



# Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension

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**Abstract** | High blood pressure is one of the most important risk factors for ischaemic heart disease, stroke, other cardiovascular diseases, chronic kidney disease and dementia. Mean blood pressure and the prevalence of raised blood pressure have declined substantially in high-income regions since at least the 1970s. By contrast, blood pressure has risen in East, South and Southeast Asia, Oceania and sub-Saharan Africa. Given these trends, the prevalence of hypertension is now higher in low-income and middle-income countries than in high-income countries. In 2015, an estimated 8.5 million deaths were attributable to systolic blood pressure >115 mmHg, 88% of which were in low-income and middle-income countries. Measures such as increasing the availability and affordability of fresh fruits and vegetables, lowering the sodium content of packaged and prepared food and staples such as bread, and improving the availability of dietary salt substitutes can help lower blood pressure in the entire population. The use and effectiveness of hypertension treatment vary substantially across countries. Factors influencing this variation include a country's financial resources, the extent of health insurance and health facilities, how frequently people interact with physicians and non-physician health personnel, whether a clear and widely adopted clinical guideline exists and the availability of medicines. Scaling up treatment coverage and improving its community effectiveness can substantially reduce the health burden of hypertension.

High blood pressure is one of the most important risk factors for ischaemic heart disease, stroke, other cardiovascular diseases (CVDs), chronic kidney disease and dementia<sup>1–10</sup>. Elevated blood pressure is a leading preventable cause of CVD mortality and disease burden, globally and in most regions of the world<sup>11–13</sup>. One of the global non-communicable disease (NCD) targets adopted by the World Health Assembly in 2013 is to lower the prevalence of raised blood pressure by 25% by 2025 compared with its 2010 level<sup>12,14</sup>. Raised blood pressure is defined as systolic blood pressure (SBP)  $\geq 140$  mmHg or diastolic blood pressure (DBP)  $\geq 90$  mmHg.

In this Review, we summarize the current data on the global epidemiology of blood pressure and hypertension and evaluate how they have changed over time. We also present estimates of the mortality effects of elevated blood pressure and summarize interventions that can reduce the burden of high blood pressure. To begin, we give a brief historical overview of how blood pressure came to be established as an important risk factor for CVDs and other diseases, emphasizing the global nature

of early research. We then review the data on worldwide levels and trends in blood pressure and hypertension, effects on mortality, and major causes of high and low blood pressure. We also review how blood pressure might be lowered in different populations, emphasizing how epidemiological evidence can be used in real-world conditions. Finally, we briefly present issues related to the global epidemiology of hypertension and its management in the context of the coronavirus disease 2019 (COVID-19) pandemic.

## History of blood pressure and hypertension

**Early knowledge and measurements.** In the *Yellow Emperor's Classic of Medicine* (first written approximately 200–400 BCE), the Yellow Emperor of China (approximately 2600–2700 BCE) was believed to have talked about the so-called 'hard pulse disease', claiming that 'if too much salt is used in food, the pulse hardens' and suggested the use of venesection for treatment<sup>15,16</sup>. Physicians in ancient Egypt (approximately 1500 BCE) and India (approximately 150 BCE) also noted the relationship between pulse quality and the development

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## Key points

- Hypertension is more prevalent in low-income and middle-income countries than in high-income countries.
- In 2015, 8.5 million deaths were associated with high blood pressure, 88% of which were in low-income and middle-income countries.
- Population-level measures, such as increasing the availability and affordability of fresh fruits and vegetables and lowering the sodium content of packaged and prepared foods, can lower blood pressure in the entire population.
- Effective use of pharmacological treatment for people with hypertension varies substantially globally and is particularly low in low-income and middle-income countries.
- Scaling up treatment coverage and improving its effectiveness can substantially reduce the health burden of hypertension.

of afflictions of the heart and brain<sup>17</sup>. Pulse also had an essential role in ancient Greek medicine, and its relationship with environment and disease was discussed at length by physicians including Hippocrates (460–370 BCE), Erasistratus (304–250 BCE) and Galen (130–210 CE)<sup>16–19</sup>. However, these physicians did not note the connection between apoplexy and high blood pressure or hardening of the pulse<sup>16</sup>.

In 1628, William Harvey described the process of blood flowing out of the heart and then returning to the heart via arteries, peripheries and veins<sup>17,20</sup>. Nearly 300 years later, blood pressure was discovered, and a reliable method for its measurement was devised. Even before this technology was developed, the work of a few physicians, including Richard Bright and Frederick Akbar Mahomed, led to the first description of essential hypertension in the nineteenth century, for example, hypertension in the absence of renal disease<sup>16,17,21</sup>.

The first accurate, direct measurement of human blood pressure was performed by the surgeon Faivre with the use of a mercury manometer during a limb amputation in 1856, with a reported arterial blood pressure of 115–120 mmHg (REFS<sup>22,23</sup>). Devices for the indirect measurement of blood pressure (that is, to measure the counter-pressure needed to stop the blood flow in an artery) evolved from the first sphygmograph to visualize pulse waves, invented by Karl Vierordt in 1855, to Samuel Siegfried Ritter von Basch's sphygmomanometer in 1880 (REF<sup>23</sup>). In 1896, Scipione Riva Rocci invented an inflatable cuff that compressed around the whole circumference of the arm to apply uniform pressure. The cuff size was later changed to 12 cm in 1901 from the original 5 cm (REFS<sup>22,23</sup>), and it became the prototype of cuffs that continue to be used in modern devices.

In 1905, Nikolai Korotkoff, a Russian surgeon, reported a method that uses the tapping sounds detected through a stethoscope at different phases during the deflation of the cuff to determine the pressure at which blood flow was completely blocked, that is, SBP, and the pressure at which blood flow was no longer restrained, that is, DBP<sup>22,23</sup>. Together, Korotkoff's auscultatory technique and Rocci's cuff formed the basis of modern blood pressure measurement devices.

**Blood pressure as a risk factor.** The quantitative connection between high blood pressure and mortality was first revealed in studies with the use of insurance data at the beginning of the twentieth century<sup>24,25</sup>. These data also revealed that blood pressure rises with age and is higher in those who have higher weight for their height<sup>26</sup>. The Framingham Heart Study<sup>27</sup> showed a greater risk of coronary heart disease in men and women with hypertension (defined as SBP  $\geq 160$  mmHg or DBP  $\geq 95$  mmHg) than in individuals with SBP  $< 140$  mmHg and DBP  $< 90$  mmHg. The study also showed an increased risk of CVD in those with high-normal blood pressure, that is, 130–139 mmHg for SBP and 85–89 mmHg for DBP, compared with those with optimal blood pressure, defined as SBP  $< 120$  mmHg and DBP  $< 80$  mmHg (REF<sup>28</sup>). The Prospective Studies Collaboration pooled 61 prospective observational studies with 1 million participants in Asia, Australasia, Canada, Europe and the USA and found a doubling of the risk of ischaemic heart disease and stroke with every 20 mmHg and 10 mmHg increase in SBP and DBP, respectively, starting from as low as 115 mmHg for SBP and 75 mmHg for DBP<sup>5</sup>. The Asia Pacific Cohort Studies Collaboration found similar associations in Asian and Australasian populations<sup>6,8</sup>. On the basis of observational studies, each 10 mmHg increase in SBP is associated with a 45% higher risk of ischaemic heart disease and about a 65% higher risk of ischaemic or haemorrhagic stroke in those aged 55–64 years<sup>5,8</sup>. The relative risk is inversely associated with age<sup>8</sup>.

The observational results were confirmed by data from clinical trials that lowered blood pressure. These trials included the VA Cooperative Trials, Multiple Risk Factor Intervention Trial (MRFIT), and those included in the Blood Pressure Lowering Treatment Trialists' Collaboration<sup>7,29–34</sup>. Other trials, including the Systolic Blood Pressure Intervention Trial (SPRINT), and meta-analyses of trials further showed reductions in CVD events but mixed results for cardiovascular and all-cause mortality with intensive blood pressure lowering to levels below the conventional cut-off for hypertension of 140/90 mmHg, for example, SBP of 120–130 mmHg (REFS<sup>2–4,35–37</sup>). However, most of the trials have been performed in Western populations, and trial evidence is especially scarce for Africa, Latin America and South Asia.

## Global, regional and national levels

**National and multi-country studies.** Supplementary Table 1 summarizes the studies that investigated blood pressure and hypertension trends in individual countries<sup>38–67</sup> for a period of  $\geq 20$  years. The studies that compared multiple countries<sup>68–95</sup> are summarized in

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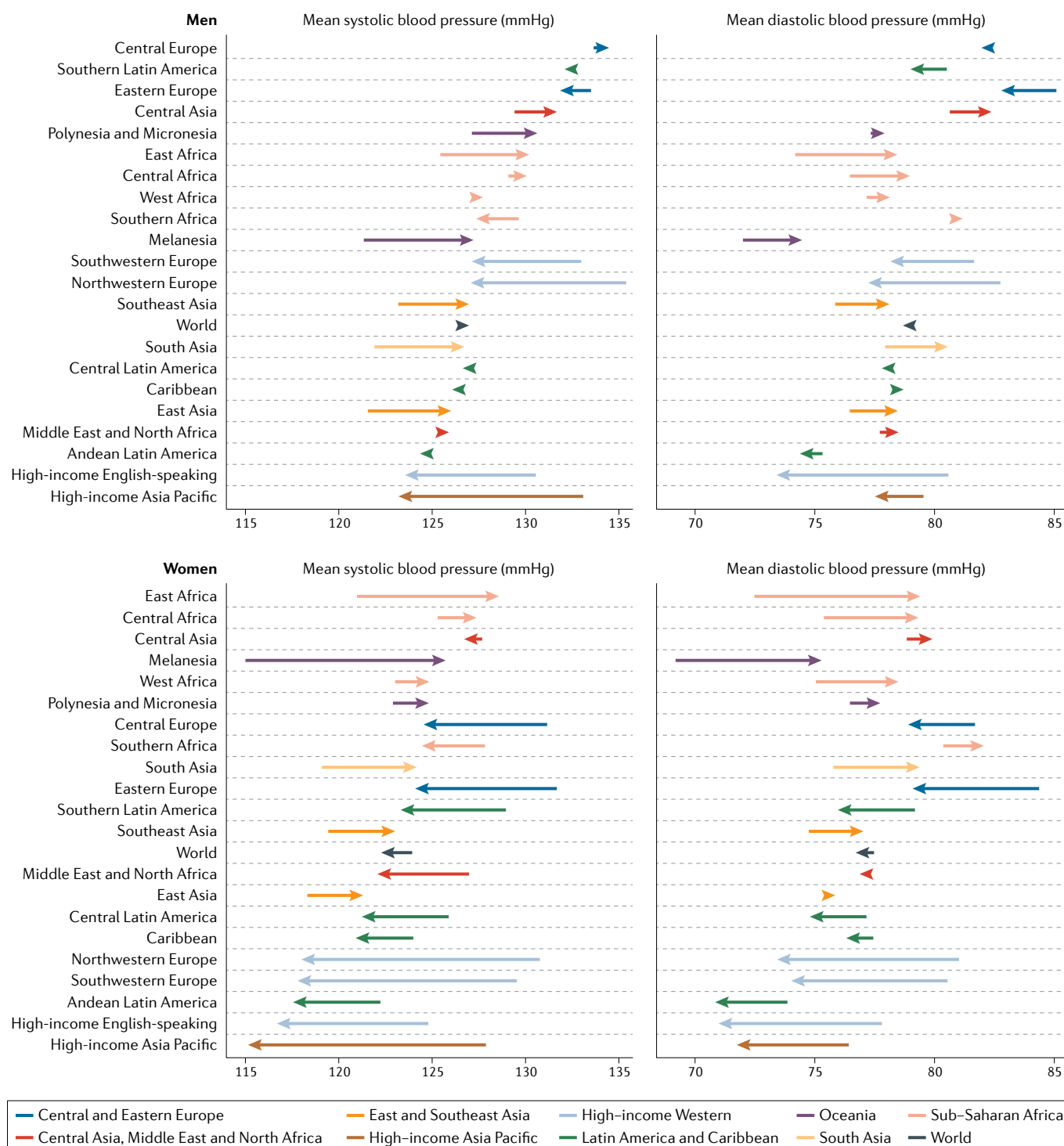
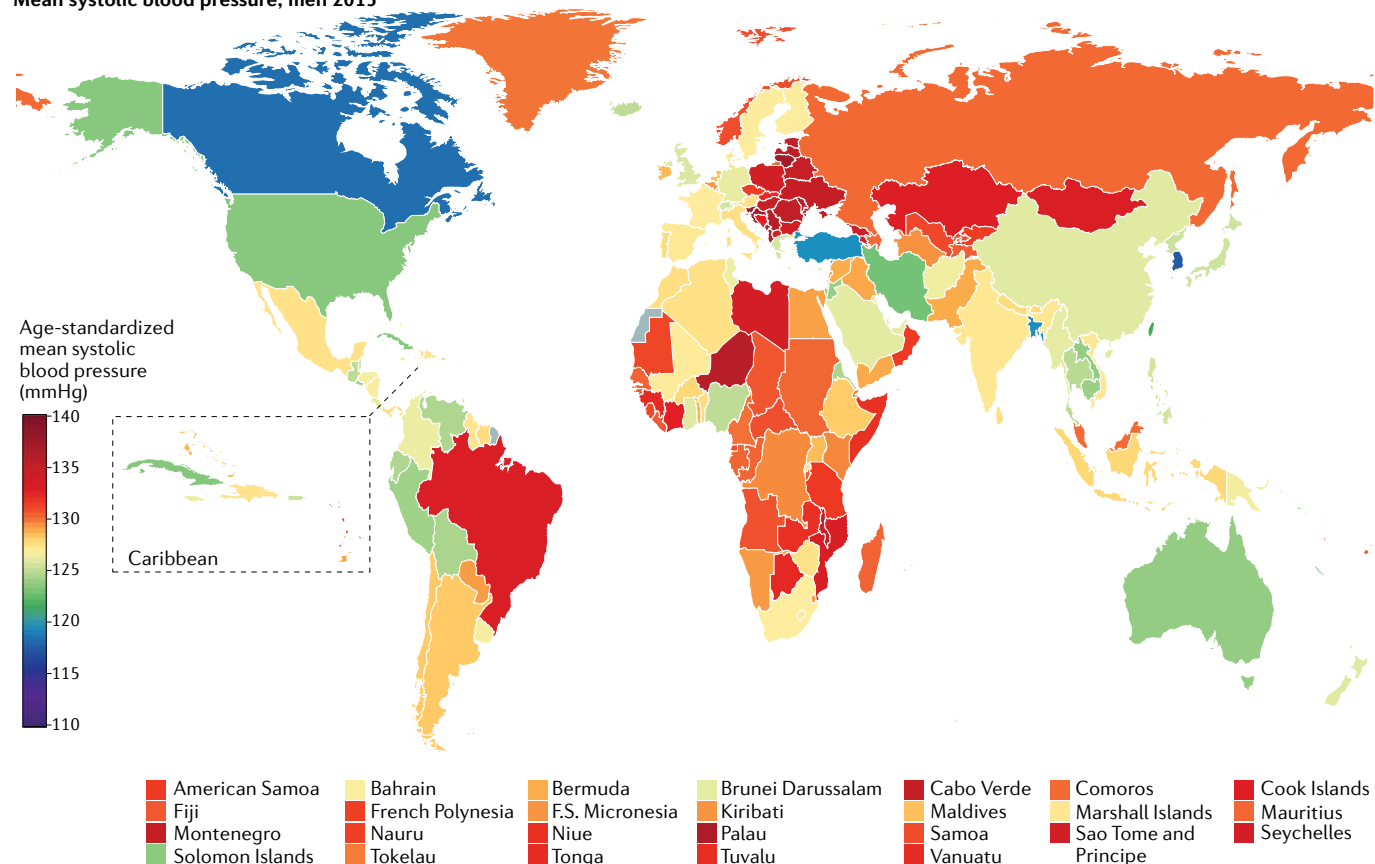


Fig. 1 | **Changes in blood pressure by region.** Changes in age-standardized mean systolic and diastolic blood pressure between 1975 and 2015 by region. The start and end points of each arrow represent the levels of blood pressure in 1975 and 2015, respectively. Rightward arrows indicate an increase in blood pressure, and leftward arrows indicate a decrease.

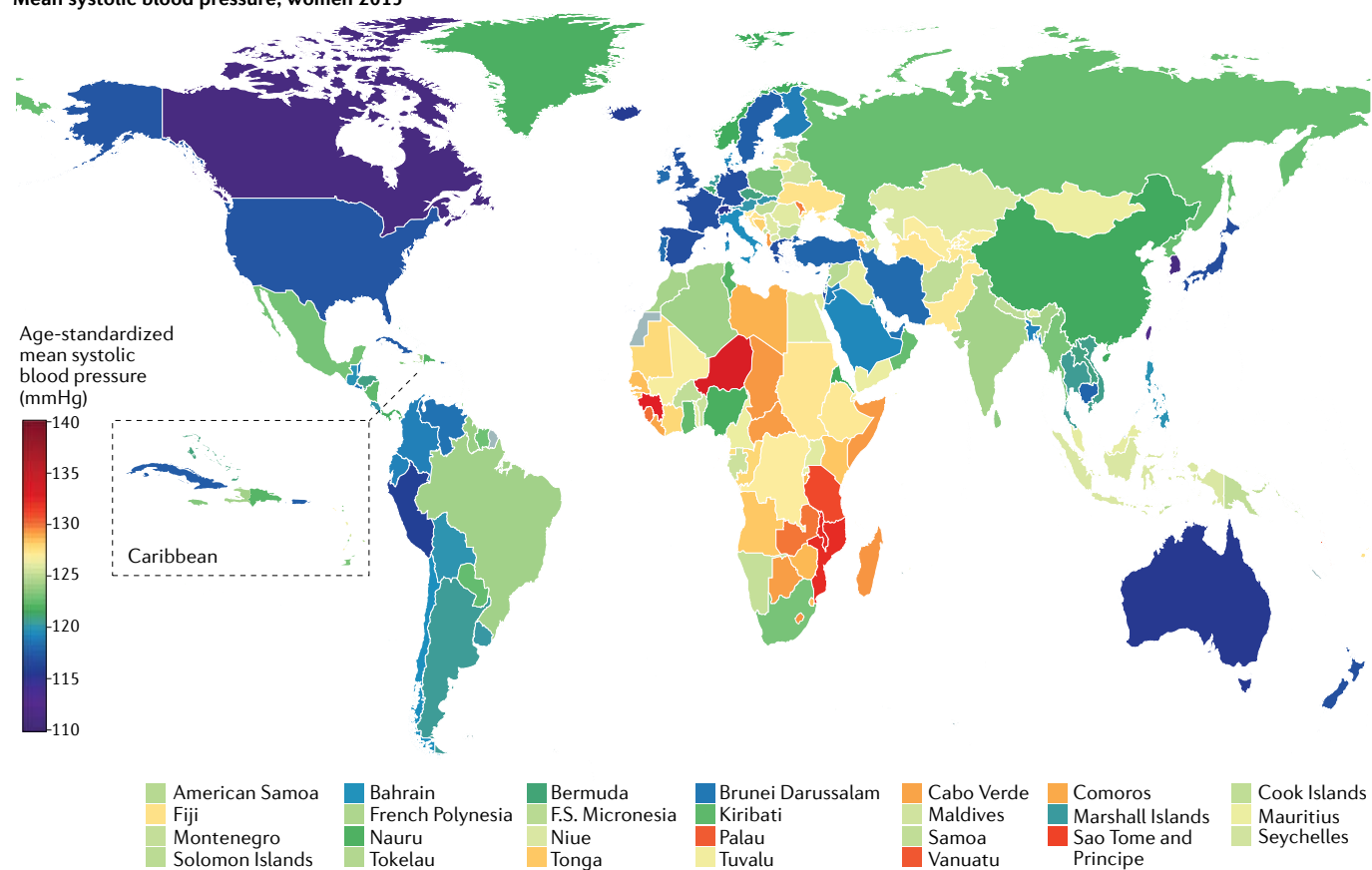
Supplementary Table 2. These studies show that blood pressure has declined in high-income countries and in some middle-income countries. By contrast, blood pressure and the prevalence of hypertension have been rising or at best stagnating in the other middle-income and low-income countries, including the world's most populous countries, China and India.

**Global studies.** Beginning in the 2000s, some studies pooled multiple data sources to understand the global patterns of blood pressure and hypertension (Supplementary Table 2). Kearney and colleagues<sup>96,97</sup> used data from 32 studies and estimated the global hypertension prevalence in 2000. Mills and co-workers<sup>98</sup> pooled 135 studies with 970,000 participants from

## Mean systolic blood pressure, men 2015



## Mean systolic blood pressure, women 2015





◀ Fig. 2 | **Worldwide systolic blood pressure.** Age-standardized mean systolic blood pressure by country in 2015. Adapted from (REF.<sup>102</sup>), CC BY 4.0 (<https://creativecommons.org/licenses/by/4.0/>).

90 countries and estimated the worldwide prevalence of hypertension for two time points in 2000 and 2010. Another study<sup>99</sup> pooled 237 data sources with >660,000 participants in a statistical model to generate global and regional estimates of mean SBP. This study also reported county results from national studies, which was possible for only eight of the 191 countries included in the analysis.

Danaei and colleagues<sup>100</sup> reported the first set of consistent and comparable country-level estimates of blood pressure trends. This study pooled 786 studies with 5.4 million participants with the use of a Bayesian meta-regression model to estimate year-on-year trends in mean SBP for 199 countries from 1980 to 2008. Forouzanfar and co-workers<sup>101</sup> pooled 844 studies with 8.7 million participants to estimate trends in mean SBP for 195 countries from 1990 to 2015. The most comprehensive estimates were produced by the NCD Risk Factor Collaboration (NCD-RisC)<sup>102</sup>, which pooled 1,479 studies with 19.1 million participants and estimated trends in mean SBP, mean DBP and the prevalence of raised blood pressure — defined as SBP  $\geq 140$  mmHg or DBP  $\geq 90$  mmHg — for 200 countries from 1975 to 2015. In the next section, we use the results from NCD-RisC to summarize the worldwide trends in blood pressure.

**Worldwide trends in blood pressure.** The global age-standardized mean SBP in 2015 among men  $\geq 18$  years of age was 127.0 mmHg, largely unchanged since 1975. SBP declined slightly among women in the same period (from 123.9 mmHg to 122.3 mmHg) (FIG. 1). Trends in the age-standardized mean DBP, which was 78.7 mmHg for men and 76.7 mmHg for women in 2015, were similar. The age-standardized prevalence of raised blood pressure declined globally in both sexes, from 29.5% to 24.1% among men and from 26.1% to 20.1% among women.

Mean SBP and DBP declined substantially in the high-income regions, from the highest in the world in 1975 to the lowest in 2015 (FIG. 1). The largest decline in mean SBP occurred in the high-income Asia Pacific region, by 3.2 mmHg and 2.4 mmHg per decade among women and men, respectively. The largest decline in mean DBP occurred in the high-income Western region: 1.8 mmHg per decade among women and 1.5 mmHg per decade among men. Mean SBP declined among women in Central and Eastern Europe, Latin America and the Caribbean and possibly in Central Asia, the Middle East and North Africa, albeit with larger uncertainty than in high-income regions. Similarly, mean DBP decreased in women in these regions, but the reduction was smaller than in high-income regions. Men had little or no change in mean SBP or DBP in these regions. In contrast to these declines, mean SBP and DBP have risen among men and women in East, South and Southeast Asia, Oceania and sub-Saharan Africa. The largest regional decrease in raised blood pressure was reported in the high-income regions, followed by Latin America

and the Caribbean, Central and Eastern Europe, Central Asia, the Middle East and North Africa. Elsewhere, the age-standardized prevalence of raised blood pressure remained unchanged, despite rising mean blood pressure.

South Korea and Canada had the lowest age-standardized mean SBP in 2015 for both men (117–118 mmHg) and women (~111 mmHg) (FIG. 2). The highest mean SBPs in men were reported in countries in Central and Eastern Europe (for example, Croatia, Lithuania and Slovenia), Oceania, Central Asia and sub-Saharan Africa, with an age-standardized mean SBP reaching 137.5 mmHg (131.2–143.8 mmHg) in Slovenia. Women in countries in sub-Saharan Africa (for example, Guinea, Malawi, Mozambique and Niger) had the highest levels of mean SBP, surpassing 132 mmHg. Countries with the lowest mean DBP were Peru and several high-income countries, including Australia, Canada, New Zealand, Singapore and the UK (FIG. 3). DBP was high throughout Central and Eastern Europe, South Asia and sub-Saharan Africa, with the age-standardized mean surpassing 85 mmHg in Lithuanian men.

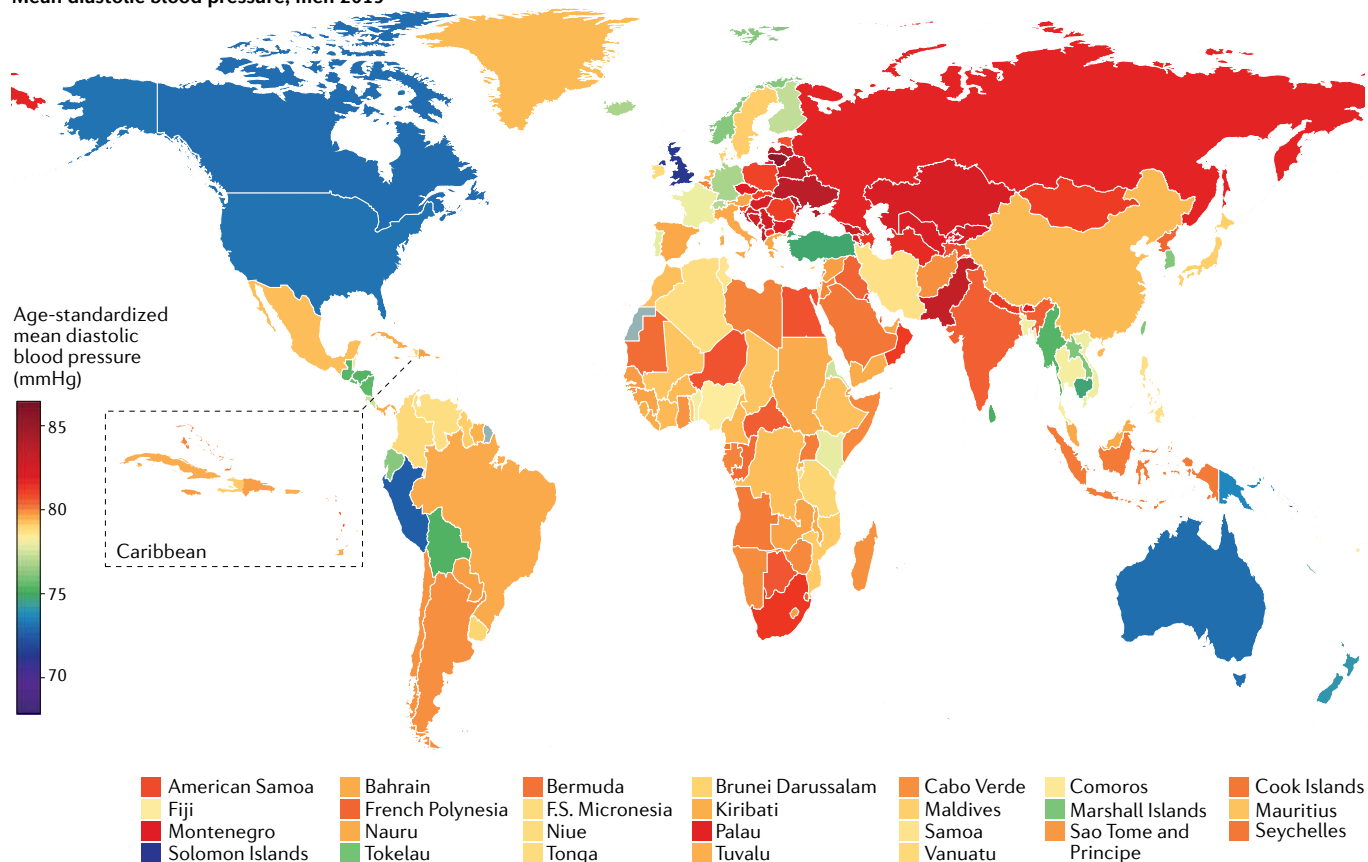
Australia, Canada, Peru, Singapore, South Korea, the UK and the USA had the lowest prevalence of raised blood pressure in 2015 for both sexes, with an age-standardized prevalence of <13% in women and <19% in men (FIG. 4). At the other extreme, the age-standardized prevalence surpassed 35% among men in some countries in Central and Eastern Europe, including Croatia, Latvia, Lithuania, Hungary and Slovenia. The prevalence of raised blood pressure was >33% among women in some countries in West Africa.

**Blood pressure and national characteristics.** Although the determinants and correlates of high versus low blood pressure at the individual level are well-established<sup>103</sup>, less is known about the association between population blood pressure and national characteristics such as national income, urbanization, diet and BMI. Two studies examined the association between population mean SBP and some national characteristics, including national income, a measure of the Western diet, the proportion of the national population living in urban areas and food share of household expenditure<sup>104,105</sup>. Next, we examine the association between mean SBP and DBP and the per capita gross domestic product (GDP), the proportion of the population living in urban areas and the age-standardized mean BMI.

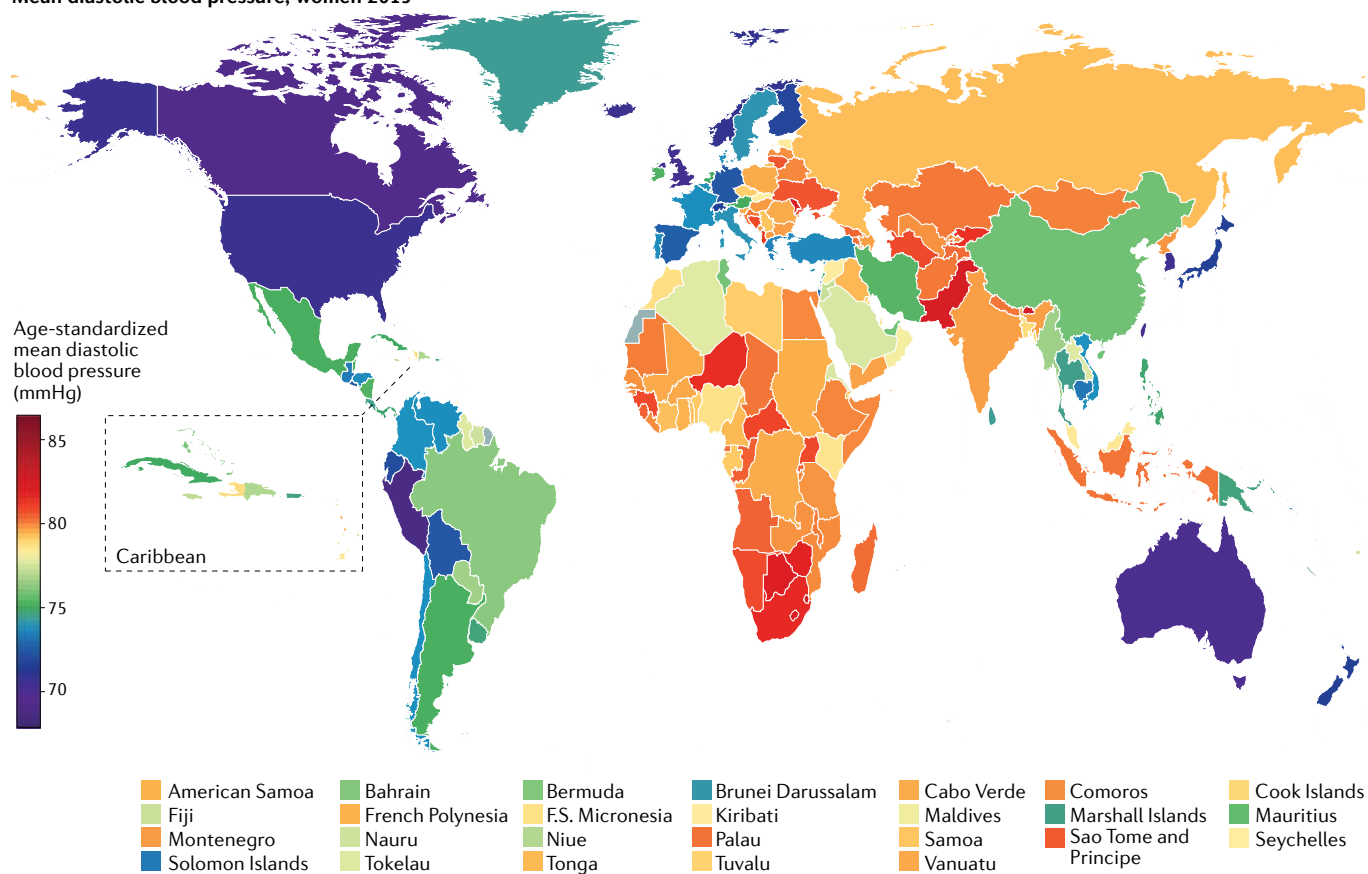
FIGURE 5 shows the associations between SBP and per capita GDP, urbanization and BMI in 1975 and 2015. In 1975, mean SBP and DBP were positively associated with per capita GDP, urbanization and BMI. By 2015, the correlation between mean SBP and these factors diminished in men and reversed in women. Correlations for mean DBP changed similarly, but the negative correlation for women was weaker than that for mean SBP.

The changing association of mean SBP and DBP with GDP and urbanization indicates that hypertension is not a 'disease of affluence' but one of poverty at the global level. The weakening of associations with BMI (FIG. 5) suggests that other dietary, environmental and health-care factors that also influence blood pressure are

## Mean diastolic blood pressure, men 2015



## Mean diastolic blood pressure, women 2015



◀ Fig. 3 | **Worldwide diastolic blood pressure.** Age-standardized mean diastolic blood pressure by country in 2015 (REF.<sup>102</sup>).

counteracting the effects of BMI. For example, higher income and more year-round availability of fruits and vegetables have increased their availability in most countries<sup>106</sup>. Similarly, at least in high-income countries, more people with hypertension are treated<sup>95</sup>, especially individuals with a high BMI<sup>107</sup>. Some low-income and middle-income countries with high blood pressure levels (for example, those in South Asia and sub-Saharan Africa) had one or more adverse factors, including low consumption of fresh fruits, high consumption of salt, and a high prevalence of maternal and childhood undernutrition<sup>106,108–112</sup>. The changing association between blood pressure and these country characteristics highlights the need to understand what factors drive the changes in high-income countries and in low-income and middle-income countries.

**Changes in blood pressure distributions.** Blood pressure is affected by nutritional, environmental and behavioural factors throughout the life course, including fetal and early childhood nutrition and growth<sup>113</sup>, adiposity<sup>103</sup>, diet (particularly sodium and potassium)<sup>114,115</sup>, alcohol use<sup>116</sup>, smoking<sup>117</sup>, physical activity<sup>118</sup>, air pollution<sup>119</sup>, noise<sup>120</sup>, psychosocial stress<sup>121</sup> and the use of blood-pressure-lowering medicines. Changes in some of these determinants, such as an increase in BMI and better nutrition in childhood and adolescence, can shift the entire population distribution of blood pressure and thereby change both the mean value and the prevalence of raised blood pressure. By contrast, medication and lifestyle change in those with elevated blood pressure would reduce the prevalence of raised blood pressure by affecting the high-blood-pressure tail of the distribution, with a fairly small effect on the mean blood pressure value.

An analysis of multi-country data from the WHO MONICA project revealed that different percentiles of population blood pressure distribution changed as much as its mean in most populations throughout the study period, which was about 10 years from the 1980s to the 1990s; nonetheless, the upper percentile changed by a larger amount in some communities<sup>71</sup>. The NCD-RisC found that from 1985 to 2016, in most regions where the prevalence of raised blood pressure decreased, the decline in mean blood pressure was the main driver of the decline in prevalence, contributing to at least half of the total decline<sup>122</sup>. In regions where the prevalence of raised blood pressure increased or remained unchanged, the increase was driven entirely by a rise in mean blood pressure.

The behavioural, nutritional and environmental drivers of the shift in the population distribution of blood pressure remain uncertain largely because these determinants are poorly measured. Salt intake might have declined in some countries where blood pressure declined<sup>123–125</sup>, but it has discordant trends with blood pressure in other countries<sup>109,126–130</sup>. The prevalence of smoking has declined in most high-income countries and some middle-income countries, but remains high or is increasing in other low-income and middle-income

regions<sup>131</sup>. Similarly, alcohol consumption has also had mixed trends across countries and regions<sup>132</sup>. In high-income countries, the decline in blood pressure has occurred despite rising BMI, an established risk factor for high blood pressure, whereas both BMI and blood pressure are rising in most low-income and middle-income countries<sup>110</sup>. Other potential population-wide determinants of blood pressure include increased availability and consumption of fruits and vegetables through better year-round availability<sup>106,108</sup>, central heating at home and work, which would lower winter blood pressure<sup>133–135</sup>, and improvements in early childhood and adolescent nutrition, as seen in greater adulthood body height in successive birth cohorts<sup>112</sup>. Blood pressure is also decreasing in adolescents in high-income countries and possibly some middle-income countries<sup>93,136–139</sup>, suggesting a role of the life-course effects from these population-wide determinants.

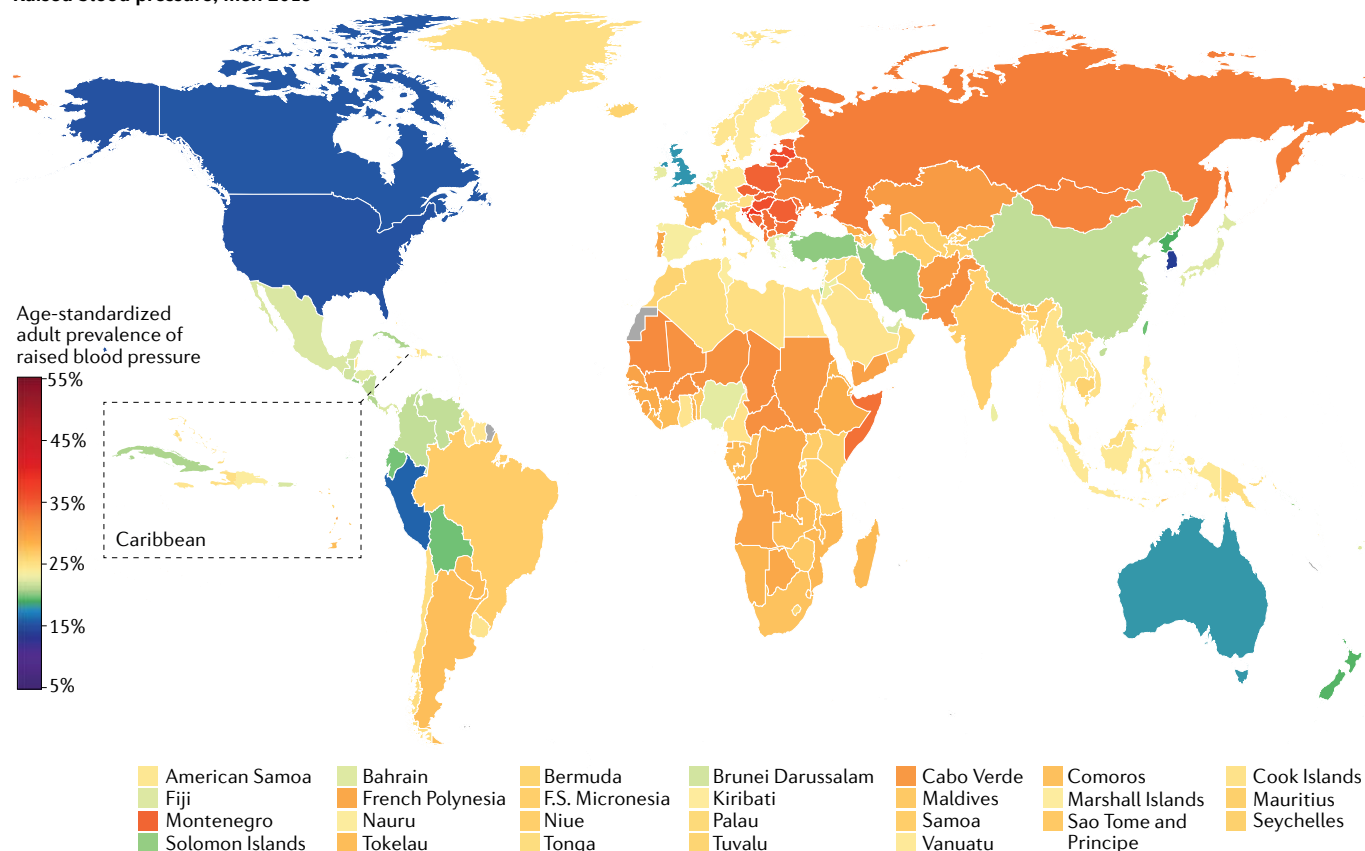
### Within country patterns

**Blood pressure in men and women.** Men are known to have a higher blood pressure than women<sup>140</sup>, but this relationship could vary by age and geography. According to NCD-RisC data, in 2015, men had a higher age-standardized mean SBP than women in most countries. Men also had higher DBP and prevalence of raised blood pressure than women in most countries, except in sub-Saharan Africa and a few countries in Oceania and Asia, where the sex-specific pattern was reversed. The male–female differences in the age-standardized mean and prevalence were mainly owing to sex-specific differences before the age of 50 years. Men and women aged  $\geq 50$  years had more similar mean SBP and DBP and prevalence of raised blood pressure, with countries divided into some with lower and others with higher blood pressure in men (FIG. 6). The male–female difference in blood pressure in 2015 was on average larger in high-income countries and those in Central and Eastern Europe than in countries in other regions.

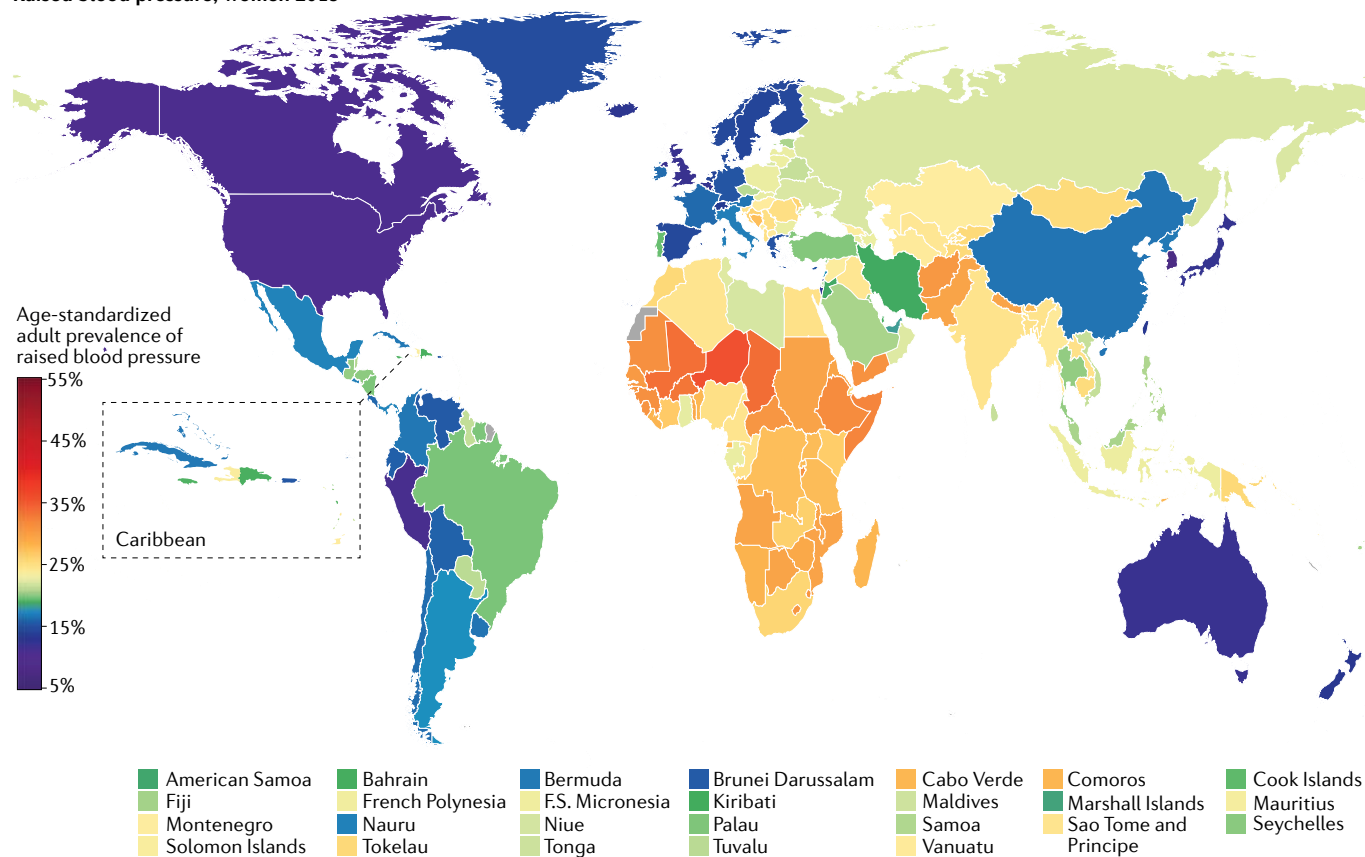
**Subnational patterns of blood pressure.** Several studies have considered differences in blood pressure between rural and urban populations or in relation to socioeconomic status (SES). In high-income countries, blood pressure has consistently been reported to be higher in low-SES groups than in high-SES groups and higher in poorer and more rural areas of countries than in richer urban centres<sup>141–145</sup>. The observed decline in blood pressure in high-income countries benefited all SES groups; however, the inverse SES gradient has persisted for as long as data have been available<sup>146–153</sup>.

Data from studies on geographical and socioeconomic patterns of blood pressure and hypertension in low-income and middle-income countries are more mixed than in high-income nations<sup>74,142,154–165</sup>. A review of early data from Africa and Asia led to the conclusion that “there are communities, in whom blood pressure does not rise with age and in whom the problem of essential hypertension and its complications appears to be virtually non-existent. I must emphasize that in the vast majority of tropical communities blood pressure patterns are similar to those seen in the economically

## Raised blood pressure, men 2015



## Raised blood pressure, women 2015



◀ Fig. 4 | **Worldwide prevalence of raised blood pressure.** Age-standardized prevalence of raised blood pressure by country in 2015 (REF.<sup>102</sup>).

advanced countries of the world”<sup>166</sup>. Meta-analyses and re-analyses of health survey data have concluded that groups with lower SES have a higher prevalence of hypertension in countries across all income levels except those in Africa<sup>167,168</sup>. The multicentre PURE study<sup>73</sup> also found that high-education groups have a lower prevalence of hypertension in all countries except those in low-income nations.

### Mortality

A few studies have combined data on the population mean blood pressure with risk ratios from epidemiological studies to estimate the number of deaths attributable to high blood pressure<sup>11,169–172</sup>. The focus of these calculations was initially on CVDs and was subsequently extended to include chronic kidney disease<sup>11,171,172</sup>. According to data from these studies, an estimated 7.7–10.4 million annual deaths are attributable to elevated blood pressure levels<sup>11,172</sup>.

FIGURE 7 shows the number of deaths from CVDs and chronic kidney disease attributable to all levels of high blood pressure by region and cause of death. In 2015, an estimated 4.5 million deaths in men and 4.0 million deaths in women were attributable to SBP higher than the optimal level of 115 mmHg, 88% of which were in low-income and middle-income regions. This figure represents an increase of 1.6 million and 0.9 million for men and women, respectively, compared with 1990. The increase was a result of doubling of deaths attributable to high blood pressure in East, South and Southeast Asia and sub-Saharan Africa. By contrast, in high-income Western and Asia Pacific regions, the number of deaths attributable to high blood pressure declined by 20–30% despite a larger and older population. In relative terms, deaths from chronic kidney disease attributable to high blood pressure increased more than deaths from CVDs (FIG. 7).

### Prevention and management

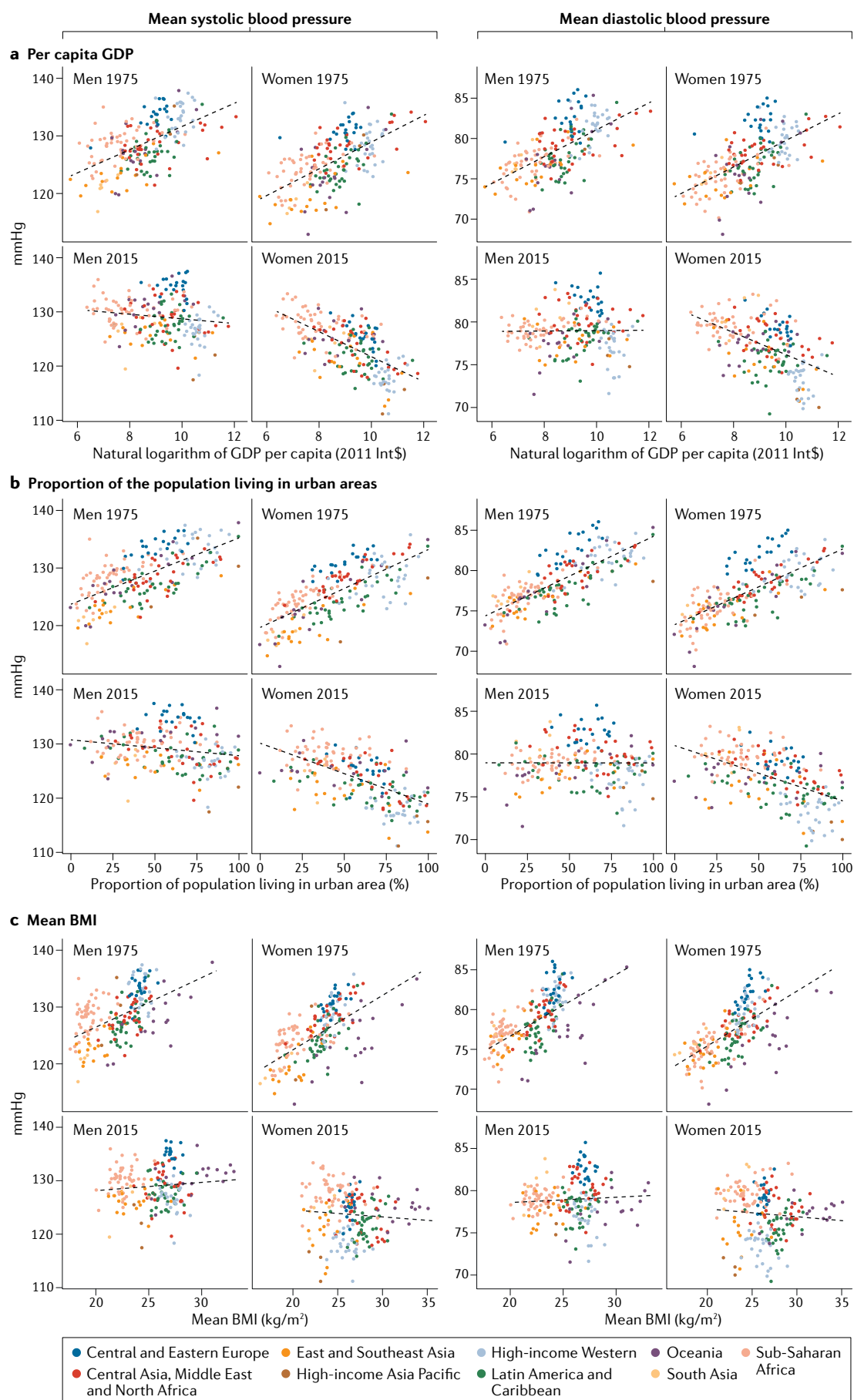
**Non-pharmacological interventions.** Successful control of hypertension should entail a comprehensive strategy of prevention at the individual and population levels, with the use of non-pharmacological interventions throughout the life course<sup>1,103,173</sup>. Although a large number of studies have established risk factors for hypertension, fewer studies have evaluated the effectiveness of non-pharmacological interventions for hypertension prevention, especially in global or multi-country contexts. Studies that have evaluated the effectiveness of non-pharmacological interventions for hypertension prevention include some of the *Lancet* Series in NCDs<sup>174</sup>, the Disease Control Priorities study<sup>175</sup>, the *Lancet* Commission on Hypertension<sup>1</sup>, and the WHO Action Plan for the Prevention and Control of NCDs<sup>176</sup>. Prevention of hypertension is also addressed in some national and regional guidelines<sup>177–179</sup>. Effective interventions at the individual level include advice from physicians and nurses to reduce dietary sodium and increase the consumption of fruits and vegetables.

At the population level, several interventions and strategies are effective in reducing the risk of hypertension. Examples of effective population-based interventions include increasing the availability and affordability of fresh fruits and vegetables through pricing and targeted subsidies for low-income families, lowering the sodium content of packaged and prepared food and staples such as bread by influencing food reformulation and regulatory and voluntary mechanisms and making dietary salt substitutes readily available and accessible<sup>1,174–176,179</sup>. The success of these strategies requires active and sustained collaboration among global, regional, national and local governments, myriad government agencies, and health promotion and disease prevention experts<sup>179–181</sup>. Implementation research is needed to identify what individual and population-level interventions and strategies work best and can be sustained in each setting and any unintended consequences<sup>1,182</sup>. In particular, studies in low-income and middle-income countries are needed to identify and evaluate effective population-level interventions in settings with limited resources available to individuals, families and governments, and with limited infrastructure, and in different social contexts.

**Pharmacological treatment.** Progress in the pharmacological treatment of hypertension in the past 50 years is among the most remarkable in medicine. With hundreds of thousands of patients recruited into trials since the landmark VA Cooperative Study<sup>29</sup>, a wide portfolio now exists of cost-effective and safe pharmacological options to treat people with hypertension. The evidence is among the most robust in clinical medicine and supported by the largest number of outcome-based randomized clinical trials<sup>178</sup>. Systematic reviews and meta-analyses of trials have shown that a 10 mmHg reduction in SBP or a 5 mmHg reduction in DBP is associated with substantial reductions in all major cardiovascular events (about 40% in heart failure, 35% in stroke, 15% in coronary heart disease, 20% in cardiovascular mortality and 10% in all-cause mortality)<sup>183</sup>. Importantly, these relative risk reductions are consistent across baseline levels of blood pressure and absolute disease risk and comorbidities<sup>4,7,33</sup>.

Many hypertension clinical guidelines exist worldwide, including the 2018 guidelines by the European Society of Cardiology and the European Society of Hypertension<sup>178</sup> and the 2020 guidelines by the International Society of Hypertension<sup>184</sup>. Several national guidelines have been developed within the past 5 years, including guidelines from Canada<sup>177</sup>, China<sup>185</sup>, India<sup>186</sup>, Kenya<sup>187</sup>, the UK<sup>188</sup> and the USA<sup>189</sup>. WHO is also working on its first hypertension clinical guideline, which is expected to be ready in 2021. Although guidelines can differ in certain features, such as the blood pressure threshold value required to start treatment or the target blood pressure for those on treatment, a clear consensus exists about the strong evidence for the effectiveness of four major classes of pharmacotherapies, including blockers of the renin–angiotensin–aldosterone system (RAAS), calcium channel blockers,  $\beta$ -blockers and thiazide or thiazide-like diuretics. Although specific indications exist for some of the pharmacological groups, such as  $\beta$ -blockers for patients with coronary artery







# Fig. 5 | Association between country characteristics and blood pressure.

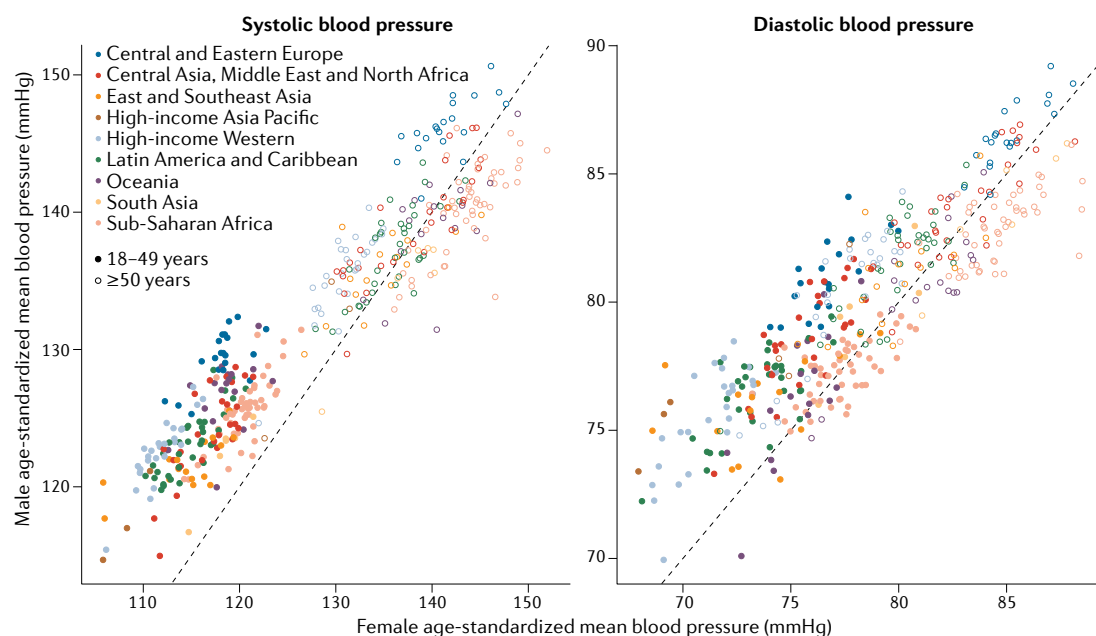
**a** | Relationship between mean systolic and diastolic blood pressure and per capita gross domestic product (GDP) for 1975 and 2015. **b** | Relationship between mean systolic and diastolic blood pressure and the proportion of the population living in urban areas for 1975 and 2015. **c** | Relationship between mean systolic and diastolic blood pressure and mean BMI for 1975 and 2015. In 1975, mean systolic and diastolic blood pressure were positively correlated with GDP, the proportion of the population living in urban areas and mean BMI. In 2015, mean blood pressure was no longer correlated with these country characteristics for men and negatively correlated with GDP and the proportion of the population living in urban areas for women. Each point shows one country, coloured by region.

disease or heart failure and RAAS blockers for patients with chronic kidney disease, a consensus has been established that all antihypertensive drugs have a similar effect on major cardiovascular outcomes, including mortality<sup>178</sup>. Fixed-dose combination therapy, with two or more agents in a single pill, is a crucial component of the current medical management of hypertension. This approach has several advantages, including pharmacological (synergies of mechanisms of action and fewer adverse effects owing to lower doses) and practical (increasing adherence) aspects, and is currently recommended as initial therapy in most guidelines<sup>190,191</sup>.

Another crucial pillar of antihypertensive treatment is the overall risk approach. The relative effect of antihypertensive treatment is approximately constant across baseline cardiovascular risks. Therefore, individuals at higher risk benefit more in absolute terms<sup>33</sup>. In addition to blood pressure levels, most current guidelines consider the overall cardiovascular risk of treatment recommendations. The overall risk can be estimated by considering age and other cardiovascular risk factors such as lipid levels, diabetes mellitus and smoking,

which can be combined statistically into risk scores<sup>192</sup>. In addition to the content of guidelines, recognition of the importance of delivery approaches for successful guideline implementation has increased. Some of the effective implementation approaches include task shifting, electronic decision-support tools and simplification of guidelines<sup>193,194</sup>. The increasing recognition of the need to simplify guidelines has influenced global hypertension programmes, such as the programmes by the Resolve To Save Lives initiative and the Global Standardization of Hypertension Treatment Project, which have adopted simplified treatment protocols guided by local circumstances to improve compliance<sup>195,196</sup>. Finally, although antihypertensive treatment counts among the most remarkable achievements in clinical medicine, and now many antihypertensive drugs are cost-effective, safe and off-patent, the availability and affordability of antihypertensive drugs are limited, and their use is still low, as we discuss in the next section<sup>197</sup>.

**Global variations in treatment.** The extent to which patients with hypertension are treated and whether their blood pressure is lowered to levels below the threshold for hypertension (that is, controlled) varies substantially across countries. A regional hypertension programme by Kaiser Permanente Northern California and the nationwide Canadian Hypertension Education Program have achieved some of the best performances in hypertension control, with 70–90% of individuals with hypertension having their blood pressure controlled<sup>198,199</sup>. This achievement demonstrates that high levels of hypertension control are feasible through improving health-care provider and patient compliance with evidence-based



**Fig. 6 | Comparison of female and male blood pressures.** Comparison of female and male blood pressures in people aged 18–49 years and ≥50 years in 2015. Each point shows one country, coloured by region. The interaction between sex and age group was significant ( $P < 0.0001$  for systolic and diastolic blood pressure) in an analysis of variance in a model with blood pressure as a dependent variable and sex, age group and their interaction as independent variables. Men aged 18–49 years have higher blood pressure levels than women of the same age in most countries, and men and women aged ≥50 years have on average similar blood pressure levels.

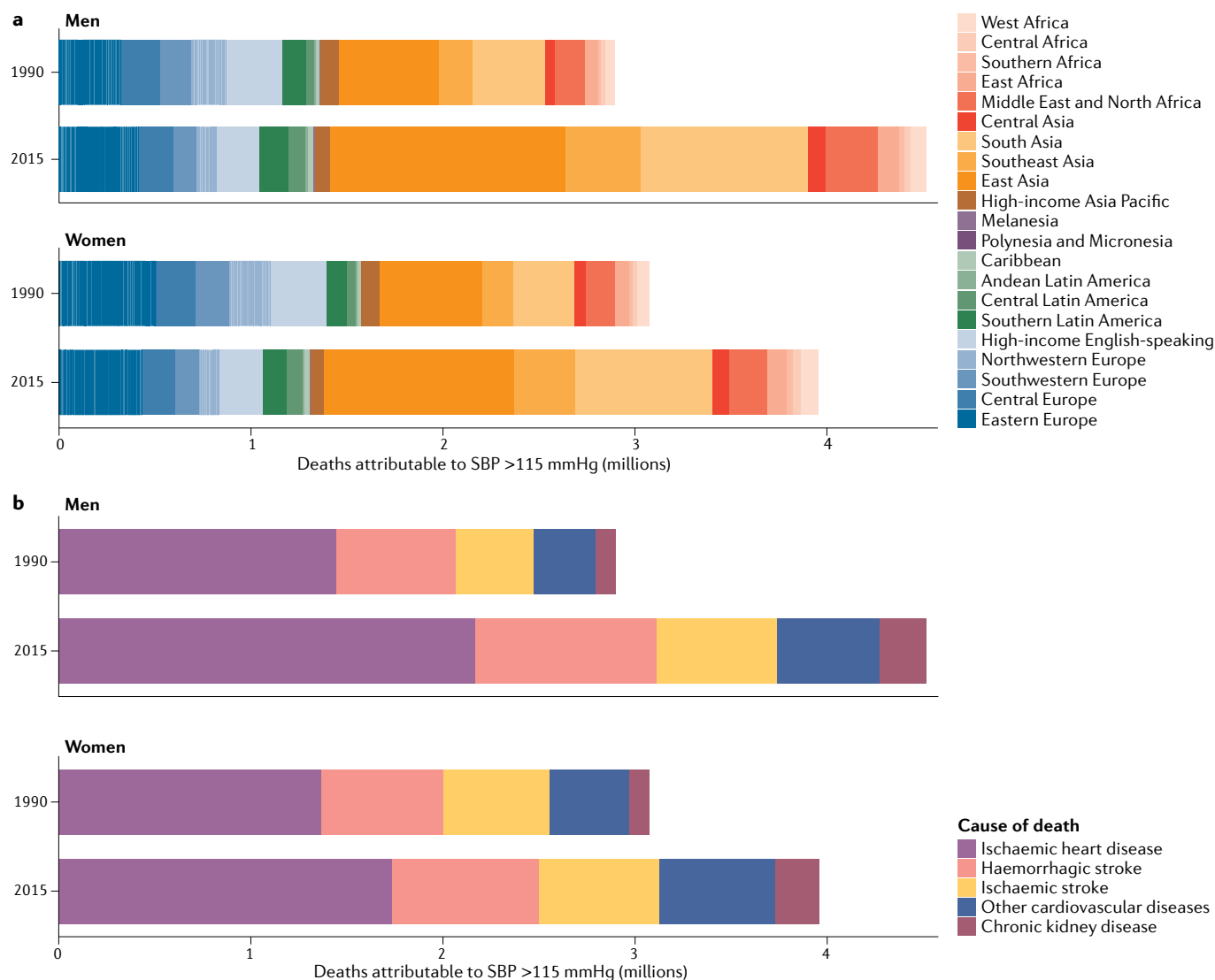


Fig. 7 | **Deaths attributable to high blood pressure.** Deaths attributable to high systolic blood pressure (SBP) in 1990 and 2015, coloured by region (part **a**) and cause of death (part **b**).

guidelines, updating recommendations annually, establishing a hypertension registry, monitoring physician performance and providing feedback, implementing regular blood pressure measurements and single-pill combination therapy, tailored knowledge dissemination and national leadership<sup>198,200</sup>.

National coverage and effectiveness of hypertension treatment vary substantially. A 2019 study used national data from 44 low-income and middle-income countries and found that only 30% of people with hypertension are receiving pharmacological treatment and only 10% have their blood pressure controlled below the hypertension threshold level<sup>92</sup>. High-income countries generally perform better, but treatment and control rates in most countries are lower than those with high-quality hypertension programmes. Another 2019 study used national data on hypertension treatment from the 1970s in 12 high-income countries<sup>95</sup>. The study showed that Canada, Germany, South Korea and the USA had the highest rates of awareness, treatment and control of hypertension, whereas Finland, Ireland, Japan and Spain

had the lowest. Even in the best-performing countries, treatment coverage for hypertension was at most 80% and control rates were <70%, with treatment and control rates being as low as 40% and 20%, respectively, in the worst-performing countries<sup>95</sup>. The study also found that hypertension treatment and control rates have plateaued since ~2010 (REF.<sup>95</sup>). Another study used data from 90 countries worldwide and found that, between 2000 and 2010, the percentage of people with hypertension who were being treated increased both in high-income and in low-income and middle-income countries, but the gap between them widened<sup>98</sup>.

Some studies have identified factors that affect the treatment of hypertension. The implementation of universal health coverage, the extent of out-of-pocket spending for care and medicines, and the number and location of health facilities influence access to health-care. The extent of diagnosis and appropriate treatment of hypertension are influenced by the number of health personnel and mechanisms such as task sharing with non-physician health workers and well-developed

clinical guidelines for hypertension management<sup>201,202</sup>. Well-developed supply chains ensure regular availability of antihypertensive medicine, which, together with their cost and the extent of the out-of-pocket payment, determine whether patients can obtain and afford the medicine<sup>197</sup>. In addition, mechanisms such as m-health (for example, text message reminders), home visits by community health workers and other community-based health promotion programmes improve patient adherence to treatment<sup>203–208</sup>. Similarly, the use of combination therapy improves both adherence to treatment and treatment effectiveness<sup>190,209,210</sup>. Evidence from trials supports the effectiveness of improving many of these factors, but macrosocial and macroeconomic factors, including insurance, procurement and personnel, affect how interventions can be scaled up regionally and nationally.

Information technology has brought new approaches to hypertension management. Telemedicine might help overcome physical barriers to accessing health care, including for remote and disparate populations and at times of restricted population mobility. However, the evidence from clinical trials is mixed on the effectiveness

of telemedicine in improving blood pressure control<sup>211–213</sup>. Other approaches are emerging, including smartphone-based apps for self-management and tracking and wearable devices (for example, smartwatches) that measure blood pressure. Although these approaches look promising, the evidence is limited to support their effectiveness in improving blood pressure control<sup>214–216</sup>. By providing remote access to health care, these approaches might partly overcome the obstacles posed by limited health infrastructure for hypertension control in low-income and middle-income countries. Conversely, they might create new barriers for some caused by the increased demand for new technology that might be available only to those with higher income and education. Therefore, a need exists to conduct implementation research on these approaches to identify the populations and contexts in which they work, and to determine how they work and their effects on inequalities.

**Global hypertension initiatives.** The public health importance of hypertension is recognized in several global initiatives. Global Hearts, led by WHO, includes

Table 1 | Features of global initiatives and programmes for hypertension treatment

Initiative or programme	Target regions	Key areas of action
Global Hearts (WHO)	NA	HEARTS (six technical packages for the prevention and control of cardiovascular disease): training health-care workers to counsel on behavioural risk factors and healthy lifestyles; simple, standardized and evidence-based treatment protocols for hypertension and diabetes mellitus; ensuring access to essential medicines and technology; risk-based approach to the management of cardiovascular disease, including country-specific risk charts; implementing team-based care and task shifting; and improved monitoring system with standardized indicators (for example, hypertension control rate) and data collection tools
WHF Hypertension Roadmap	NA	Opportunistic screening; promoting use of inexpensive, good-quality generic medications for hypertension; education on adherence to lifestyle modification and medication use
Pan-African Society of Cardiology Roadmap	Sub-Saharan Africa	A ten-point action plan for African ministries of health, including: creating or adopting simple and practical clinical evidence-based hypertension management guidelines; annual monitoring and report of the detection, treatment and control rates of hypertension, with a clear target for improvement by 2025, with use of the WHO STEPwise approach to surveillance; integrating hypertension management within existing health services such as disease-specific vertical programmes (for example, HIV and tuberculosis); task-sharing with trained community health workers; and ensuring availability of essential equipment and medicines
Resolve To Save Lives	China, India, Thailand	Practical treatment protocols with specific medications, dosages and steps to take if blood pressure is not controlled; adopting community-based care and task sharing; ensuring supply of medications; adopting easy-to-take medicine regimens, using free or low-cost medications and follow-up visits, and making blood pressure monitoring readily available; and leveraging technology to develop information systems that allow for continuous, real-time improvement
Global Standardization of Hypertension Treatment Project	Barbados, Malawi	Using nationally relevant, evidence-based and implementable treatment protocols that are endorsed by key stakeholders; identifying a core set of widely available medications that are safe and effective; ensuring the quality, safety and consistent supply of the core set of medications; developing hypertension registries and monitoring targets (for example, blood pressure control) within a care system or programme to evaluate the efficacy of the system or programme and make adjustments accordingly; empowering patients by involving them in decisions related to their treatment, creating a physician–patient relationship on the basis of mutual respect, and utilizing educational materials and peer-support groups to improve the knowledge, attitude and adherence to treatment of the patients; use of team-based care that coordinates care delivery within the team (task sharing) and ensures continuity of care; and use of community-based settings for services such as blood pressure checks and education and engaging community partners (for example, civil society organizations and media)

NA, not applicable; WHF, World Heart Federation.

two specific components related to hypertension; the SHAKE package (salt reduction) and the HEARTS technical package (strengthening the management of CVDs in primary health care)<sup>217</sup>. The World Heart Federation Hypertension Roadmap, and its regional adaptations such as the one developed by the Pan-African Society of Cardiology, aims to provide a framework for countries and regions to implement policy and health system solutions for hypertension control<sup>218,219</sup>. The Resolve To Save Lives initiative aims to prevent 100 million deaths globally and has two hypertension-related components (salt reduction and hypertension control)<sup>220</sup>. The global importance of hypertension is also recognized because hypertension treatment coverage is considered a tracer indicator in the WHO universal health coverage index<sup>221</sup>. The key features of global hypertension initiatives and programmes are summarized in TABLE 1.

**Hypertension and the COVID-19 pandemic.** Hypertension has emerged as a common comorbidity in patients hospitalized with COVID-19 (REFS<sup>222–230</sup>). Studies in China, Italy, the UK and the USA found a strong association between pre-existing hypertension and disease severity and mortality. However, findings were mixed after accounting for age and other comorbidities and risk factors, particularly obesity and diabetes, which often co-occur with hypertension<sup>222,223,230–237</sup>. Therefore, at the time of this Review, insufficient evidence exists to establish hypertension or high blood pressure as a risk factor for hospitalization with, or prognosis of, COVID-19 independent of age and other conditions.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) binds to angiotensin-converting enzyme 2 receptors to gain access to cells<sup>238</sup>. Therefore, concerns existed about the safety of RAAS inhibitors for patients with COVID-19 (REF.<sup>239</sup>). However, a growing body of evidence has emerged to allay this concern<sup>231,240,241</sup>, and clinical groups have recommended the continued use of RAAS inhibitors in these patients<sup>242–248</sup>. In addition, studies have shown a potential protective effect of RAAS inhibitors in patients with COVID-19 with or without hypertension<sup>249–252</sup>, but data are limited beyond recommending that patients receiving RAAS inhibitors should continue with their medication as usual.

At the time of this Review, the COVID-19 pandemic has also had an important indirect effect on hypertension and CVDs<sup>243,253,254</sup>. Elective patient care and routine contact with health-care services, including hypertension care, has plummeted since the outbreak,

especially where national or local lockdowns have been implemented<sup>255–258</sup>. The reduced contact with health-care services might delay the diagnosis of hypertension and disrupt the treatment of hypertension. A WHO survey revealed that 53% of countries have reported disruptions in hypertension management<sup>256</sup>, but the precise effect of this disruption remains unknown. The COVID-19 pandemic might also affect social networks and interactions, physical activity, smoking, mental stress, alcohol use and diet<sup>259,260</sup>, all of which influence hypertension directly or indirectly. Together with other disruptions in care, these issues might have already contributed to excess deaths beyond those caused by COVID-19 directly<sup>261</sup>.

What long-term effect the COVID-19 pandemic will have on hypertension management remains uncertain. For example, there might be an increased uptake of telemedicine or remote consultation with general practitioners<sup>243,253</sup>. In the short term, efforts should be focused on ensuring that all social groups, particularly poor and vulnerable groups, have opportunities and support to access healthy foods and to have outdoor time, and that preventive and treatment care continues to be available.

## Conclusions

This Review demonstrates that hypertension has always been present in low-income populations throughout the world to varying degrees. After decades of decline in high-income countries and an increase in some low-income and middle-income regions, blood pressure levels are now much higher in lower-income countries, especially in sub-Saharan Africa and South Asia, and in Central and Eastern Europe. Consequently, now 88% of the mortality attributable to high blood pressure is outside high-income regions. We have also found that the evidence on whether blood pressure and hypertension are higher in rural or urban populations is equivocal.

The reasons for the massive declines in blood pressure in high-income countries are probably multifaceted and include both general economic and infrastructural development and specific actions in the health systems towards prevention and treatment<sup>71,122</sup>. Although overall economic and health development over the coming decades might replicate these achievements elsewhere, the large and globally inequitable burden of high blood pressure should motivate the use of the personal and population-based interventions reviewed here so that rising trends are reversed and declines are accelerated.

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