized mortality rate among females and males vs. current health expenditure per capita in ESC member countries (2015). *Data not available*: Algeria, Lebanon, Libya, Morocco, Republic of Kosovo, and Syrian Arab Republic.

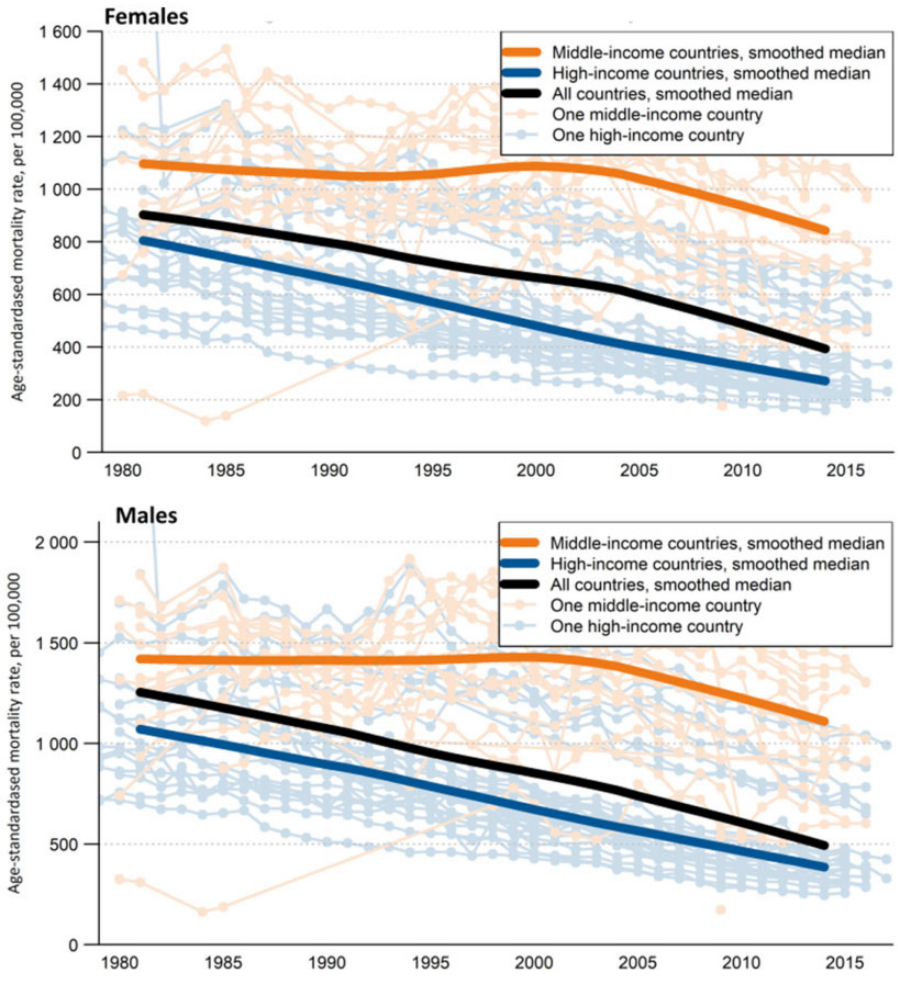

Figure 62 Cardiovascular disease age-standardized mortality in females and males living in ESC member countries (1990–2017). *Data source*: WHO Mortality Database, https://www.who.int/healthinfo/statistics/mortality_rawdata/en. *Data not available*: Algeria, Kosovo, Lebanon, Libya, and Morocco (Supplementary file: S6.xlsx).

females was greatest in Republic of Kosovo, UK and Ireland where females comprised <15% of cardiologists compared with >70% in Latvia, Lithuania, Republic of Moldova and Armenia.

- *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 [61.8 (IQR 54.3–85.4) vs. 90.8 (IQR 70.9–110.9)] (Supplementary material online, *Figure S7.2*). Female cardiologists comprised 32% of the cardiological workforce in middle-income countries, compared with 27% in high-income countries. These averaged data, however, conceal considerable variation and the four ESC member countries in which >70% of cardiologists were females were evenly distributed between middle-income (Armenia, Republic of Moldova) and high-income (Lithuania, Latvia) countries.

7.2 Diagnostic coronary angiography

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Hospitals with cath labs; Completeness: High-income countries 28/31 (90%), middle-income countries 15/25 (60%); Year of data: Latest available between 2013 and 2017, median 2016.

Data: Coronary angiographies and diagnostic heart catheterizations; Completeness: High-income countries 27/31 (87%), middle-income countries 15/25 (60%); Year of data: Latest available between 2010 and 2017, median 2016.

- *Infrastructure*: A median of 2.8 (IQR 1.9–4.2) hospitals per million inhabitants of ESC member countries reported having facilities for cardiac catheterization in the 2018/19 survey (Supplementary material online, *Figure S7.3*). Provision ranged from <1 hospital per million in Ukraine, Republic of Moldova, Kyrgyzstan and Egypt to >4.5 in Switzerland, Austria, Greece, Cyprus and Bulgaria.
- *Service delivery*: A median of 4601 (IQR 3146–5516) diagnostic coronary angiograms per million people were performed across ESC member countries in 2017, or the most recent year that data were available, ranging from <1000 in Kyrgyzstan, Ukraine

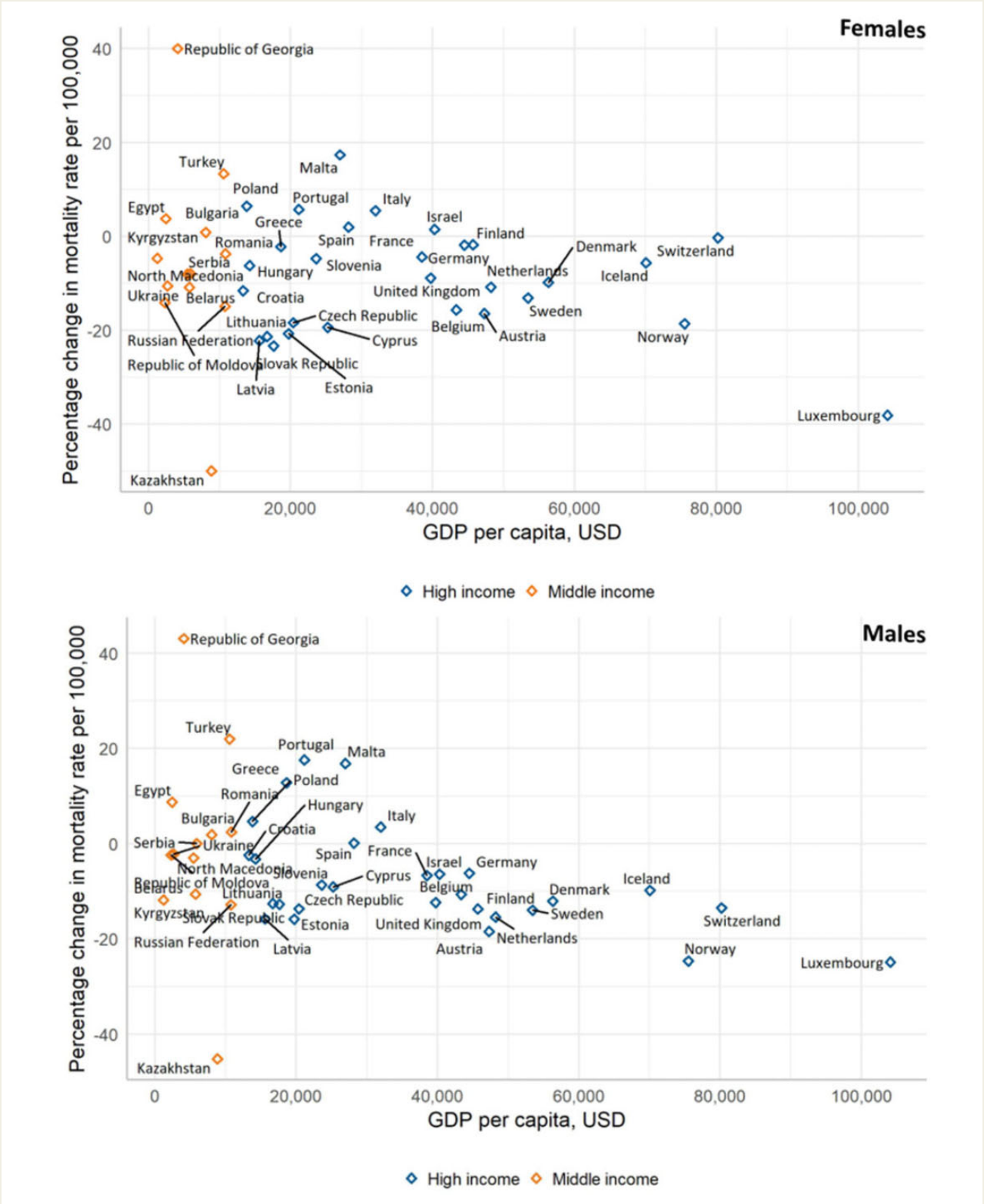

Figure 63 Change in cardiovascular disease crude mortality rates between 2010 and latest year available among females and males aged <70 years in ESC member countries vs. GDP per capita (US$, 2017). *Data not available*: Albania, Algeria, Armenia, Azerbaijan, Bosnia and Herzegovina, Ireland, Lebanon, Libya, Montenegro, Morocco, Republic of Kosovo, Republic of San Marino, Syrian Arab Republic, and Tunisia.

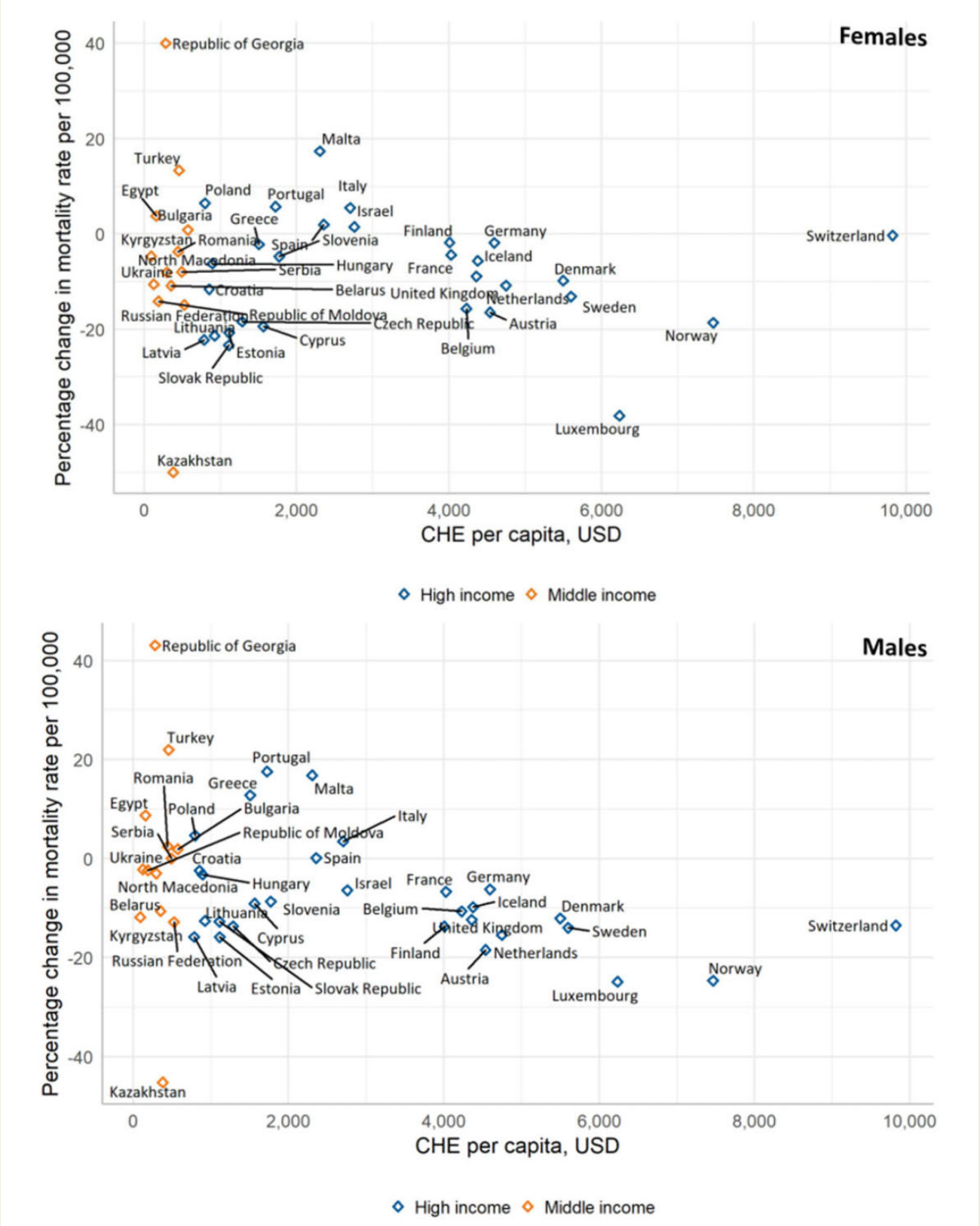

Figure 64 Change in cardiovascular disease crude mortality rates between 2010 and latest year available among females and males aged <70 years in ESC member countries vs. current health expenditure per capita (US$, 2015). *Data not available*: Albania, Algeria, Armenia, Azerbaijan, Bosnia and Herzegovina, Ireland, Lebanon, Libya, Montenegro, Morocco, Republic of Kosovo, Republic of San Marino, Syrian Arab Republic, and Tunisia.

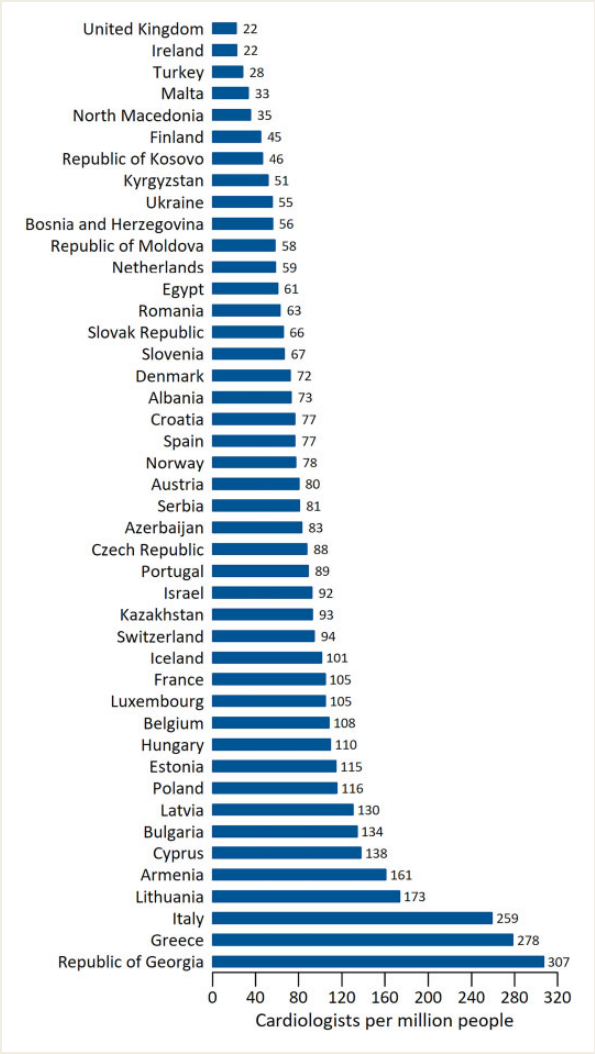

Figure 65 Cardiologists per million people in ESC member countries (2016 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Germany, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Sweden, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

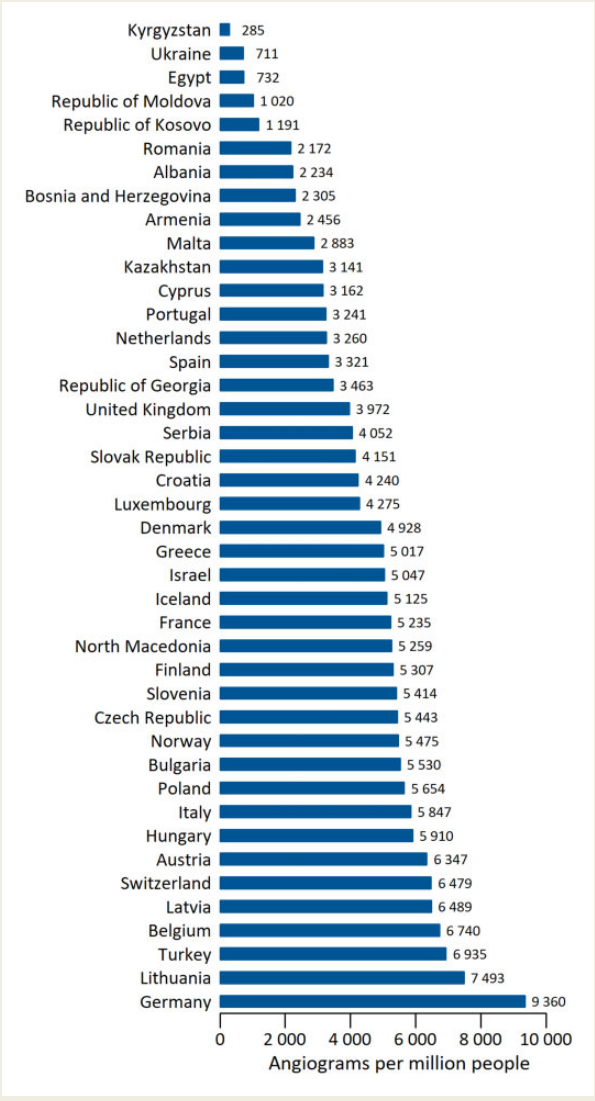

Figure 66 Invasive coronary angiograms per million people in ESC member countries (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Azerbaijan, Belarus, Estonia, Ireland, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Sweden, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

and Egypt to >7000 in Lithuania and Germany (*Figure 66*, Supplementary material online, *Figure S7.4*).

- *Stratification by national income status*: The median number of hospitals per million inhabitants of ESC member countries that provided catheter laboratory facilities for diagnostic cardiac catheterization was lower in middle-income compared with high-income countries [1.8 (IQR 1.3–3.2) vs. 3.1 (IQR 2.2–4.3)] (Supplementary material online, *Figure S7.5*), although Bulgaria and Republic of Georgia were outliers among middle-income countries in providing more than seven hospitals per million people, more than any of the high-income ESC member countries. With fewer facilities for cardiac catheterization, median numbers of diagnostic catheter procedures per million people were also lower in middle-income compared with high-income countries [2306 (IQR 1106–3758) vs. 5235 (IQR 4196–5878)] although these averaged data concealed important differences with North Macedonia, Bulgaria and Turkey among middle-income countries performing more procedures than many high-income countries (*Figure 67*).

7.3 Interventional cardiology

7.3.1 Percutaneous coronary intervention

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Interventional cardiologists; Completeness: High-income countries 28/31 (90%), middle-income countries

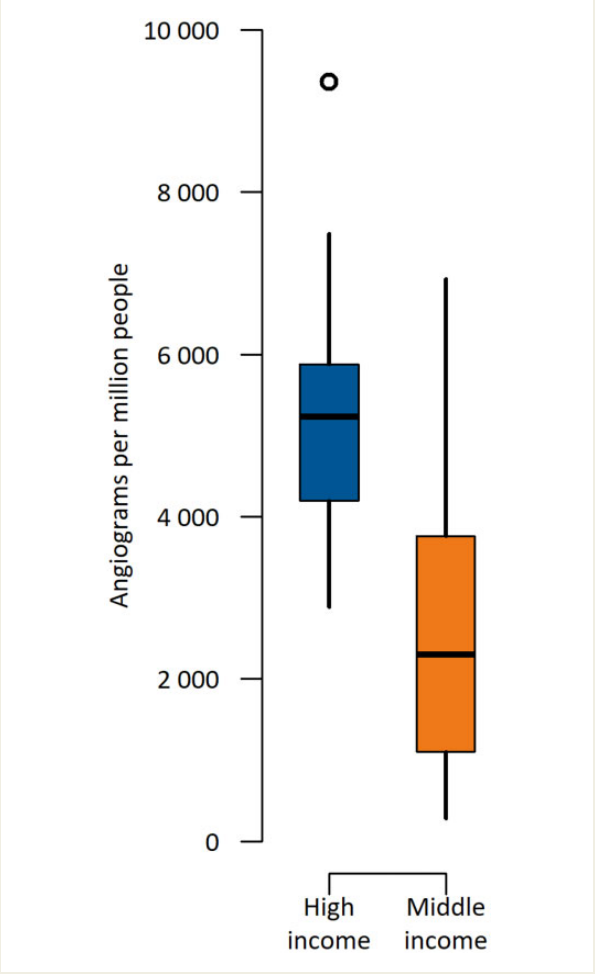

Figure 67 Invasive coronary angiograms per million people in ESC member countries by national income status (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Estonia, Ireland, Republic of San Marino, Sweden; *middle-income countries*: Algeria, Azerbaijan, Belarus, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

14/25 (56%); Year of data: Latest available between 2012 and 2017, median 2016.

Data: Hospitals with cath labs working 24 h a day, 7 days a week; Completeness: High-income countries 29/31 (94%), middle-income countries 15/25 (60%); Year of data: Latest available between 2013 and 2017, median 2016.

- *Human resource*: The 2018/19 survey showed a median of 13.4 (IQR 9.0–17.9) interventional cardiologists per million inhabitants of ESC member countries, with numbers ranging from <5 per million in Republic of Moldova, Azerbaijan, Romania, Egypt and Ukraine to >25 per million in Malta, Switzerland and Austria (*Figure 68*, Supplementary material online, *Figure S7.6*).
- *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 1.1–2.8), ranging from <1 hospital per million people in Egypt, Kyrgyzstan, Ukraine, Romania, Denmark, Republic of Moldova and Slovenia to >4 in Poland, Belgium, Cyprus and Bulgaria.
- *Service delivery*

a. Percutaneous coronary intervention

Completeness: High-income countries 29/31 (94%), middle-income countries 16/25 (64%); Year of data: Latest available between 2014 and 2017, median 2016.

A median of 2047 (IQR 1478–2588) percutaneous coronary intervention (PCI) procedures per million inhabitants of ESC member countries were reported in the 2018/19 survey (*Figure 69*). Numbers ranged from <500 procedures per million people in Kyrgyzstan, Ukraine and Azerbaijan to >3500 in Germany and Bulgaria.

b. Primary PCI

Completeness: High-income countries 29/31 (94%), middle-income countries 16/25 (64%); Year of data: latest available between 2014 and 2017, median 2016.

A median of 462.1 (IQR 346.4–624.2) primary PCI procedures per million inhabitants of ESC member countries were reported in the 2018/19 survey (*Figure 70*). Numbers ranged from <200 procedures per million people in Kyrgyzstan, Egypt, Azerbaijan and Ukraine to >1000 in Lithuania and Bulgaria (Supplementary material online, *Figure S7.7*).

- *Stratification by national income status*: The median number of interventional cardiologists per million inhabitants of the ESC member countries reported in the 2018/19 survey was lower in middle-income countries compared with high-income countries [6.3 (IQR 4.4–10.9) vs. 15.1 (IQR 11.9–20.3)] (*Figure 71*) and there was further inequality in 24 h/7 day catheter laboratory availability [1.4 (IQR 0.7–2.4) vs. 2.0 (IQR 1.5–3.0)]. Median numbers of PCI procedures per million inhabitants of ESC member countries reported in the 2018/19 survey were also lower in middle-income compared with high-income countries [944 (IQR 564–1715) vs. 2454 (IQR 1781–2628)] (*Figure 72*) but primary PCI numbers were more similar [428.2 (IQR 257.2–682.7) vs. 462.1 (IQR 382.5–600.1)] (Supplementary material online, *Figure S7.8*).

7.3.2 Interventional heart valve procedures

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Hospitals with cath labs for structural interventions; Completeness: high-income countries 28/31 (90%), middle-income countries 14/25 (56%); Year of data: Latest available between 2016 and 2017, median 2016.

- *Infrastructure*: In the 2018/19 survey, a median of only 0.8 (IQR 0.5–1.4) hospitals per million inhabitants of ESC member countries reported catheter laboratories equipped for structural heart interventions. Numbers ranged from <0.5 hospitals per million people in Kazakhstan, Kyrgyzstan, Republic of Moldova and Egypt to >3.0 in Italy and Switzerland. In Bosnia and Herzegovina and Republic of Kosovo there were no hospitals offering this service and an additional 5 countries (Albania, Armenia, Azerbaijan and Republics of Georgia and Moldova) reported having performed no interventional aortic or mitral valve procedures despite availability of appropriately equipped laboratories.

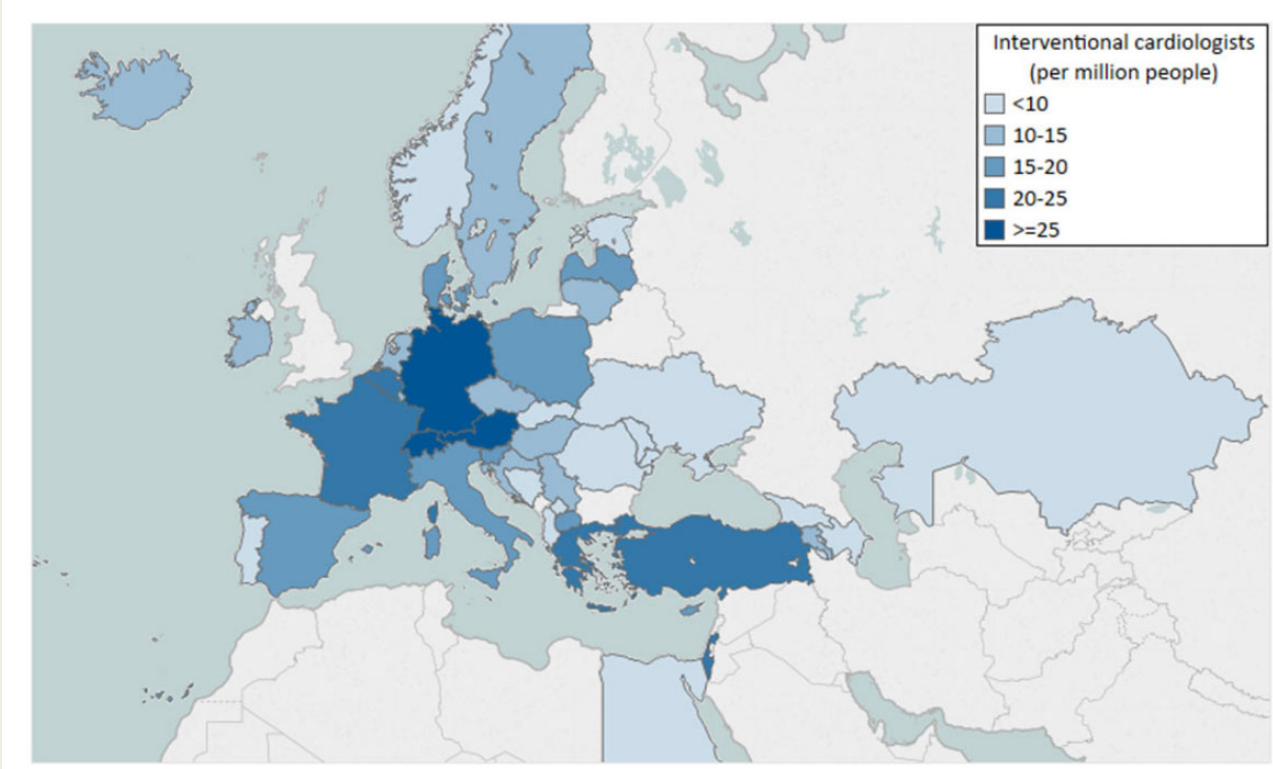

Figure 68 Interventional cardiologists per million people in ESC member countries (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Bulgaria, Finland, Kyrgyzstan, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Syrian Arab Republic, Tunisia, and United Kingdom (Supplementary file: S7.xlsx).

- Service delivery
  a. Transcatheter aortic valve implantation (TAVI)

  Completeness: High-income countries 28/31 (90%), middle-income countries 15/25 (60%); Year of data: Latest available between 2015 and 2017, median 2016.

  Transcatheter aortic valve implantation procedures were performed in all 43 ESC member countries that returned data except Albania, Azerbaijan, Bosnia and Herzegovina, Kyrgyzstan and Republics of Georgia, Kosovo and Moldova. A median of 25.5 (IQR 3.0–62.2) TAVI procedures per million inhabitants of ESC member countries were performed in 2017, or the most recent year that data were available, numbers ranging from <1 procedure per million people in Egypt and Serbia to >200 in Switzerland and Germany (*Figure 73*, Supplementary material online, *Figure S7.9*).

  b. Percutaneous mitral valve repair

  Completeness: High-income countries 24/31 (77%), middle-income countries 12/25 (48%); Year of data: Latest available between 2015 and 2017, median 2016.

  All of the 43 ESC member countries that returned data reported performing percutaneous mitral valve repair procedures with the exception of Albania, Armenia, Azerbaijan, Bulgaria, Estonia, Iceland, Serbia, North Macedonia and Republics of Georgia, Kosovo and Moldova. A median of 2.7 (IQR 0–7.2) procedures per million people were performed across ESC member countries in 2017, or the most recent year that data were available, with Switzerland and Germany reporting >40 procedures per million people.
- *Stratification by national income status*: In the 2018/19 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. 1.1 (IQR 0.7–1.7)] (Supplementary material online, *Figure S7.10*). Procedure rates were accordingly low in middle-income countries where TAVIs were performed in only Egypt, Serbia, Kazakhstan, North Macedonia, Bulgaria and Turkey while percutaneous mitral valve repairs were performed in only Romania, Kyrgyzstan and Bosnia and Herzegovina (*Figure 74*). In high-income countries procedure rates for TAVI and mitral valve repair were much higher, with median numbers per million people 52.6 (IQR 29.7–100.2) and 5.1 (IQR 2.5–9.8) in 2017, or the most recent year that data were available.

7.4 Electrophysiology

7.4.1 Diagnostic electrophysiology

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Electrophysiologists; Completeness: High-income countries 23/31 (74%), middle-income countries 12/25

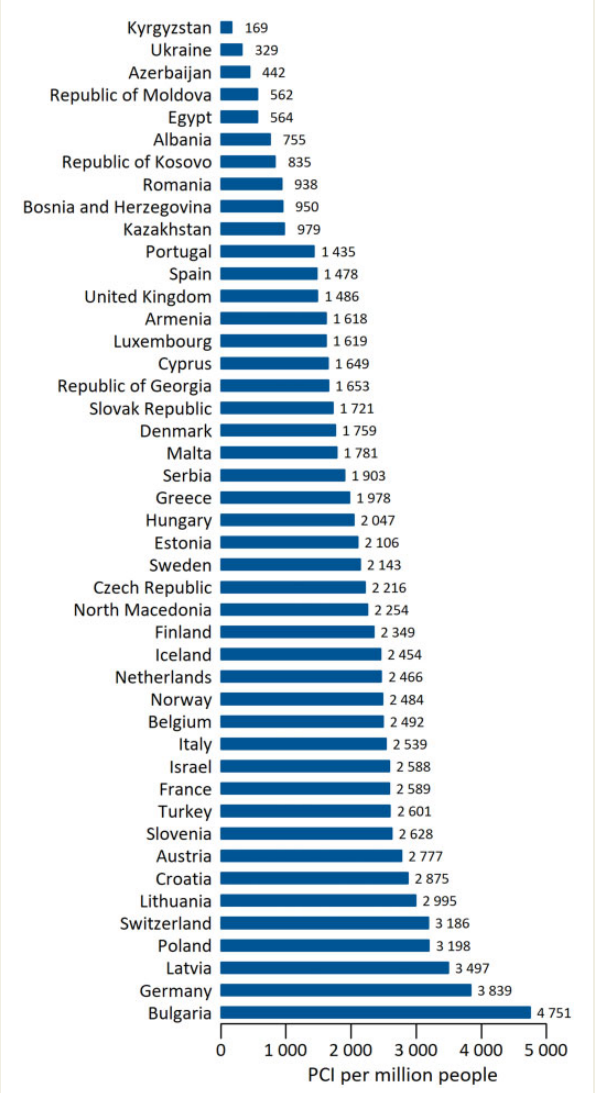

Figure 69 Percutaneous coronary intervention per million people in ESC member countries (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Ireland, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

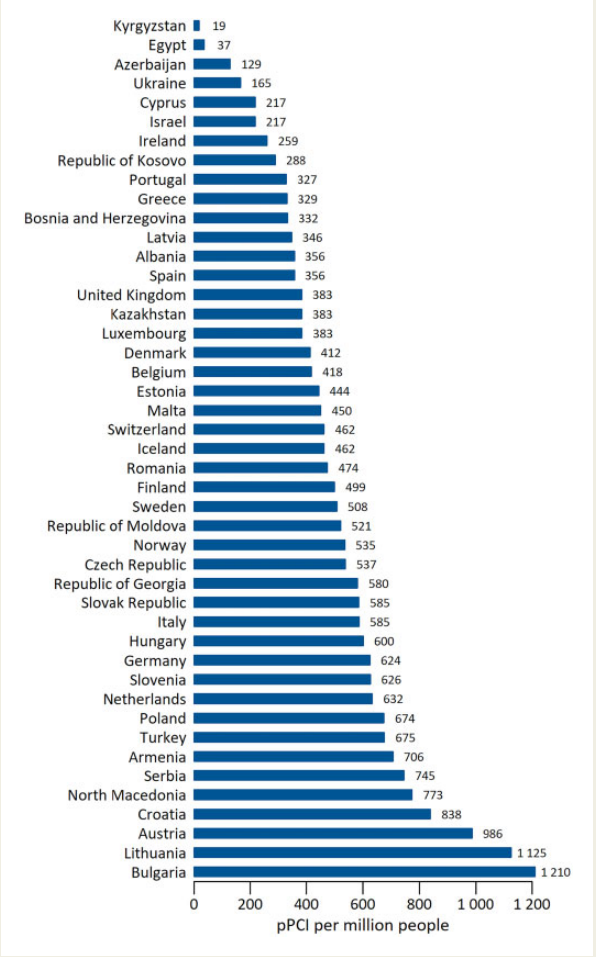

Figure 70 Primary percutaneous coronary interventions per million people in ESC member countries (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, France, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

(48%); Year of data: Latest available between 2014 and 2017, median 2016.
Data: Hospitals performing electrophysiology procedures; Completeness: High-income countries 30/31 (97%), middle-income countries 16/25 (64%); Year of data: Latest available between 2013 and 2017, median 2016.
Data: Electrophysiology procedures; Completeness: High-income countries 25/31 (81%), middle-income countries 14/25 (56%); Year of data: Latest available between 2012 and 2017, median 2016.

- *Human resource*: The 2018/19 survey identified a median of 4.4 (IQR 2.3–7.0) cardiac electrophysiologists per million people working in the ESC member countries, ranging from <1 in Egypt, Azerbaijan, Kyrgyzstan and Republic of Moldova to >10 in Sweden, Czech Republic, Italy, Greece and Luxembourg. In Iceland, there were >20 cardiac electrophysiologists per million people and in Switzerland >35 cardiac electrophysiologists per million people.
- *Infrastructure*: Across ESC member countries, a median of 1.5 (IQR 0.9–2.1) hospitals per million people reported performing electrophysiology procedures in the 2018/19 survey, ranging from <0.5 hospitals per million in Kyrgyzstan, Romania, Ukraine, Azerbaijan and Egypt to >3 hospitals per million in Ireland, Germany, Belgium, Italy and France. Republic of Kosovo was an outlier in reporting no hospitals performing electrophysiology procedures.
- *Service delivery*: A median of 106.8 (IQR 49.5–320.4) diagnostic electrophysiology procedures per million inhabitants of the ESC

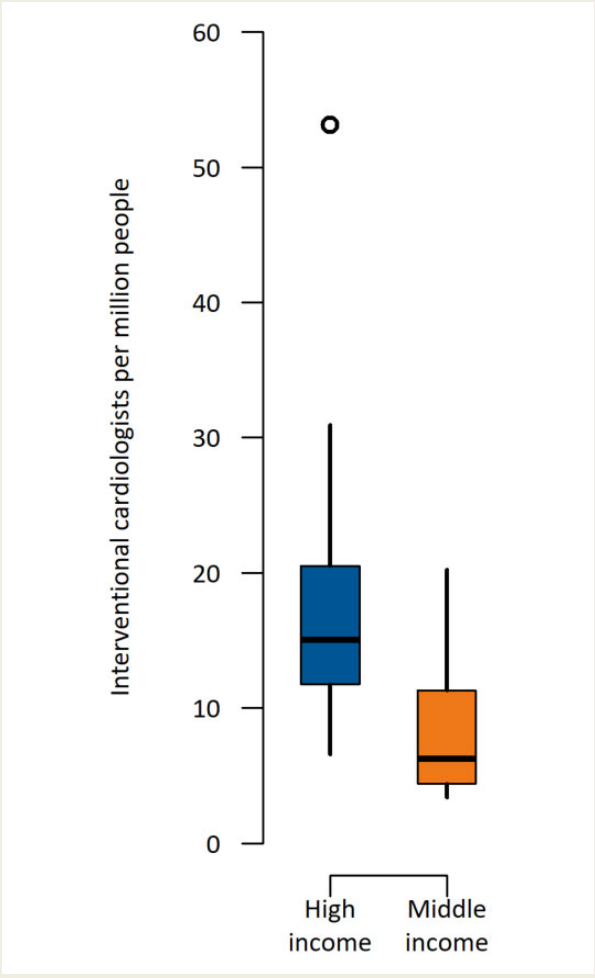

Figure 71 Interventional cardiologists per million people in ESC member countries by national income status (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Finland, Republic of San Marino, United Kingdom; *middle-income countries*: Algeria, Belarus, Bulgaria, Kyrgyzstan, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

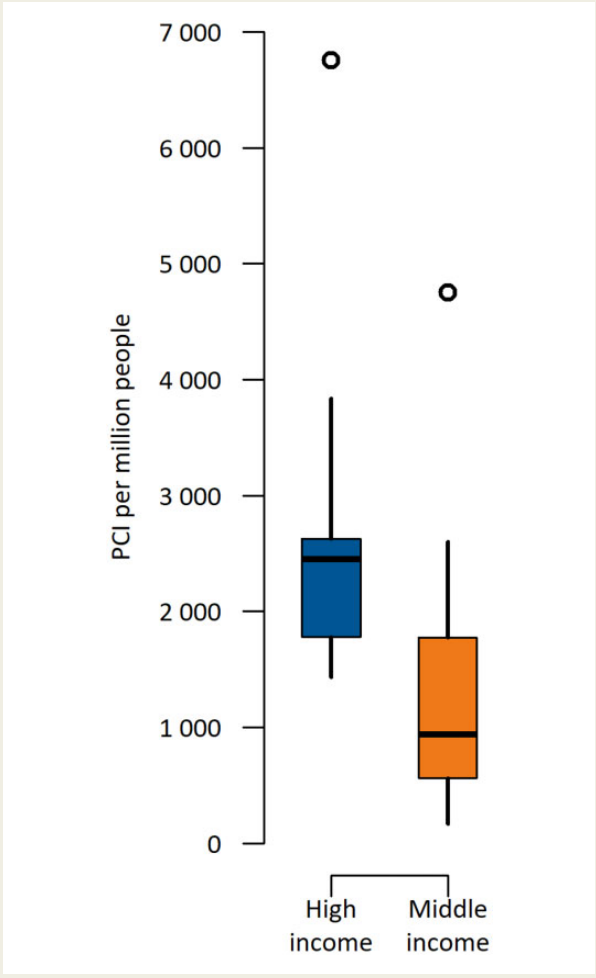

Figure 72 Percutaneous coronary interventions per million people in ESC member countries by national income status (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Ireland, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

member countries were reported in the 2018/19 survey (*Figure 75*). Rates ranged from fewer than 20 procedures per million people in Republic of Moldova, Albania and Kyrgyzstan to more than 500 in Croatia and Sweden. In the Czech Republic, 957.8 diagnostic electrophysiology procedures per million people were performed in 2016, but in Republic of Kosovo none was performed (Supplementary material online, *Figure S7.11*).

- *Stratification by national income status*: The 2018/19 survey showed that, compared with high-income ESC member countries, the median number of electrophysiologists per million inhabitants of middle-income countries was lower [1.6 (IQR 0.8–2.3) vs. 5.1 (IQR 4.0–10.5)] (*Figure 76*), and fewer hospitals per million people were performing electrophysiological procedures [0.6 (IQR 0.4–1.0) vs. 1.8 (IQR 1.2–2.5)] (Supplementary material online, *Figure S7.12*).

7.4.2 Ablation procedures and device implants

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Hospitals implanting pacemakers; Completeness: High-income countries 30/31 (97%), middle-income countries 17/25 (68%); Year of data: Latest available between 2016 and 2017, median 2016.

Data: Hospitals implanting implantable cardioverter-defibrillators; Completeness: High-income countries 30/31 (97%), middle-income countries 18/25 (72%); Year of data: Latest available between 2015 and 2017, median 2016.

Data: Hospitals implanting CRT devices; Completeness: High-income countries 30/31 (97%), middle-income countries 18/25 (72%); Year of data: Latest available between 2014 and 2017, median 2016.

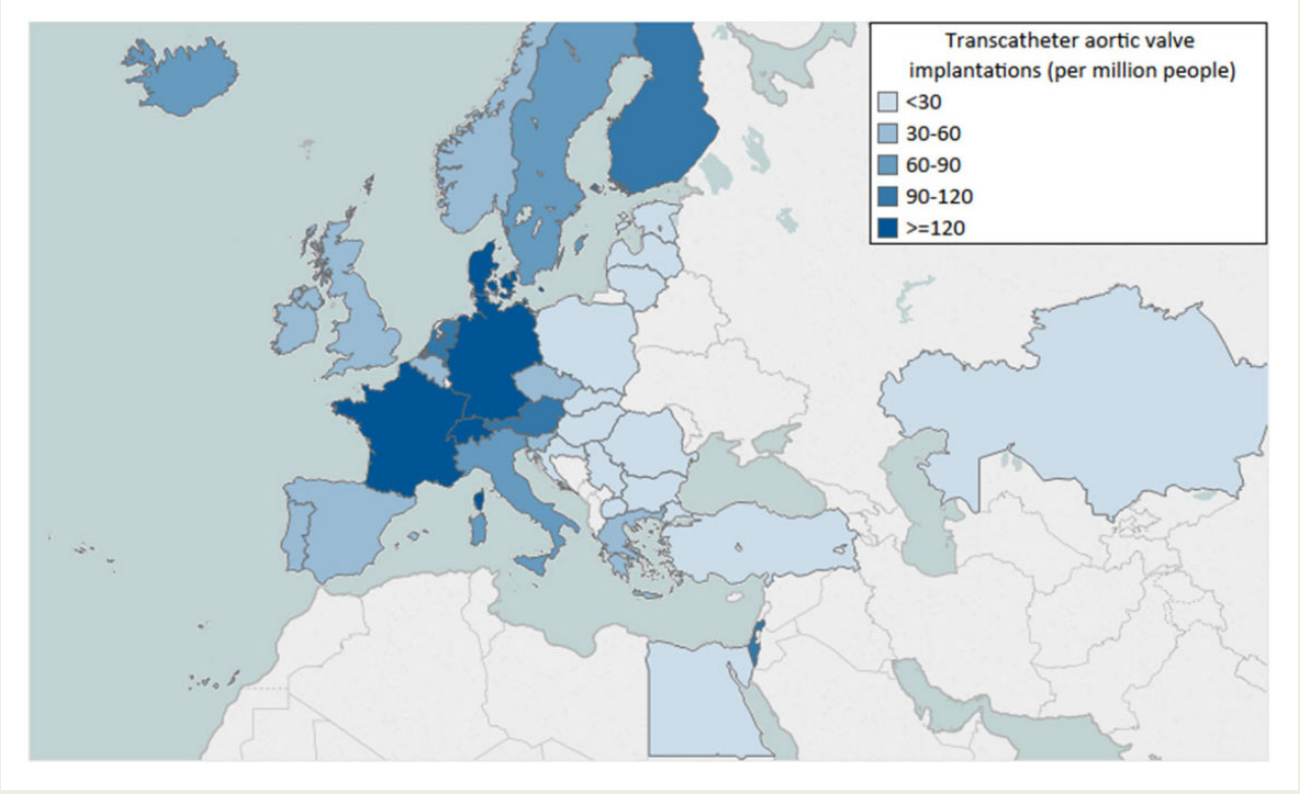

Figure 73 Transcatheter aortic valve implantations (transvascular and transapical) per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Cyprus, Lebanon, Libya, Luxembourg, Montenegro, Morocco, Republic of San Marino, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine (Supplementary file: S7.xlsx).

- *Infrastructure*: The 2018/19 survey of the ESC member countries recorded a median of 3.5 (IQR 1.7–5.0) hospitals per million people implanting pacemakers, 1.8 (IQR 1.1–3.2) implanting implantable cardioverter-defibrillators and 1.6 (IQR 1.0–2.7) implanting cardiac resynchronization therapy pacemakers. Generally speaking, it was middle-income countries where the density of hospitals performing device implantation procedures was low (*Figure 77*). Pacemakers, for example, were implanted in <1 hospital per million people in Ukraine, Republic of Moldova, Kyrgyzstan, Azerbaijan and Egypt compared with >7 hospitals per million people in Italy, Austria, Switzerland and Belgium. In Germany, 13.5 hospitals per million people performed pacemaker implantations (Supplementary material online, *Figures S7.13 and S7.14*).
- Service delivery

  a. Ablation procedures

  Completeness: High-income countries 29/31 (94%), middle-income countries 17/25 (68%); Year of data: Latest available between 2015 and 2017, median 2016.

  A median of 287.1 (IQR 69.0–474.0) ablation procedures per million inhabitants of the ESC member countries were performed for treatment of heart rhythm disorders (*Figure 78*). Rates ranged from <15 procedures per million people in Republic of Moldova, Kyrgyzstan and Albania to >600 procedures per million people in Czech Republic, Belgium, Norway, Denmark, Switzerland and Germany. (Supplementary material online, *Figure S7.15*).

  b. Pacemaker implants

  Completeness: High-income countries 30/31 (97%), middle-income countries 17/25 (68%); Year of data: Latest available between 2015 and 2017, median 2016.

  A median of 694.1 (IQR 238.1–860.7) pacemaker implants per million inhabitants of ESC member countries were reported in the 2018/19 survey (*Figure 79*, Supplementary material online, *Figure S7.16*). Rates ranged from <60 implants per million people in Republic of Kosovo, Azerbaijan, Egypt and Kyrgyzstan to >1000 per million people in France, Belgium, Italy, Portugal, Finland and Germany.

  c. Implantable cardioverter-defibrillator (ICD) implants

  Completeness: High-income countries 30/31 (97%), middle-income countries 17/25 (68%); Year of data: Latest available between 2015 and 2017, median 2016.A median of 100.2 (IQR 21.5–150.8) ICD implants per million inhabitants of ESC member countries were reported in the 2018/19 survey (*Figure 80*). Rates ranged from <5 implants per million people in Azerbaijan, Egypt, Republic of Moldova, Ukraine and Kyrgyzstan to more than 300 per million people in Netherlands, Germany and Czech Republic (Supplementary material online, *Figure S7.17*).

  d. Cardiac resynchronization therapy pacemaker (CRT-P) implants

  Completeness: High-income countries 29/31 (94%),

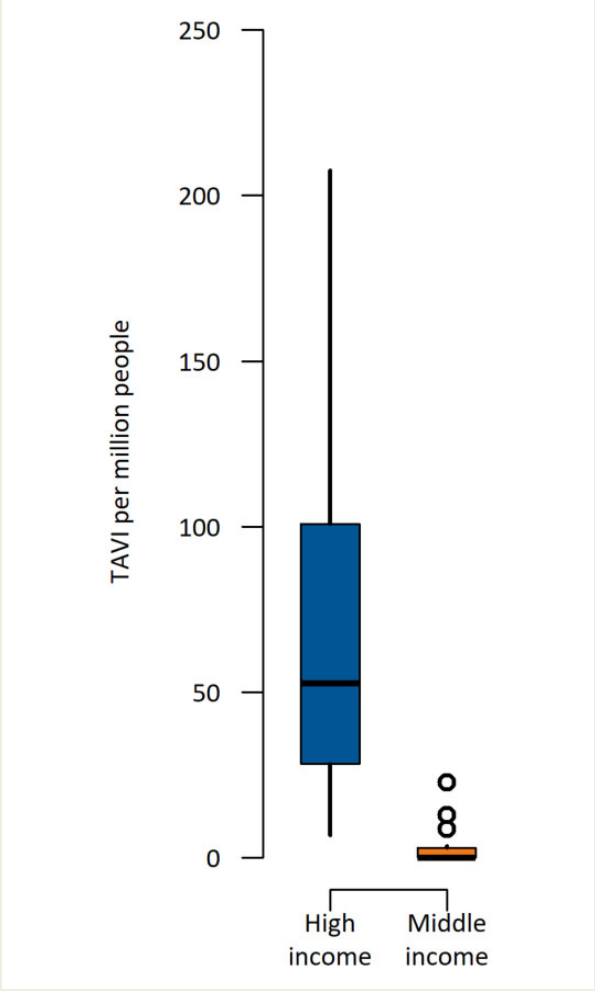

Figure 74 Transcatheter aortic valve implantations (transvascular and transapical) per million people in ESC member countries by national income status (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Cyprus, Luxembourg, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine (Supplementary file: S7.xlsx).

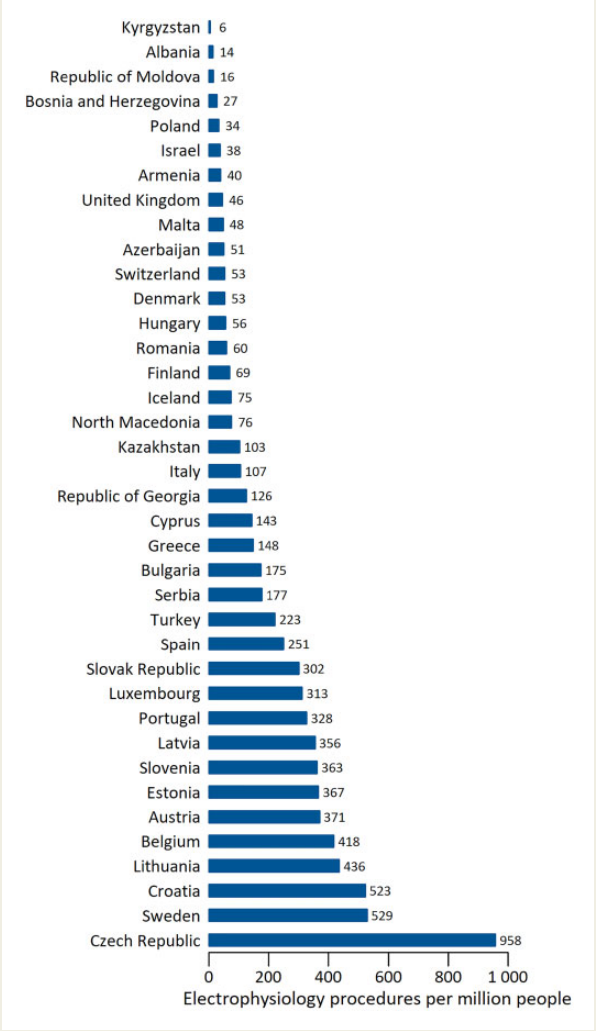

Figure 75 Electrophysiology procedures per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Egypt, France, Germany, Ireland, Lebanon, Libya, Montenegro, Morocco, Netherlands, Norway, Republic of San Marino, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine. *Zero*: Republic of Kosovo (Supplementary file: S7.xlsx).

middle-income countries 17/25 (68%); Year of data: Latest available between 2016 and 2017, median 2016.

A median of 24.1 (IQR 4.8–41.6) CRT-P implants per million inhabitants of ESC member countries were reported in the 2018/19 survey (Supplementary material online, *Figure S7.18*). Rates ranged from <2 implants per million people in Ukraine, Republic of Kosovo, Kazakhstan, Kyrgyzstan and Azerbaijan to >50 per million people in Iceland, France, UK, Sweden and Denmark. Republic of Moldova was the only ESC member country reporting no CRT-P implants (Supplementary material online, *Figure S7.19*).

e. Cardiac resynchronization therapy defibrillator (CRT-D) implants

Completeness: High-income countries 29/31 (94%), middle-income countries 17/25 (68%); Year of data: Latest available between 2016 and 2017, median 2016.

A median of 43.2 (IQR 8.0–89.3) CRT-D implants per million inhabitants of ESC member countries were reported in the 2018/19 survey (Supplementary material online, *Figure S7.20*). Rates ranged from <2 implants per million people in Republic of Kosovo, Albania, Ukraine and Kyrgyzstan to >150 per million in Israel, Czech Republic, Italy and Germany. Republic of Moldova was the only ESC member country reporting no CRT-D implants (Supplementary material online, *Figure S7.21*).

- *Stratification by national income status*: The 2018/19 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 pacemakers were implanted [1.4 (IQR 0.9–2.3) vs. 4.3 (IQR 3.5–6.4)] (*Figure 81*),

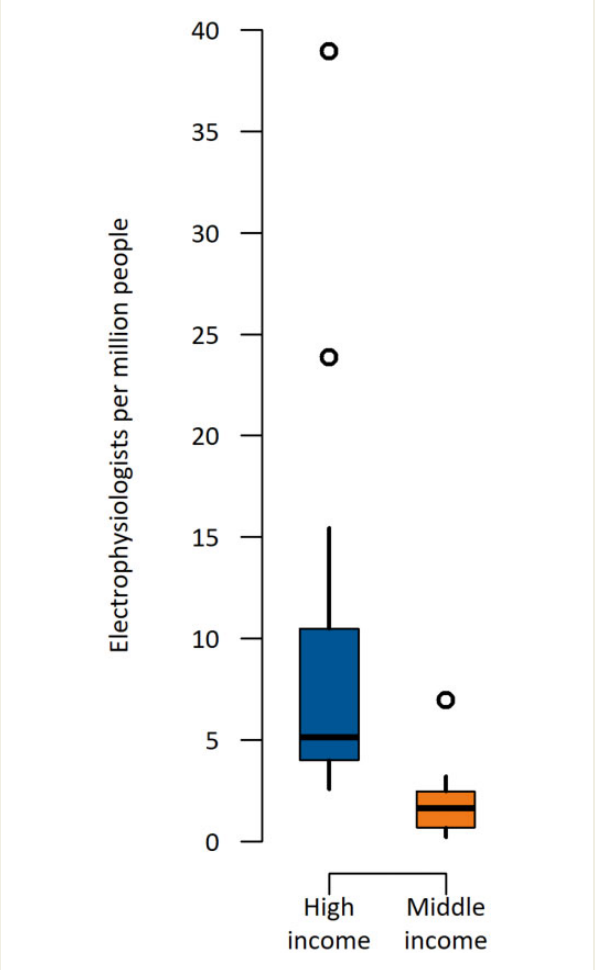

Figure 76 Electrophysiologists per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Austria, Belgium, Finland, France, Germany, Poland, Republic of San Marino, United Kingdom; *middle-income countries*: Algeria, Belarus, Kazakhstan, Lebanon, Libya, Montenegro, Morocco, Republic of Kosovo, Russian Federation, Syrian Arab Republic, Tunisia, Turkey, and Ukraine (Supplementary file: S7.xlsx).

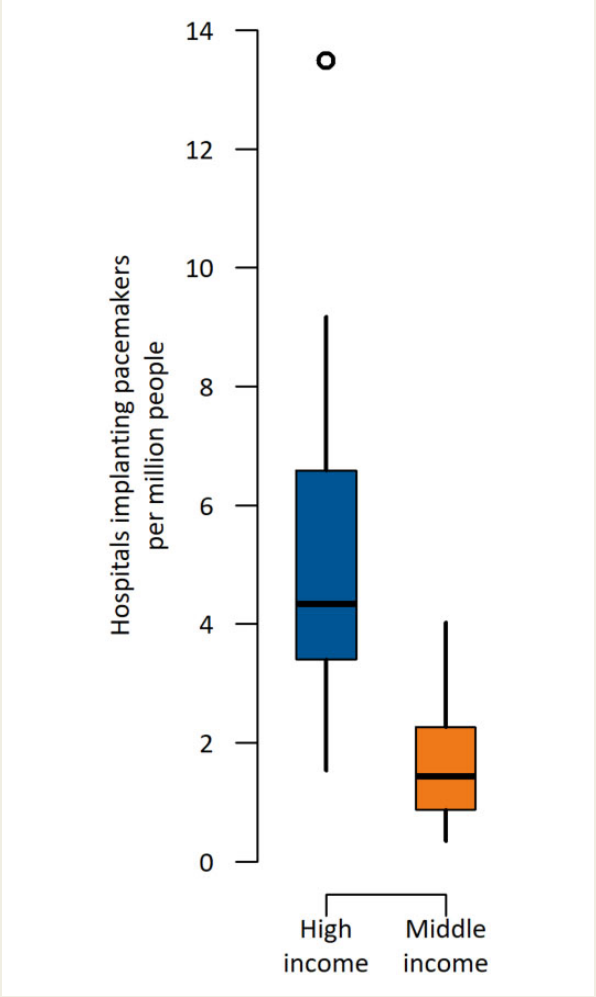

Figure 77 Hospitals per million people implanting pacemakers in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

fewer ablation procedures for treatment of cardiac arrhythmias were performed [59.9 (IQR 16.6–145.9) vs. 402.7 (IQR 309.4–538.1)] (*Figure 82*) and fewer pacemakers [125.7 (IQR 64.3–252.6) vs. 794.1 (IQR 697.7–932.0)], ICDs [10.1 (IQR 4.5–27.2) vs. 133.5 (IQR 102.7–206.9)] (*Figure 83*), CRT-Ps [3.1 (IQR 1.7–6.3) vs. 34.2 (IQR 24.1–45.8)] (*Figure 84*), and CRT-Ds [4.0 (IQR 1.1–9.3) vs. 68.1 (IQR 48.6–100.0)] (*Figure 85*) were implanted. Concealed within these averaged data, however, were many outliers. For example, among middle-income ESC member countries, Bulgaria and Serbia implanted as many pacemakers, and Turkey as many ICDs, as were implanted in many high-income countries. Conversely, there were high-income countries with device implantation rates per million people comparable to many middle-income countries including Cyprus for pacemakers, Lithuania and Estonia for ICDs and Latvia and Poland for CRT-P implants.

7.5 Cardiac surgery

7.5.1 Coronary artery bypass grafting

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Cardiac surgeons; Completeness: High-income countries 29/31 (94%), middle-income countries 15/25 (60%); Year of data: Latest available between 2012 and 2017, median 2016.

Data: Hospitals with cardiac surgery facilities; Completeness: High-income countries 29/31 (94%),

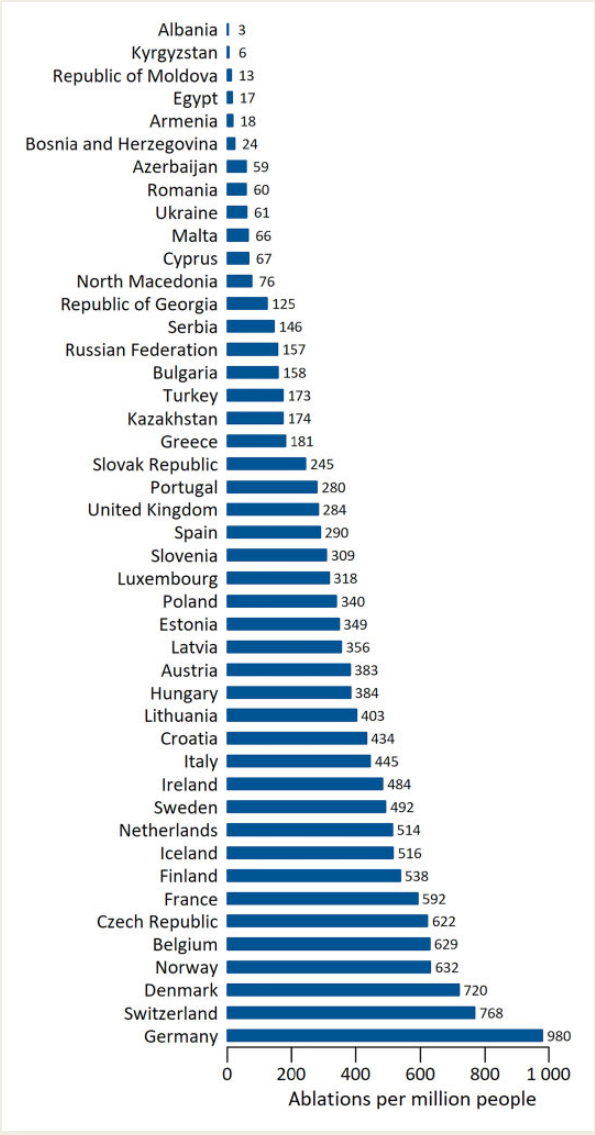

Figure 78 Ablation procedures per million people to correct heart rhythm disorders in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Israel, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Syrian Arab Republic, and Tunisia. *Zero*: Republic of Kosovo (Supplementary file: S7.xlsx).

middle-income countries 15/25 (60%); Year of data: Latest available between 2013 and 2017, median 2016.
Data: Coronary artery bypass graft procedures; Completeness: High-income countries 29/31 (94%), middle-income countries 13/25 (52%); Year of data: Latest available between 2012 and 2017, median 2016.

- *Human resource*: The 2018/19 survey identified a median of 6.8 (IQR 4.9–11.4) cardiac surgeons per million people working in the ESC member countries (*Figure 86*). Numbers ranged from <3 surgeons per million in North Macedonia, Azerbaijan and Kyrgyzstan to >15 per million in, Finland, Italy, Lithuania and Switzerland. Greece reported 35.3 cardiac surgeons per million people (Supplementary material online, *Figure S7.22*).
- *Infrastructure*: A median of 1.3 (IQR 0.9–1.6) hospitals per million inhabitants of ESC member countries were reported to have facilities for cardiac surgery in the 2018/19 survey, ranging from <0.7 hospitals in Kyrgyzstan, UK, Republic of Moldova, Slovak Republic, Latvia and Ukraine to >2.3 in Greece, Belgium, Republic of Georgia, Iceland and Turkey (Supplementary material online, *Figures S7.23 and S7.24*).
- *Service delivery*: A median of 301.1 (IQR 245.0–440.0) coronary artery bypass graft (CABG) procedures per million inhabitants of ESC member countries were reported in the 2018/19 survey (*Figure 87*). Rates ranged from <100 CABG procedures per million people in Ukraine, Kyrgyzstan and Republics of Moldova and Kosovo to >500 in Serbia, Turkey, Lithuania, Slovenia, Belgium, Croatia and Netherlands (Supplementary material online, *Figure S7.25*).
- *Stratification by national income status*: The 2018/19 survey showed that the median number of cardiac surgeons per million inhabitants was lower in middle-income countries [4.5 (IQR 2.7–6.0)] compared with high-income countries 8.2 (IQR 6.7–13.4) (*Figure 88*) although there was little difference in the median number of hospitals with cardiac surgical facilities [1.3 (IQR 0.9–1.5) vs. 1.2 (IQR 0.9–1.6)] or the median number of CABG procedures per million inhabitants [263.0 (IQR 82.8–442.0) vs. 324.2 (IQR 254.8–433.9)] (Supplementary material online, *Figures S7.26 and S7.27*). These averaged data concealed considerable variation with Republic of Georgia, Bulgaria, Serbia and Turkey among middle-income countries reporting over 400 procedures per million people per year, more than were reported by many of the high-income ESC member countries.

7.5.2 Heart transplant surgery and left ventricular assist devices

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology
Data: Hospitals with heart transplant programmes; Completeness: High-income countries 29/31 (94%), middle-income countries 16/25 (64%); Year of data: Latest available between 2013 and 2017, median 2016
Data: Heart transplantations; Completeness: High-income countries 30/31 (97%), middle-income countries 16/25 (64%); Year of data: Latest available between 2012 and 2017, median 2016.
Data: Left ventricular assist devices implants; Completeness: High-income countries 25/31 (81%), middle-income countries 12/25 (48%); Year of data: Latest available between 2012 and 2017, median 2016.

- *Infrastructure*: Fourteen ESC member countries reported no hospitals with heart transplant programmes in the 2018/19 survey and the median number among all countries was 0.18 (IQR 0–0.4) hospitals per million inhabitants. Only Latvia, Belgium, Germany, Lithuania and Malta reported more than 0.5 hospitals per million inhabitants with transplant programmes (Supplementary material online, *Figure S7.28*).

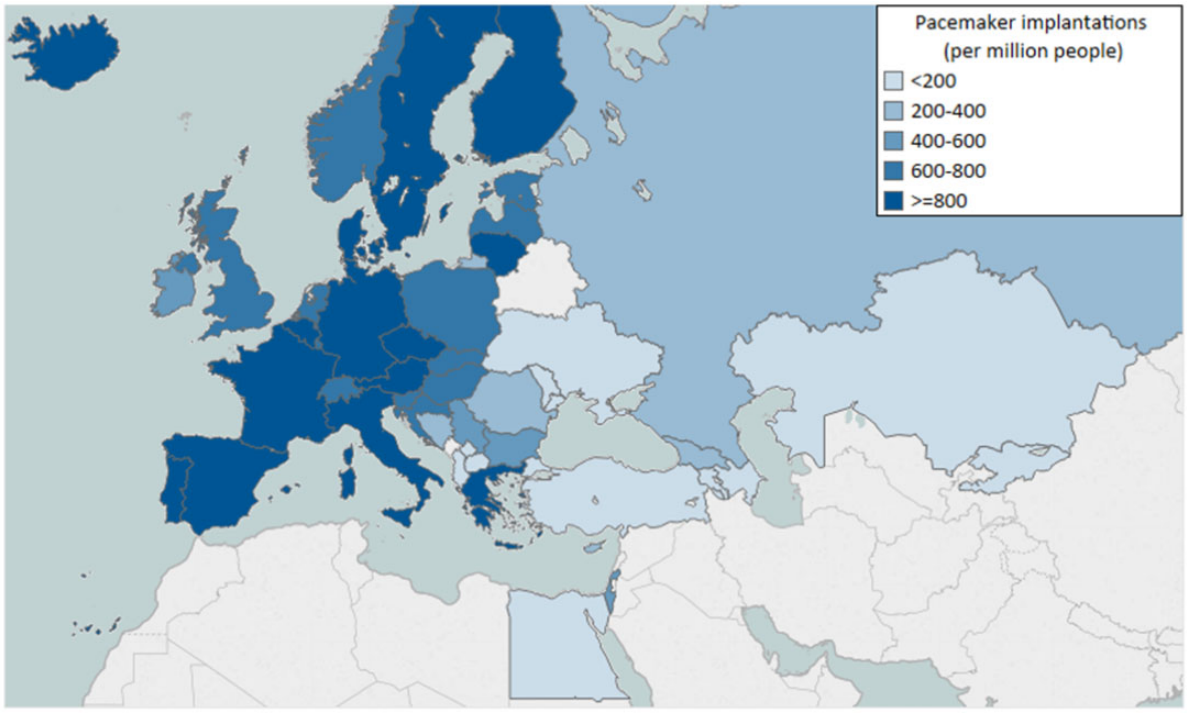

Figure 79 Pacemaker implantations per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

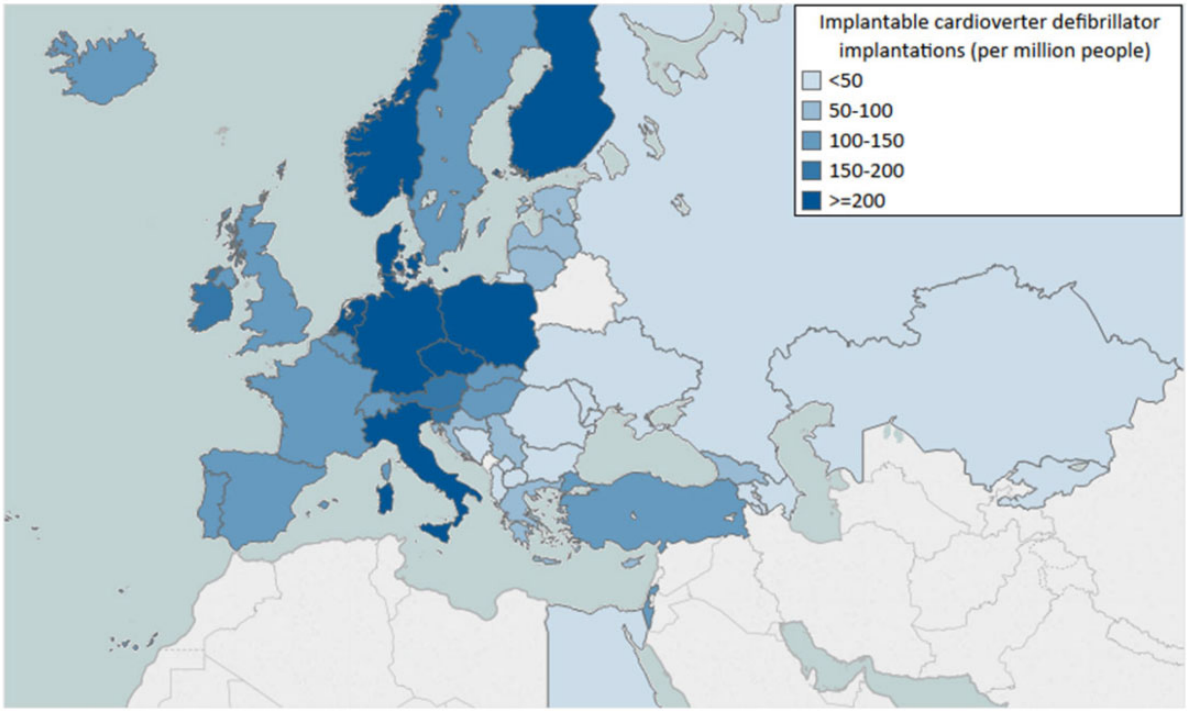

Figure 80 Implantable cardioverter-defibrillator implantations per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

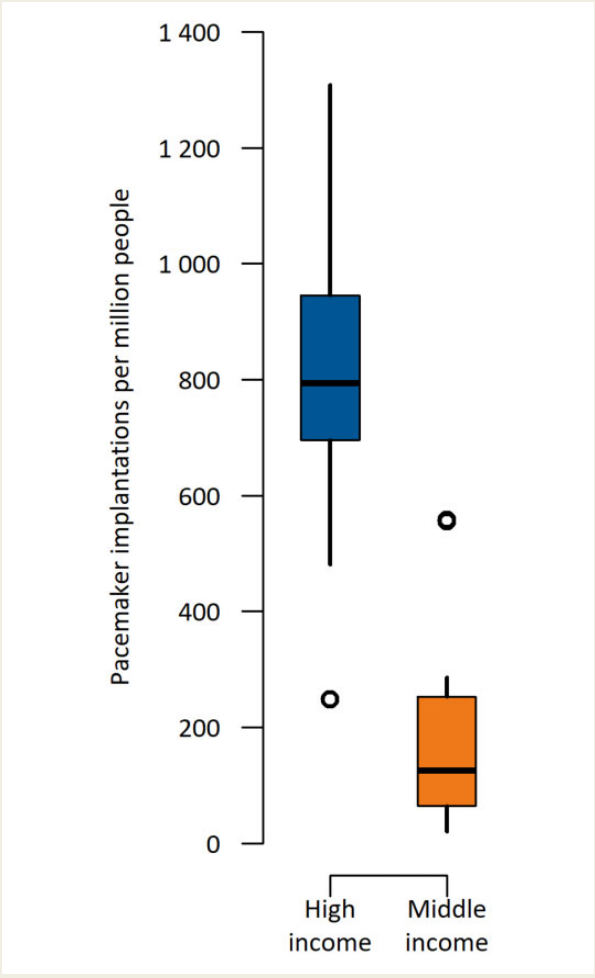

Figure 81 Pacemaker implantations per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

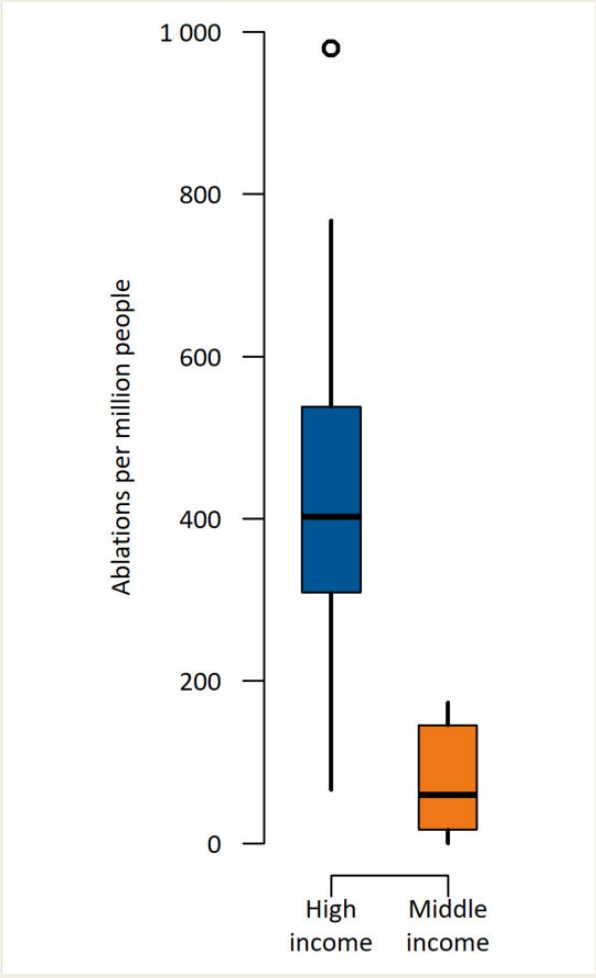

Figure 82 Cardiac ablation procedures per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Israel, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

- *Service delivery*: Across ESC member countries, a median of 2.1 (IQR 0–5.2) hospitals per million people reported performing heart transplantation procedures in the 2018/19 survey. Rates ranged from <2 transplants per million people per year in Latvia and Greece to >10 in Czech Republic and Slovenia. The variation in Left ventricular assist device (LVAD) implants was even greater with 11 ESC member countries reporting none while the average among all countries was 2.7 ± 4.2 per million people per year, ranging from <1.5 in Serbia, Kyrgyzstan, Egypt, Poland, Hungary, UK and Greece to >5.0 in Croatia, Germany, Slovenia and Lithuania.
- *Stratification by national income status*: ESC member countries without transplant programmes in the 2018/19 survey were predominately middle-income and included Albania, Azerbaijan, Bosnia and Herzegovina, Egypt, Kyrgyzstan, Republic of Georgia, Republic of Kosovo, Republic of Moldova, North Macedonia and Ukraine (Supplementary material online, *Figure S7.29*). Among high-income countries only Cyprus, Iceland and Luxembourg were without transplant programmes. Transplant activity was generally greater in high-income countries where a median of 4.6 (IQR 2.3–6.0) procedures were reported in the 2018/19 survey ranging from <2.5 in Malta, Netherlands, Latvia and Greece to >7 in France, Croatia, Czech Republic and Slovenia. In those middle-income countries reporting transplant programmes (Romania, Bulgaria, Serbia, Turkey and Kazakhstan), <0.9 procedures per million people were undertaken. Left ventricular assist devices too were largely the preserve of high-income countries with only Malta, Iceland and Cyprus reporting no implantations. Among middle-income countries only Egypt, Kyrgyzstan, Serbia, and Kazakhstan reported LVAD implantations but rates were never >1.8 procedures per million people.

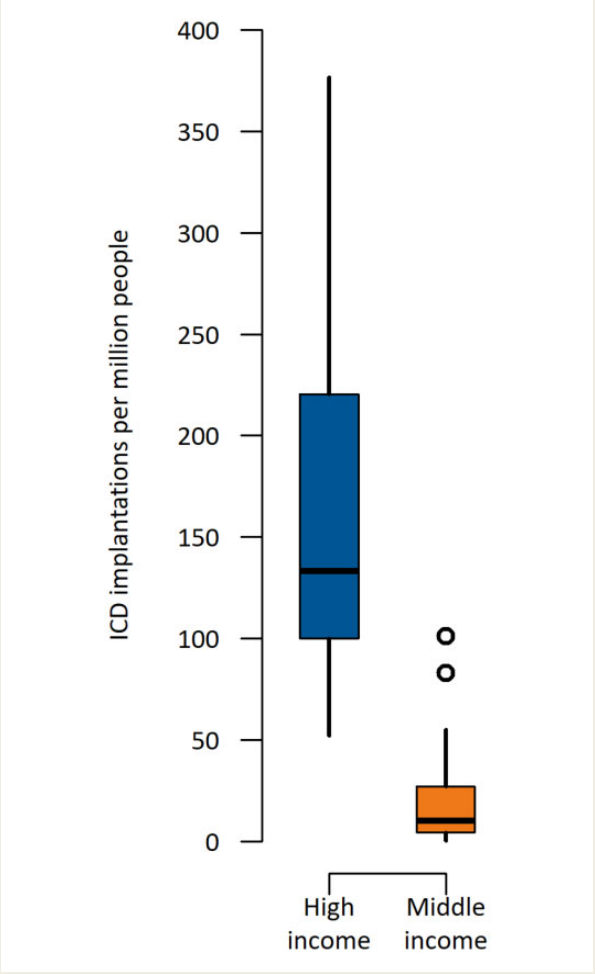

Figure 83 Implantable cardioverter-defibrillator implantations per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

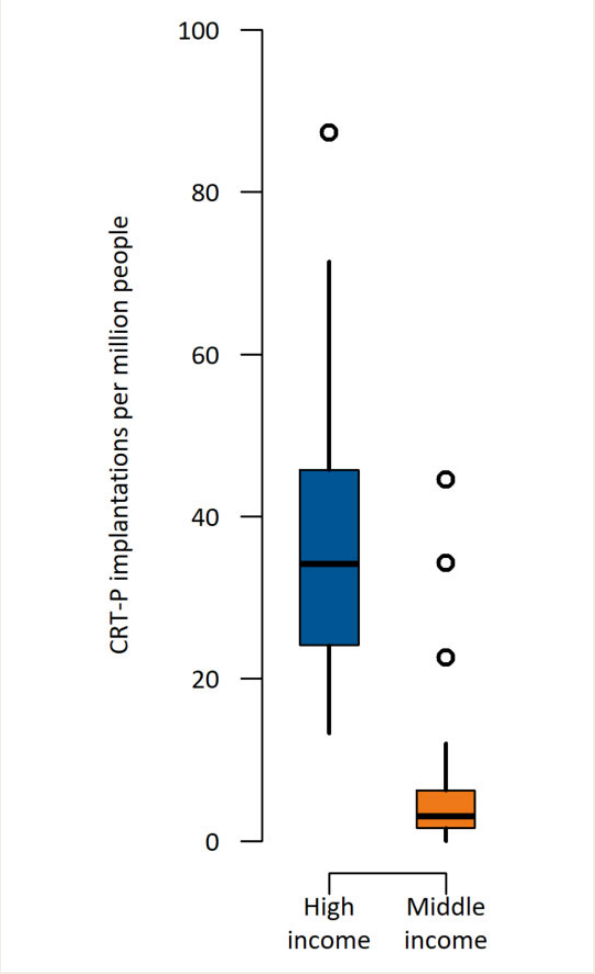

Figure 84 Cardiac resynchronization therapy pacemaker implantations per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Cyprus, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

7.6 Congenital heart disease

Data source in this section: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology

Data: Hospitals undertaking percutaneous congenital heart disease procedures; Completeness: High-income countries 23/31 (74%), middle-income countries 12/25 (48%); Year of data: Latest available between 2015 and 2017, median 2016.

Data: Hospitals undertaking congenital heart disease surgeries; Completeness: High-income countries 28/31 (90%), middle-income countries 12/25 (48%); Year of data: Latest available between 2013 and 2017, median 2016.

Data: Percutaneous procedures for congenital heart disease; Completeness: High-income countries 26/31 (84%), middle-income countries 14/25 (56%); Year of data: Latest available between 2013 and 2017, median 2016.

Data: Surgical interventions in congenital heart disease; Completeness: High-income countries 27/31 (87%), middle-income countries 11/25 (44%); Year of data: Latest available between 2012 and 2017, median 2016.

- *Infrastructure*: A median of 0.5 (IQR 0.3–1.0) and 0.4 (IQR 0.3–0.7) hospitals per million inhabitants of middle- and high-income ESC member countries, respectively reported performing percutaneous and surgical procedures for treatment of congenital heart disease in the 2018/19 survey. Numbers ranged from <0.2 hospitals per million people undertaking percutaneous procedures in Norway and Finland to >2.0 in Malta, Italy and Iceland and from <0.2 hospitals per million people undertaking surgical procedures in Norway, Greece, Finland and France to >2.0 in Malta and Iceland (Supplementary material online, *Figures S7.30* and *S7.31*).

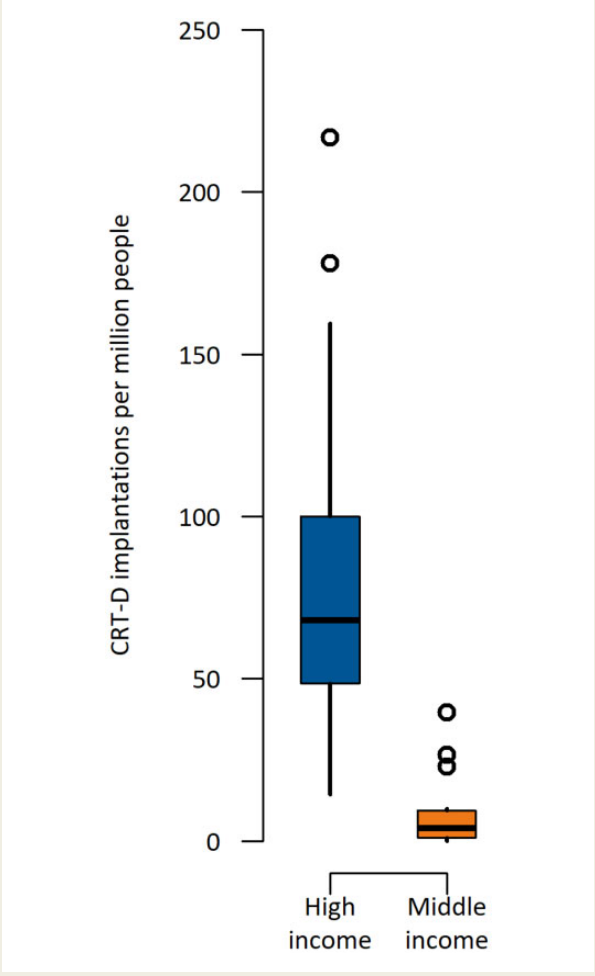

Figure 85 Cardiac resynchronization therapy defibrillator implantations per million people in ESC member countries by national income status (2017 or latest year available). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Cyprus, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

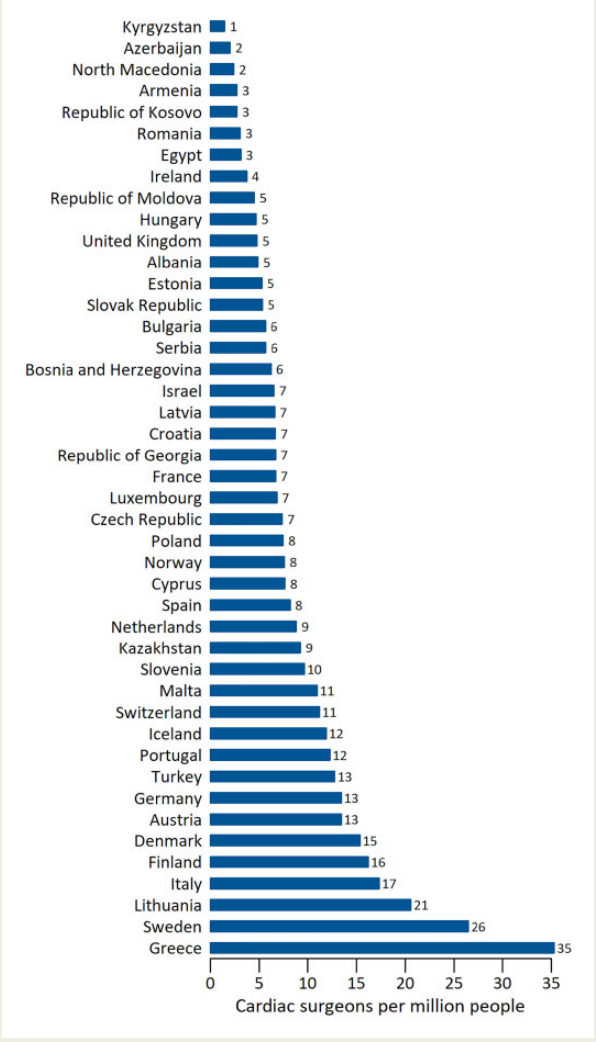

Figure 86 Cardiac surgeons per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Belarus, Belgium, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine (Supplementary file: S7.xlsx).

- *Service delivery*: Across the ESC member countries, a median of 26.0 (IQR 13.4–39.7) percutaneous procedures and 49.4 (IQR 22.4–69.8) surgical procedures for congenital heart disease were reported in the 2018/19 survey. Rates ranged from <10 percutaneous procedures per million people per year in Romania, Albania, Kyrgyzstan, Azerbaijan, Bosnia and Herzegovina and Armenia to >90 in Switzerland, Croatia and Iceland and from <10 surgical procedures per million people per year in Malta and Sweden to >100 in Republic of Moldova, Lithuania, Israel and Kazakhstan (Supplementary material online, *Figures S7.32 and S7.33*).
- *Stratification by national income status*: In comparing middle-income and high-income countries, the median number of hospitals per million people providing percutaneous [0.6 (IQR 0.3–0.9) vs. 0.5 (IQR 0.4–1.1)] and surgical [0.6 (IQR 0.4–0.8) vs. 0.3 (IQR 0.2–0.6)] procedures for treatment of congenital heart disease were similar (Supplementary material online, *Figure S7.34*). North Macedonia and Albania, for example, reported as many hospitals offering percutaneous treatment as Austria and Luxembourg, while Kazakhstan reported as many offering surgical treatment as Iceland. Nevertheless, the median number of procedures per million inhabitants was lower in middle-income compared with high-income ESC member particularly for percutaneous interventional management [11.1 (IQR 5.8–28.0) vs. 34.7 (IQR 21.2–56.4)] (*Figure 89*, Supplementary material online, *Figure S7.35*).

7.7 Summary

- Huge variation in cardiological person-power across ESC member countries likely reflects under-provision in many countries although definitions of what constitutes a cardiologist may also vary.

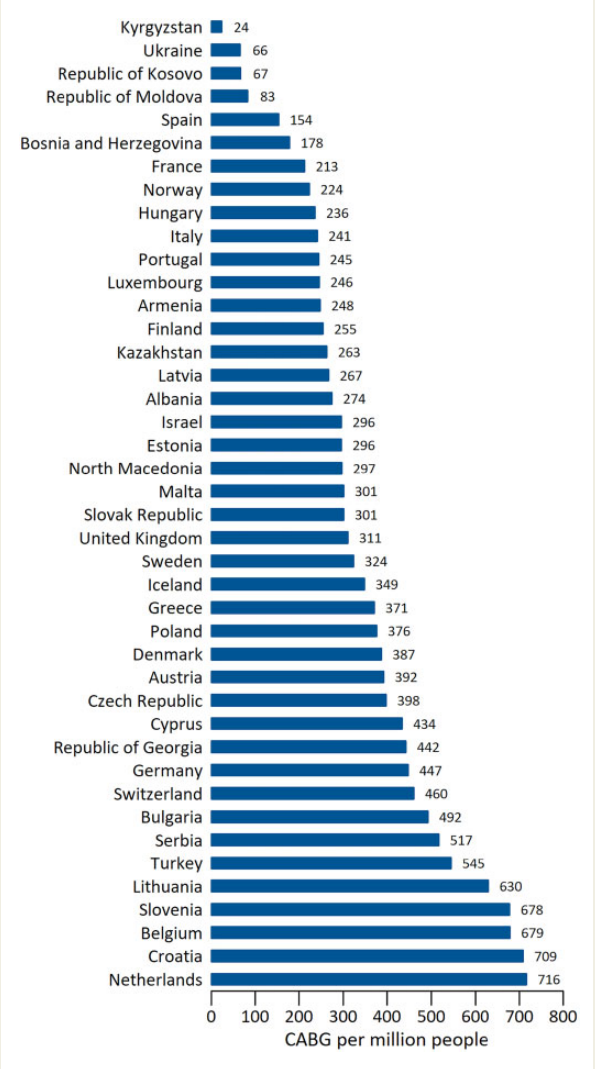

Figure 87 Coronary artery bypass graft procedures per million people in ESC member countries (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available*: Algeria, Azerbaijan, Belarus, Egypt, Ireland, Lebanon, Libya, Montenegro, Morocco, Republic of San Marino, Romania, Russian Federation, Syrian Arab Republic, and Tunisia (Supplementary file: S7.xlsx).

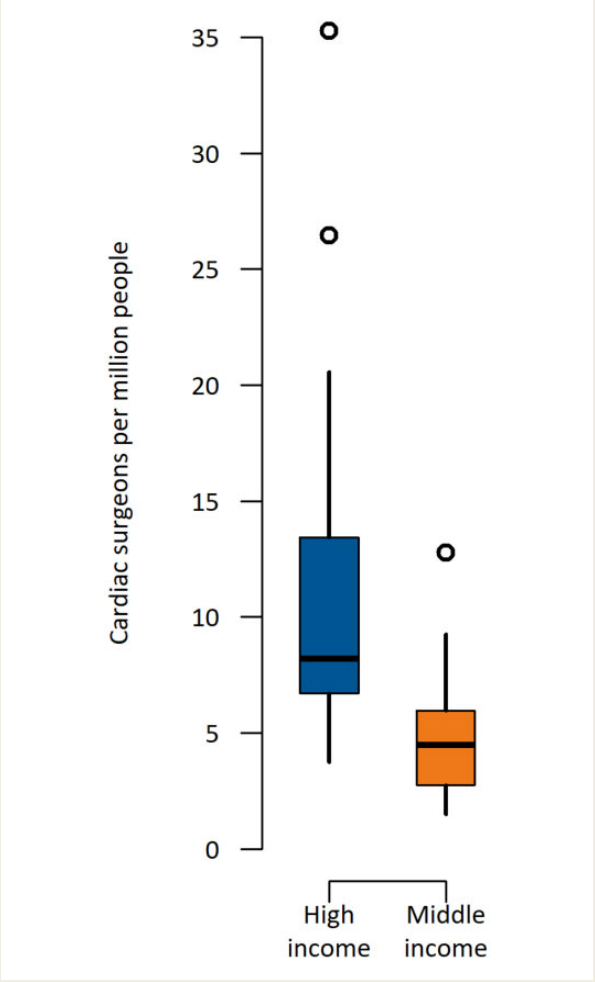

Figure 88 Cardiac surgeons per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Belgium, Republic of San Marino; *middle-income countries*: Algeria, Belarus, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine (Supplementary file: S7.xlsx).

- Compared with high-income countries, middle-income countries are severely under-resourced 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, device implantation and cardiac surgical procedures.
- While many middle-income countries are under-resourced in terms of cardiological person-power, infrastructure and procedure rates, outliers can often be identified emphasizing that national income status is not the only driver for cardiological healthcare delivery.

7.8 Comment

The 2018/19 survey of ESC member countries shows continuing heterogeneity in cardiological specialist provision, hospital facilities, and healthcare delivery that likely contribute to the inequalities in cardiovascular outcomes documented elsewhere in this report. There is no clear consensus about what constitutes optimal specialist provision but the 15-fold variation in cardiologists per million people across ESC member countries suggests that the definition of 'a cardiologist' may vary and that under-provision may be common with potentially deleterious effects on cardiovascular outcomes. Certainly, there is considerable evidence that outcomes in patients with CVD are more favourable when clinical management involves a specialist cardiologist and this is reflected in contemporary quality indicators.[99–101] Moreover, there are now data showing that patients hospitalized for myocardial infarction and heart failure in those US regions that have a

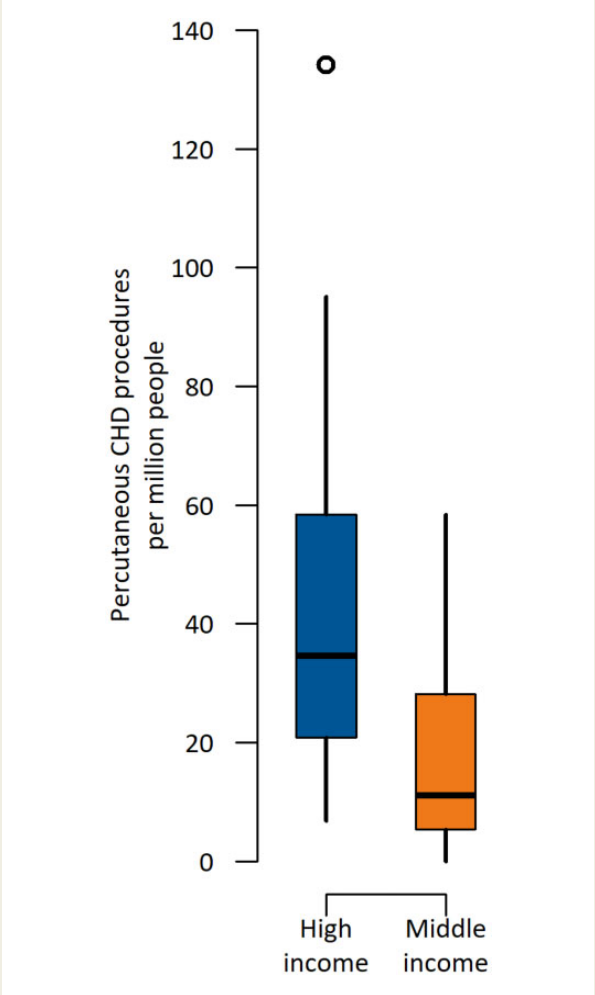

Figure 89 Percutaneous procedures for congenital heart disease per million people in ESC member countries by national income status (2017 or latest available year). *Data source*: ESC Atlas of Cardiology, https://www.escardio.org/Research/ESC-Atlas-of-cardiology. *Data not available for the following high-income countries*: Czech Republic, Ireland, Norway, Republic of San Marino, Sweden; *middle-income countries*: Algeria, Belarus, Egypt, Lebanon, Libya, Montenegro, Morocco, Russian Federation, Syrian Arab Republic, Tunisia, and Ukraine (Supplementary file: S7.xlsx).

high density of cardiologists experience lower 30-day and 1-year mortality, compared with patients hospitalized in regions with a low density of cardiologists.[102] The under-provision of cardiologists in many ESC member countries is compounded by under-representation of females which is now recognized as a particular problem for cardiology as it affects diversity within the specialty.[103,104] Reasons for the under-representation of females are complex, but need correction so that the benefits of a more diversified work force can be realized.

Heterogeneity of capital resources was a major finding of the 2018/19 survey with a tendency for fewer hospitals per million people offering facilities for treatment of coronary disease, structural heart disease, and electrophysiological disorders in middle-income compared with high-income ESC member countries. There was similar inequality in rates of interventional procedures, no doubt driven in part by their collective expense, with new technology a key contributor to the spiralling costs of contemporary healthcare.[98] For some of these programmes, costs are expected to rise further, with potential candidates for TAVI in the EU, for example, on a steep upward trajectory as cost effectiveness is confirmed and indications expand to include patients at low surgical risk.[105–107] Implantable cardioverter-defibrillator treatment is also on an upward trajectory, but remains severely under-utilized across Europe.[108] Substantial growth in ICD implantations is expected in future years as the divergence between its utilization compared with the USA is corrected. These changes in interventional and device treatments of CVD are likely to have major implications for healthcare costs in the ESC member countries.

The data in our report indicate that national economic resource is not the only driver for delivery of equitable cardiovascular healthcare across ESC member countries. Thus, rates of coronary artery bypass graft are similar across middle-income and high-income countries despite its increased cost compared with medical therapy and PCI.[109] In some middle-income countries, rates for interventional procedures and device implantations match or exceed rates in wealthier high-income countries. Even within high-income countries the 2018/19 survey identified substantial differences in procedure rates, with ICD implantations per million people, for example, varying sevenfold between Lithuania and Czech Republic. Explanations for these inequalities may need to look beyond economic resource at differences in the national priorities given to healthcare and differences in the way in which healthcare systems are funded. Healthcare expenditure per capita in the USA, for example, is higher than in the UK, yet the ways in which expenditures are allocated are very different and contribute to better outcomes for cardiac revascularization in the UK despite lower costs.[110]

The WHO's global targets on prevention and control of NCDs provide interesting context to the CVD healthcare needs of the ESC member countries.[8] The ninth global target calls for an 80% availability of the affordable basic technologies and essential medicines, including generics, 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 with strips, and urine strips for albumin assay. It is reasonable to assume that this target has long been achieved by ESC member countries none of which meet WB low-income criteria. Yet, the fact that low-income countries 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 2018/19 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.

The paradox of greater cardiological provision in those high-income ESC member countries where need is manifestly less provides an exemplar of Tudor Hart's inverse care law[12] and together with inequalities in hypertension and smoking must contribute to the continued inequality in cardiovascular mortality between high- and middle-income member countries. Resolution of this paradox will require cardiovascular healthcare to be placed at the top of national

agendas with the development of targeted policies for CVD prevention. Examples of policies which, in recent years, have delivered step-changes in CVD burden at a national level include:

- Smoking legislation in many European member states which have resulted in almost immediate reductions in the incidence of ST-elevation myocardial infarction.[111]
- Alcohol policy in Russian Federation which has reduced consumption and increased life expectancy to an historic peak in 2018.[112]
- Primary PCI networks which in Poland have been associated with substantial reductions in mortality of patients with ST-segment elevation myocardial infarction.[113]

It is a key objective of the ESC Atlas to drive new CVD policy initiatives as part of the ESC's global mission to reduce the burden of CVD.

Supplementary material

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

Disclaimer

The main purpose of the Atlas is to map the status of the ESC member countries from a cardiovascular point of view. Such data can be useful to provide a broad profile and to identify inequalities and disparities between middle-income and high-income ESC countries to draw attention to the need for investing more resources into proper implementation of guidelines and into increasing the standards of cardiovascular disease care. Although sources of data are clearly referenced throughout the report, the summaries, interpretations, and conclusions are those of the authors. The ESC Atlas comprises national level data coming from a variety of different sources that have been processed using different methods such that data quality is variable. The ESC countries exhibit different socioeconomic, risk, and disease prevalence dynamics and hence the data contained in the present publication should be used responsibly and with caution.

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