

# Global burden of blood-pressure-related disease, 2001



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## Summary

**Background** Few studies have assessed the extent and distribution of the blood-pressure burden worldwide. The aim of this study was to quantify the global burden of disease related to high blood pressure.

**Methods** Worldwide burden of disease attributable to high blood pressure ( $\geq 115$  mm Hg systolic) was estimated for groups according to age ( $\geq 30$  years), sex, and World Bank region in the year 2001. Population impact fractions were calculated with data for mean systolic blood pressure, burden of deaths and disability-adjusted life years (DALYs), and relative risk corrected for regression dilution bias.

**Findings** Worldwide, 7.6 million premature deaths (about 13.5% of the global total) and 92 million DALYs (6.0% of the global total) were attributed to high blood pressure. About 54% of stroke and 47% of ischaemic heart disease worldwide were attributable to high blood pressure. About half this burden was in people with hypertension; the remainder was in those with lesser degrees of high blood pressure. Overall, about 80% of the attributable burden occurred in low-income and middle-income economies, and over half occurred in people aged 45–69 years.

**Interpretation** Most of the disease burden caused by high blood pressure is borne by low-income and middle-income countries, by people in middle age, and by people with prehypertension. Prevention and treatment strategies restricted to individuals with hypertension will miss much blood-pressure-related disease.

## Introduction

Cardiovascular disease is now endemic worldwide and no longer limited to economically developed countries.<sup>1,2</sup> About a third of all deaths in middle-income countries are caused by cardiovascular disease; this proportion is similar to that in many developed nations.<sup>1</sup> Furthermore, rates of disease are generally much higher in developing than in developed countries—for example, age-specific stroke rates in Tanzania are about three to six times higher than those in the UK.<sup>3</sup> Cardiovascular disease also typically occurs at a younger age in developing than in developed countries:<sup>1</sup> for example, about 52% of deaths from such disorders in India occur before 70 years of age, compared with 23% in established-market economies.<sup>4,5</sup>

In the context of this large and growing disease burden, strategies to improve population health require consistent and comprehensive measures of the contribution of major risk factors to premature mortality and disability.<sup>6,7</sup> These estimates can elucidate the potential for prevention and provide an important input into health planning and other cost-utility decisions. Therefore, the importance of modifiable cardiovascular health risks, such as blood pressure,<sup>8–14</sup> should not be overestimated or underestimated.

This report provides updated estimates of the global burden of disease attributable to high blood pressure by age and sex for adults and by World Bank region. It also summarises work done as part of the disease control priorities in developing countries Global Burden of Disease study (DCP2).<sup>15,16</sup>

## Methods

### Data collection

The population attributable risk method was used to estimate disease burden related to high blood pressure.<sup>17</sup>

Population attributable risk (or population attributable burden) is the proportional reduction in average disease risk over a specified time interval that would be achieved by eliminating the exposure of interest from the population if the distributions of other risk factors remain unchanged.<sup>18</sup> The key data inputs for population attributable risk are current blood pressure levels, associations between blood pressure and disease outcomes, and disease burden.

Data for systolic blood pressure were obtained from the Global Burden of Disease 2000 study and updated to include more recent, country-level data.<sup>15,16</sup> The search strategies are described elsewhere,<sup>19,20</sup> but, in brief, included a review of studies published between 1980 and 2001 inclusive, complemented by data from personal communications with researchers and study investigators. For the current analyses, mean blood pressure was re-estimated by age group (30–44, 45–59, 60–69, 70–79, and  $\geq 80$  years), sex, and World Bank regions (low-income and middle-income regions of east Asia and Pacific, Europe and central Asia, Latin America and the Caribbean, Middle East and north Africa, south Asia, and sub-Saharan Africa, and high-income regions globally; webtable).<sup>16</sup>

For calculation of attributable burden, a best population distribution of blood pressure with which current distributions can be compared is needed. The best distribution is that which would yield the lowest population risk of adverse health outcomes,<sup>1,21,22</sup> and as such is different from individual treatment targets. A mean systolic blood pressure of 115 mm Hg for all age, sex, and region groups was chosen as the best distribution on the basis of two main sources of evidence: cohort-study data for the level of systolic blood pressure associated with the lowest

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See [Comment](#) page 1480

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See Online for webtable

	Deaths				DALYs			
	Stroke	Ischaemic heart disease	Hypertensive disease	Other cardiovascular disease	Stroke	Ischaemic heart disease	Hypertensive disease	Other cardiovascular disease
East Asia and Pacific	951	471	254	97	12 955	5365	3083	1045
Europe and central Asia	709	1024	100	150	8895	11 070	1201	1609
Latin America and the Caribbean	144	169	71	43	2112	1962	813	442
Middle East and north Africa	71	155	61	29	990	1939	728	352
South Asia	449	711	62	75	6397	9302	926	1082
Sub-Saharan Africa	179	148	50	52	2551	1934	681	630
Low-income and middle-income economies*	2502	2678	598	445	33 899	31 572	7432	5161
High-income economies	418	668	109	197	5265	5994	990	1638
World†	2921	3346	706	642	39 164	37 566	8421	6798

Data are in 1000s and rounded to the nearest 1000. \*Combined data for previous six regions. †Combined data for all regions.

**Table 1: Attributable deaths and disability-adjusted life years (DALYs) for high blood pressure for various cardiovascular endpoints in 2001 by World Bank region**

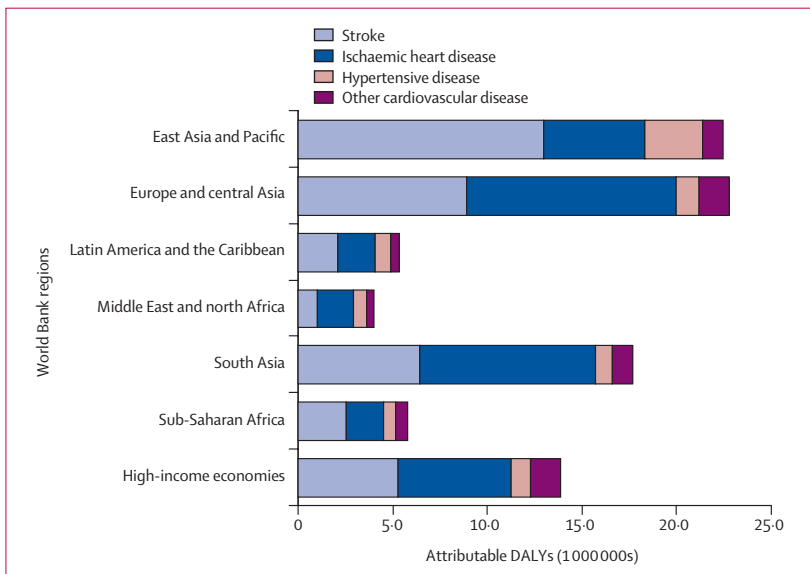
relative risk for cardiovascular disease,<sup>10,11</sup> and mean systolic blood pressure in populations with very low prevalences of cardiovascular disease.<sup>14,19,23–28</sup> In this paper, high blood pressure refers to systolic blood pressure greater than 115 mm Hg; this includes all categories of prehypertension and hypertension as defined in Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure 7 guidelines.<sup>29</sup>

Estimates of disease burden were obtained from the WHO 2003 *World health report*<sup>30</sup> and reattributed to World Bank regions.<sup>16</sup> Estimates for both death and disability-adjusted life years (DALYs) were used. DALYs quantify burden of disease and disability in populations by incorporating both life-expectancy and some measure of

quality of life.<sup>16</sup> The methods used to make these estimates are described elsewhere.<sup>14,19</sup>

All blood-pressure-related disease outcomes had to be Global Burden of Disease endpoints, limiting analyses to cerebrovascular disease (ICD 10 I60–69), ischaemic heart disease (I20–25), hypertensive disease (I10–13), including essential hypertension, hypertensive heart disease, and hypertensive renal disease, and other cardiovascular diseases (I00, I26–28, I34–37, I44–51, I70–99). Hypertensive disease is not an ideal category and is somewhat artificial, because disorders in this category are more likely to be part of a continuum rather than a distinct group. Much of the blood-pressure-related disease burden will therefore be missed by this endpoint. However, this code is typically used when hypertension is presumed to be the main underlying cause of death. The positive association of blood pressure with this outcome is steep but not vertical, implying less than 100% causation. Other cardiovascular disease consists of various disorders, including heart failure (which is the most common, even after many deaths cited as heart failure have been recoded to coronary heart disease),<sup>19</sup> pulmonary heart disease, diseases of the pericardium and endocardium, and conduction disorders. In view of the positive association between blood pressure and cardiovascular deaths not caused by stroke, ischaemic heart disease, or hypertensive disease,<sup>10</sup> this endpoint had to be included. Data were not available for stroke subtypes or renal failure; however, a more restricted hypertensive renal disease category was incorporated into the hypertensive-disease endpoint.

Finally, for the calculation of attributable burden, data were needed for the relative risk of disease endpoints that were causally related to blood pressure. These data relating to the effects of prolonged blood-pressure differences were obtained from overviews of cohort studies, which provide more reliable estimates of risk than individual studies because of greater sample sizes, greater number of



**Figure 1: Disability-adjusted life years (DALYs) attributable to high blood pressure by region and endpoint in 2001**

endpoints,<sup>8-11</sup> and correction for regression dilution bias.<sup>8,31</sup> Although some uncertainties exist about exactly how well data from cohort studies and trials match,<sup>32</sup> there is evidence that the relative risks per mm Hg change in blood pressure are much the same<sup>8,12,33,34</sup> and most, if not all, of the beneficial effects of blood-pressure-lowering drugs are probably mediated by how much they reduce blood pressure. Several overviews have quantified relative risk, and the current analyses used age-specific estimates from an overview<sup>11</sup> that was larger and more recent than that used in the Global Burden of Disease 2000 study;<sup>10</sup> however, all the overviews have produced broadly consistent results.

### Statistical analysis

We used population attributable risk methods to estimate the disease burden due to high blood pressure.<sup>17</sup> Population attributable fractions were calculated with a population impact fraction to estimate the attributable burden due to excess blood pressure. The method is described in detail elsewhere.<sup>16</sup> Briefly, the population attributable fraction is calculated by comparing the current worldwide distributions of a risk factor with the theoretical minimum distribution and estimates the percentage reduction in disease or death if exposure to that risk factor were reduced to that minimum distribution. This method takes into account the entire population risk-factor distribution by focusing on continuous (rather than categorical) associations between risk factor and disease. The attributable fraction or fraction of disease or death attributable to the risk factor in a population is found with the following equation:

$$PIF = \frac{\int_{x=0}^m RR(x)P(x) - \int_{x=0}^m RR(x)P'(x)}{\int_{x=0}^m RR(x)P(x)}$$

PIF=population impact fraction

RR(x)=relative risk at exposure level *x*

*P*(*x*)=population distribution of exposure

*P'*(*x*)=counterfactual distribution of exposure

*m*=maximum exposure level

Uncertainty in estimated disease burden can arise from incomplete information, potential biases or heterogeneity of input data, or uncertainty in the analysis models used. Issues around this uncertainty and sensitivity analyses are discussed elsewhere.<sup>16</sup>

### Role of the funding source

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### Results

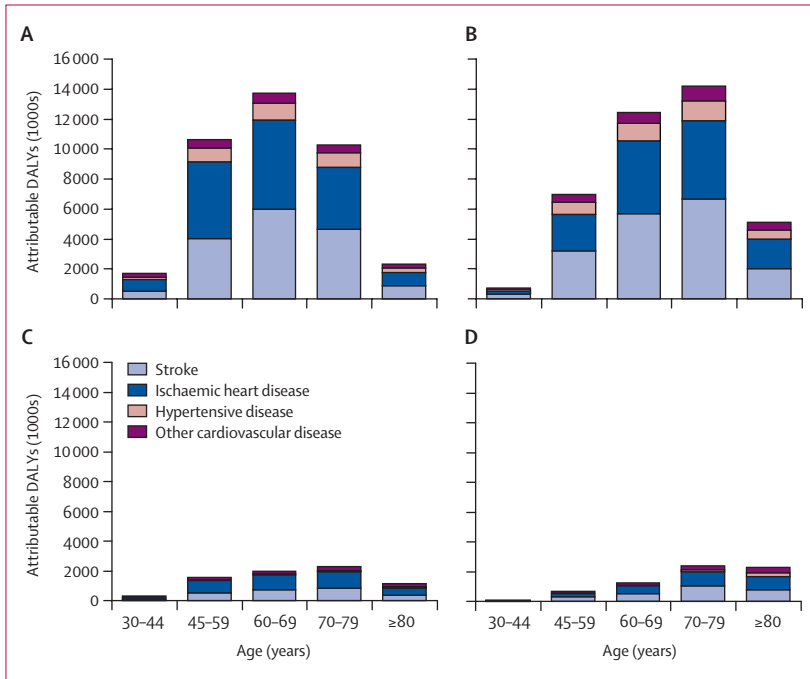
About 54% of stroke, 47% of ischaemic heart disease, 75% of hypertensive disease, and 25% of other cardiovascular disease worldwide was attributable to high blood pressure. In total, about 7.6 million (13.5%) of all deaths and 92 million (6.0%) of all DALYs in the year 2001 were attributable to high blood pressure as a cause of these diseases. Burden attributable to high blood pressure was greatest for stroke and ischaemic heart disease (table 1).

Over 80% of the attributable burden of disease was seen in low-income and middle-income regions. The highest number of attributable deaths and DALYs occurred in these regions of Europe and central Asia (predominantly eastern Europe), and east Asia and the Pacific (including China), followed by south Asia

	Deaths				DALYs			
	Stroke	Ischaemic heart disease	Hypertensive disease	Other cardiovascular disease	Stroke	Ischaemic heart disease	Hypertensive disease	Other cardiovascular disease
East Asia and Pacific	215	106	57	22	2947	1220	701	238
Europe and central Asia	605	874	85	128	6397	7962	864	1157
Latin America and the Caribbean	140	165	69	42	1899	1764	731	398
Middle East and north Africa	134	294	115	54	1890	3702	1389	673
South Asia	168	266	23	28	2496	3629	361	422
Sub-Saharan Africa	200	166	56	58	2649	2008	707	654
Low-income and middle-income economies*	233	250	56	42	3096	2884	679	471
High-income economies	143	229	37	68	1775	2021	334	552
World†	214	245	52	47	2815	2700	605	489

\*Calculated from combined data for six previous regions. †Calculated from combined data for all regions.

**Table 2: Attributable deaths and disability-adjusted life years (DALYs) per 100 000 population per year for high blood pressure for various cardiovascular endpoints in 2001 by region**



**Figure 2: Disability-adjusted life years (DALYs) attributable to high blood pressure**  
Men (A) and women (B) in low-income and middle-income countries. Men (C) and women (D) in high-income countries.

	Deaths	DALYs
East Asia and Pacific	13.6%	6.5%
Europe and central Asia	35.0%	19.6%
Latin America and the Caribbean	13.0%	5.1%
Middle East and north Africa	16.5%	6.1%
South Asia	9.6%	4.3%
Sub-Saharan Africa	4.0%	1.7%
Low-income and middle-income economies	12.9%	5.6%
High-income economies	17.6%	9.3%
World	13.5%	6.0%

**Table 3: Deaths and disability-adjusted life years (DALYs) attributable to high blood pressure in 2001**

(including India) and high-income economies (table 1, figure 1). Although the order of rankings changed when examined by disease endpoint, these regions remained the ones with the greatest attributable burden.

When expressed in terms of rates (ie, attributable deaths and DALYs per 100 000 of population; table 2), the ranking of the regions changed. Europe and central Asia had some of the highest attributable death rates for all endpoints, but a mix of other low-income and middle-income regions also ranked consistently higher than high-income regions. Attributable death and DALY rates were generally about 1.5–2 times higher in low-income or middle-income regions than in high-income regions for most disease endpoints.

More deaths and DALYs were attributable to stroke than to ischaemic heart disease in east Asia and the

Pacific and sub-Saharan Africa, but in most other subregions there were more deaths and DALYs attributable to ischaemic heart disease than to stroke (figure 1, table 1). This pattern—and the differing ratios of ischaemic heart disease to stroke between regions—largely indicates the overall estimates of burden of stroke and ischaemic heart disease for the regions.

About 39% of DALYs in high-income regions were in those aged 45–69 years, but in low-income and middle-income regions this proportion was 56% (figure 2). The total attributable burden was almost evenly split between men and women in all regions. In terms of blood pressure, about just over half the attributable burden occurs in people with mean systolic blood pressure less than 145 mm Hg.<sup>14</sup> This finding results from the continuous associations of blood pressure with disease and the many people with blood pressure in the 120–150 mm Hg range.

Estimates of attributable deaths and DALYs in any given region are determined by population size, estimated number of events, and age structure in that region. The effect of the attributable burden in a specific region might therefore be better estimated as the percentage of all deaths and DALYs in that region (table 3). The proportion of burden attributable to high blood pressure varied from 4% to 35% for deaths and from 2% to 20% for DALYs across the regions. Blood-pressure-related attributable burden for both deaths and DALYs was greatest in Europe and central Asia and lowest in sub-Saharan Africa. However, the effect of blood-pressure-related burden was still large in all economies. About 18% of all deaths and 9% of all DALYs were attributable to high blood pressure in high-income regions, and 13% and 6% in low-income or middle-income regions.

### Discussion

This study has shown that about 7.6 million deaths (about 13.5% of the total) and 92 million DALYs (6.0% of the total) worldwide were attributed to high blood pressure in 2001. Overall, more than 80% of the attributable burden of disease was in low-income and middle-income regions, and a greater proportion of the burden was in young age groups in these regions than it was in high-income regions. High blood pressure was a major health issue in all world regions, and it accounted for more than a third of deaths and almost a fifth of DALYs in Europe and central Asia.

Risk assessment always includes some degree of uncertainty. In this study, blood-pressure estimates were based on many surveys done around the world, with systematic averaging and extrapolation methods.<sup>16,19,20</sup> The best available epidemiological data provide estimates of optimum blood pressure and the strength of associations with different disease outcomes.<sup>14,16,19</sup> All disease outcomes related to blood pressure had to map to Global Burden of Disease endpoints, which limited some analyses as the endpoints were not always ideally

specific—for example, renal disease related to blood pressure was not estimated directly. However, given that there are direct and positive associations with blood pressure and all the outcomes all these endpoints were included despite their shortcomings. The mortality and morbidity data were based on updated WHO estimates<sup>16</sup> and are the best available global data.

Reduced estimated current blood-pressure values, a raised threshold for defining optimum values, and decreased estimates of relative risk would each have resulted in lower estimates of attributable fraction. Conversely, changing demographics in many middle-income and low-income regions since the data were gathered are likely to result in greater attributable burden than estimated here. Other major drivers of uncertainty are the assumptions around discounting rates and age weighting. Although these factors do not seem to affect the overall ranking of various disorders, they do affect the age distribution of the burden.<sup>16</sup> Overall, the results of this study are likely to be within 5–10% of the burden in high-income regions, and 10–15% for many low-income and middle-income regions. Uncertainty is greatest in low-income and middle-income regions with the fewest input data.<sup>14,19</sup>

Estimates from both the current burden of disease analyses and the 2002 WHO Global Burden of Disease study<sup>1,2,14,19,20</sup> indicate that the burden of disease attributable to high blood pressure was about double that suggested by the 1990 Global Burden of Disease study.<sup>35–37</sup> The main reason for this disparity was lack of correction for regression-dilution bias in the earlier analysis.<sup>8,31</sup> These analyses also gave higher estimates of attributable burden than those made for burden of hypertension,<sup>38–40</sup> in view of the very large number of people with high blood pressure but who are not classified as hypertensive. Despite substantial differences in the input data used, both the WHO study and the current study produced broadly similar results, with about 13% and 14% of deaths, respectively, and 4·4% and 6·0% of DALYs attributed to high blood pressure.

These analyses accord with previous WHO findings that a substantial proportion of cardiovascular disease is attributable to high blood pressure. The results also emphasise that this burden is distributed over different economic regions, age groups, and blood-pressure levels and is certainly not limited to people with hypertension. Furthermore, the combined burden attributable to major modifiable risk factors for cardiovascular disease is substantial, and much greater than the so-called 50% myth.<sup>41</sup> Previous analyses have suggested that blood pressure, along with other established cardiovascular risk factors, such as high cholesterol, being overweight or obese, smoking, and physical inactivity, could cause about 80–90% of ischaemic heart disease and 70–75% of stroke globally.<sup>1,42</sup>

These and similar analyses therefore provide an estimate of the potential scale of benefits from prevention strategies.

The optimum mix of interventions to achieve this aim requires detailed cost-utility analyses, and the societal benefits are dependent on the costs of these interventions and the costs of untreated high blood pressure.

#### Contributors

CMML drafted the paper. SVH analysed the data. All authors contributed to the design of the paper and analysis and revisions to the Article.

#### Conflict of interest statement

CMML and SVH declare that they have no conflict of interest. AR has minority shares in Iusero, which is developing blood-pressure-lowering implants, has several research grants in the area of blood-pressure lowering, and has consulted for several companies that market blood-pressure-lowering drugs.

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