Epidemiology and risk of hypertension

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Abstract

Hypertension is the most prevalent cardiovascular (CV) disorder, affecting 20-50% of the adult population in developed countries. Prevalence of hypertension increases with age, rising steeply after the age of 50, and affecting more than 50% of this population. Females generally have lower BP values except those aged ≥60 years, whose systolic BP tends to be higher than in males. Findings from the WHO MONItoring Trends and Determinants in CArdiovascular Diseases (MONICA) Project showed a remarkably higher prevalence of hypertension in Eastern Europe, and virtually no difference in the rates of controlled hypertension among Eastern and Western populations. Over the past one to two decades, the prevalence has remained stable or decreased in developed countries, and has increased in developing countries. Awareness and treatment of hypertension has increased in most developed countries but hypertension is poorly controlled worldwide, with less than 25% controlled in developed countries, and less than 10% in developing countries.

Key words: prevalence of hypertension, awareness of hypertension, treatment of hypertension, control of hypertension, population impact of hypertension.

Hypertension is the most prevalent cardiovascular (CV) disorder, affecting 20-50% of the adult population in developed countries [1]. Prevalence of hypertension increases with age, rising steeply after the age of 50, and affecting more than 50% of this population.

Blood pressure as a risk factor for cardiovascular disease

Elevated BP has been identified as a risk factor for coronary heart disease (CHD), heart failure, stroke, peripheral arterial disease, and renal failure in both men and women in a large number of epidemiological studies [2-5] (Figure 1). Observational evidence is also available that blood pressure (BP) levels correlate inversely with cognitive function and that hypertension is associated with an increased incidence of dementia [6]. Historically, diastolic BP was long considered a better predictor of cerebrovascular disease and CHD than systolic BP. This was reflected in the design of major randomized controlled trials of hypertension management, which used diastolic BP as an inclusion criterion until the 1990s [7]. Individuals with isolated systolic hypertension were excluded from such

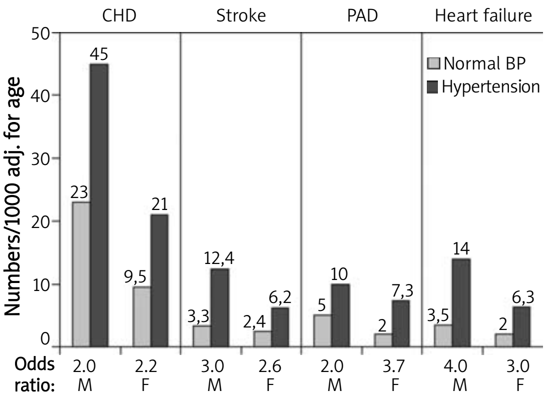


Figure 1. Risk of cardiovascular events related to hypertension and normotension. Adapted from ref. [3]
M – males, F – females

trials by definition. Nevertheless, a large compilation of observational data before [2] and since the 1990s [8] confirms that both systolic and diastolic BP show a continuous graded independent relationship with the risk of stroke and coronary events (Figures 2, 3). Data from observational studies involving one million individuals have indicated that death from both CHD and stroke increases progressively and linearly from BP levels as low as 115 mm Hg systolic and 75 mm Hg diastolic upward [8]. The increased risks are present in all age groups ranging from 40 to 89 years old. For every 20 mm Hg systolic or 10 mm Hg diastolic increase in BP, there is a doubling of mortality from both CHD and stroke.

In addition, longitudinal data obtained from the Framingham Heart Study indicated that BP values in the 130-139/85-89 mm Hg range are associated with a more than twofold increase in relative risk from cardiovascular disease (CVD) compared with those with BP levels below 120/80 mm Hg (Figure 4) [9].

The apparently simple direct relationship between increasing systolic and diastolic BP and CV risk is confounded by the fact that systolic BP rises throughout adult life in the vast majority of populations whereas diastolic BP peaks at about age 60 in men and 70 in women, and falls gradually thereafter [10].

This observation helps to explain why a wide pulse pressure (systolic BP – diastolic BP) has been shown in some observational studies to be a better predictor of adverse CV outcomes than either systolic or diastolic BP individually [11] and to identify patients with systolic hypertension who are at specifically high risk [12]. However, the largest meta-analysis of observational data in one million patients in 61 studies (70% of which were conducted in Europe) [8] showed that both systolic and diastolic

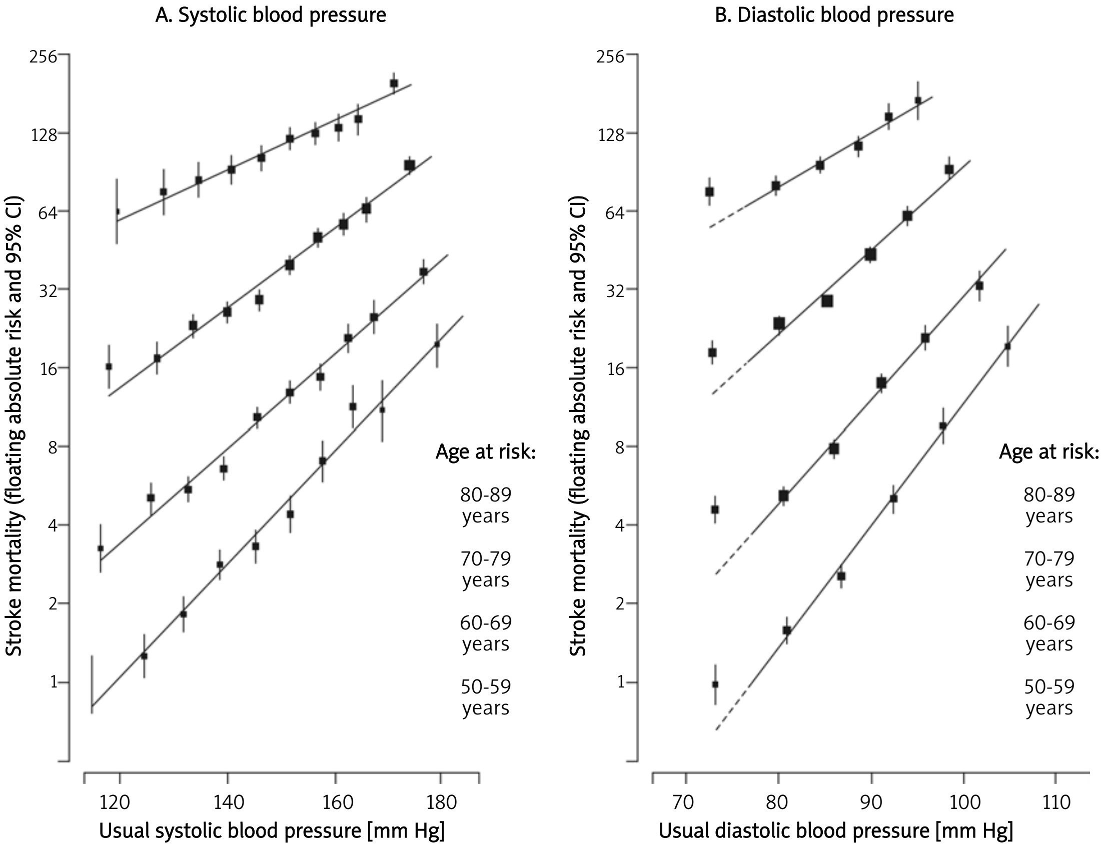


Figure 2. Stroke mortality rate in each decade of age plotted for the usual systolic (A) and diastolic (B) blood pressure at the start of that decade. Data from one million adults in 61 prospective studies. Adapted from ref. [8]

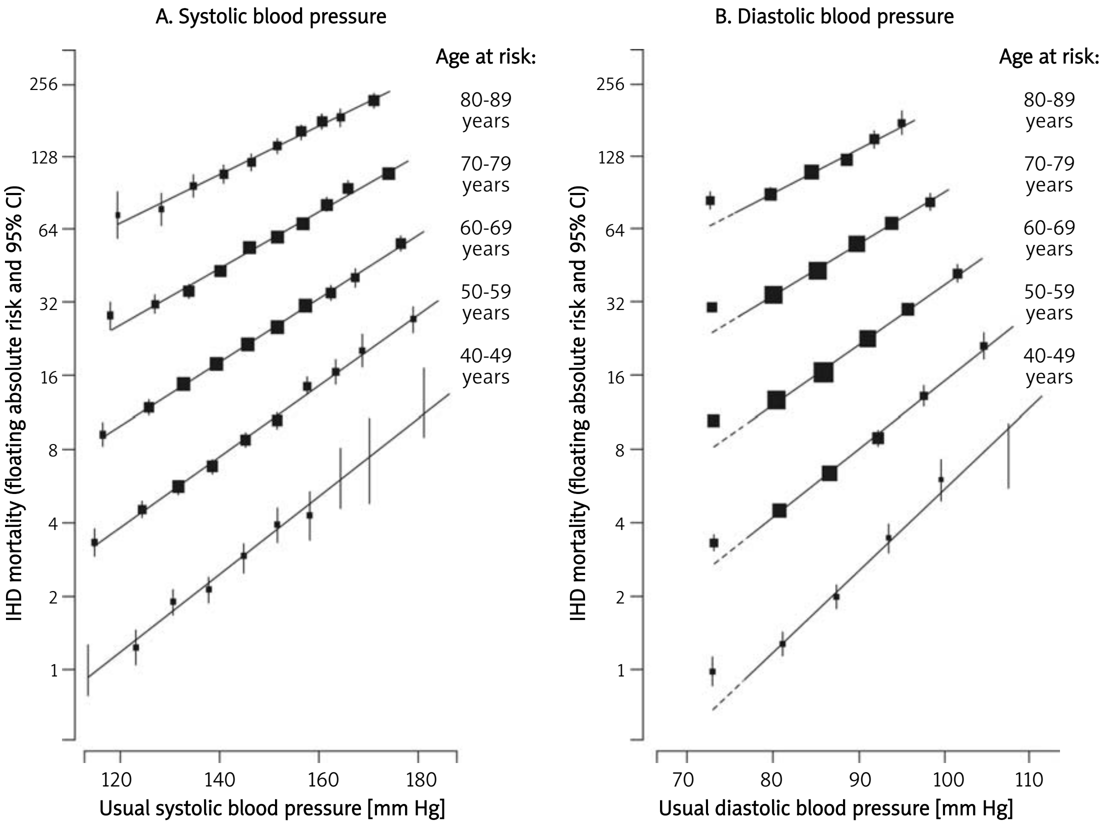
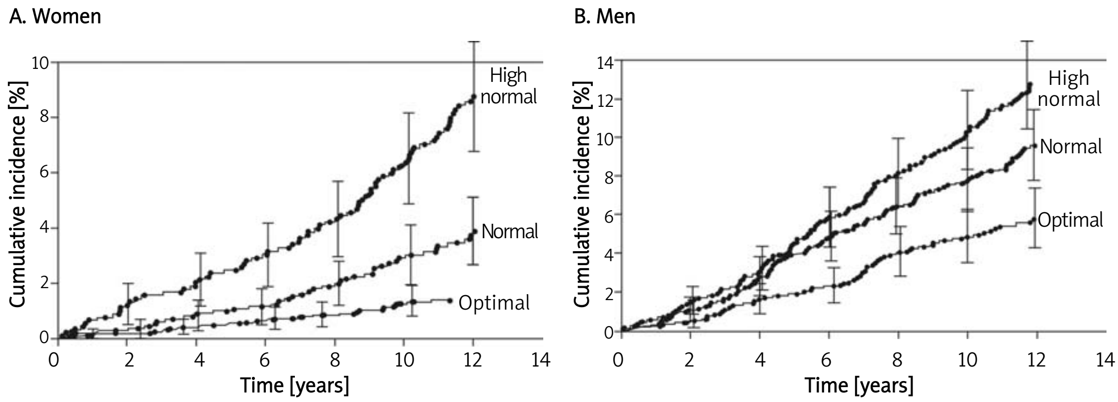


Figure 3. Ischaemic heart disease (IHD) mortality rate in each decade of age plotted for the usual systolic (A) and diastolic (B) blood pressure at the start of that decade. Data from one million adults in 61 prospective studies. Adapted from ref. [8]

BP were independently predictive of stroke and CHD mortality, and more so than pulse pressure. This meta-analysis also confirmed the increasing contribution of pulse pressure after age 55.

Recently, Bryan Williams, Lars Lindholm, and Peter Sever proposed a simplified view of hypertension for most affected patients – i.e., those aged over 50 years – whereby the thresholds for the diagnosis and treatment of hypertension can be expressed in one dimension: systolic pressure [13].

It has been shown that, compared to normotensive individuals, those with an elevated BP have more commonly other risk factors for CVD (diabetes, insulin resistance, dyslipidaemia) [4, 14-16] and various types and degrees of target



No. at risk (A. Women)							
Optimal	1875	1867	1851	1839	1821	1734	887
Normal	1126	1115	1097	1084	1061	974	649
High normal	891	874	859	840	812	722	520

No. at risk (B. Men)							
Optimal	1005	995	973	962	934	892	454
Normal	1059	1039	1012	982	952	892	520
High normal	903	879	857	819	795	726	441

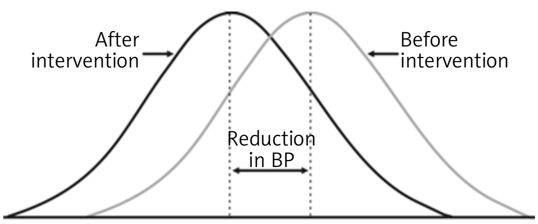
Figure 4. Cumulative incidence of cardiovascular events in men and women enrolled in the Framingham Heart Study with initial blood pressure classified as optimal (<120/80 mm Hg), normal (120-129/80-84 mm Hg), or high normal (130-139/85-89 mm Hg) over a 12-year follow-up. Adapted from ref. [9]

organ damage (TOD). Because risk factors may interact positively with each other, total CV risk of hypertensive patients is not infrequently high also when the BP elevation is only mild or moderate [4, 9, 17]. In a study by Anderson et al. [18], 686 treated hypertensive men, followed for 20-22 years, had a significantly increased CV mortality, especially from CHD, compared with non-hypertensive men from the same population. These differences were observed during the second decade of follow-up. The high incidence of myocardial infarction was related to organ damage, smoking, and cholesterol at the time of entry to the study, and to achieved serum cholesterol during follow-up.

Population impact

The impact of hypertension on the incidence of CVD in the general population is best evaluated from the population-attributable risk or, more correctly, the population-attributable burden, which 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 while the distribution of other risk factors remains unchanged [19]. For BP, attributable burden can therefore be defined as the proportion of disease that would not have occurred if BP levels had been at the same alternative distribution [20]. The statistics take into account both the prevalence of the risk factor (hypertension) and the strength of its impact (risk ratio) on CVD.

Because of the high prevalence of hypertension in the general population and its risk ratio, approximately 35% of atherosclerotic events are attributable to hypertension. The odds ratio or the relative risk to the individual increases with the severity of hypertension, but the attributable risk is greatest for mild hypertension because of its greater prevalence in the general population. Therefore, the burden of CVD arising from hypertension in the general population comes from those with relatively mild BP elevation [21]. About half of CV events in the general population occur at BP levels below those currently recommended for treatment with antihypertensive medications. The burden of non-optimal BP is almost double that of the only previous global estimates [22]. Worldwide, about 54% of strokes, and 47% of ischaemic heart disease were attributable to high blood pressure in 2001. About half of this burden was in individuals with hypertension. This equates to approximately 7.6 million premature deaths (about 13.5% of the global total) and 92 million DALYs (1 DALY is one lost year of healthy life; 6% of the global total). 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 [23]. This indicates a need for vigorous non-pharmacological treatment of individuals with high-normal BP and for initiating drug treatment in the vast majority of patients with mild hypertension based on their total CV risk.



Reduction in BP [mm Hg]	% reduction in mortality Stroke	CHD	total
2	–6	–4	–3
3	–8	–5	–4
5	–14	–9	–7

Figure 5. Estimated effects on population-wide shifts in systolic blood pressure distribution on mortality. Adapted from ref. [26]

Population strategy

In the past, most effort was aimed at the group with the highest levels of BP. However, this "high-risk" strategy, effective as it may be for those affected, does little to reduce total morbidity and mortality if the "low-risk" patients who make up the largest share of the population at risk are ignored [24].

Most people with mild hypertension are now being treated with antihypertensive drugs. However, as emphasized by Rose [25], a more effective strategy would be to lower the BP level of the entire population, as might be accomplished by reduction of sodium intake. Rose estimated that lowering the entire distribution of BP by only 2-3 mm Hg would be as effective in reducing the overall risk of hypertension as prescribing current antihypertensive drug therapy for all individuals with definite hypertension. This has been further elaborated by Stamler [26], who made the assumption that a reduction in systolic BP by 2 mm Hg may lead to a 6% reduction in stroke mortality, 4% reduction in CHD mortality, and 3% reduction in total mortality (Figure 5). The following environmental factors affect BP: diet, physical activity, and psychosocial factors. Dietary factors have a prominent and likely predominant role in BP homeostasis. In nonhypertensive individuals, including those with high-normal BP, dietary changes that lower BP have the potential to prevent hypertension and, more broadly, to reduce BP, thereby lowering the risk of BP-related clinical complications [27]. Lifestyle modifications which may induce more reduction in BP at the population level include weight reduction in overweight or obese persons, lower sodium intake, consumption of a diet rich in fruits and vegetables, and rich in low-fat dairy products, and reduced intake of saturated fat and cholesterol (DASH-like diet) [28].

Redon published a study showing differences in BP control and stroke mortality across Spain. Poor hypertension control and prevalence of ECG left ventricular hypertrophy were the main factors related to stroke mortality rates [29]. Cooper, in an editorial commentary, suggests that we can begin to consider stroke as a surveillance measure that indicates the quality of hypertension control [30]. Several decades ago, there was general agreement that medical care did not have a sufficiently widespread effect on population health (e.g., life expectancy or mortality), which were considered to be influenced only by living conditions and nutrition. However, a recent analysis suggests that medical care may have made a significant contribution to extending life expectancy in the US [31]. In fact, pill-taking to prevent CV events has become a mass phenomenon, with more than half of the US population over 60 years of age taking anti-hypertensive medication alone. Long-term therapy has thus become a public health intervention and can be considered a bridge between clinical medicine and traditional population-wide preventive measures.

Global burden of hypertension

Overall, 26.4% (26.6% in men and 26.1% in women) of the world adult population in 2000 had hypertension and 29.2% (29.0% in men and 29.5% in women) were predicted to have hypertension in 2025 [32]. Regions with the highest estimated prevalence of hypertension had roughly twice the rate of regions with the lowest estimated prevalence. In men, the highest estimated prevalence was in the region "Latin America and the Caribbean", whereas for women the highest estimated prevalence was in the former socialist economies, represented in Kearney's paper by Slovak data from 1978-1979. The lowest estimated prevalence of hypertension for both men and women was in the region of Asia represented by Korea, Thailand, and Taiwan. Although hypertension is more common in developed countries (37.3%) than in developing ones (22.9%), the much larger population of the developing countries results in a considerably larger absolute number of individuals affected. The projection of the number of individuals with hypertension for 2025 is probably an unde-restimate since it does not account for the rapid changes in lifestyle and concurrent increase in the risk of hypertension taking place in these countries.

Blood pressure and age

The relationship between age and BP has been demonstrated in a number of cross-sectional studies conducted in populations with different economic status. A remarkable finding is the consistent relationship between BP and age in developed countries.

Childhood and adolescence

Perhaps the most valuable data for this population are contained in the Second Task Force on Blood Pressure Control in Children [33]. Data were obtained by BP measurements in over 70,000 children enrolled into nine cross-sectional studies in the USA and the UK. Blood pressure was determined in the sitting position using a mercury sphygmomanometer (Doppler ultrasound in infants). In an effort to maintain a uniform metho-dology that would allow pooling of data, only the first measurement was used for analysis. In children aged 3-12 years, Phase IV Korotkoff sounds were recorded, while in adolescents aged 13-18 years, both Phase IV and V Korotkoff sounds were recorded. While at birth mean BP levels are 70/50 mm Hg, systolic BP starts to rise soon after birth, reaching a mean value of 94 mm Hg by the first year of life. In contrast, the increase in diastolic BP is a mere 2 mm Hg. Systolic and diastolic BP levels do not change substantially over the next 2-3 years. After this period, i.e., from 4 years of age onward, there is a tendency toward a progressive increase with age throughout childhood and adolescence (Figure 6). The increase in systolic BP tends to be somewhat more rapid (1-2 mm Hg/year) than in diastolic BP (0.5-1 mm Hg/year). The rate of BP rise is about the same for both sexes up to 10 years of age, with the curve becoming flatter for girls in the ensuing period. In adolescence, the mean (particularly systolic) BP of boys is higher than that of girls. As a result, systolic BP of boys aged 18 years

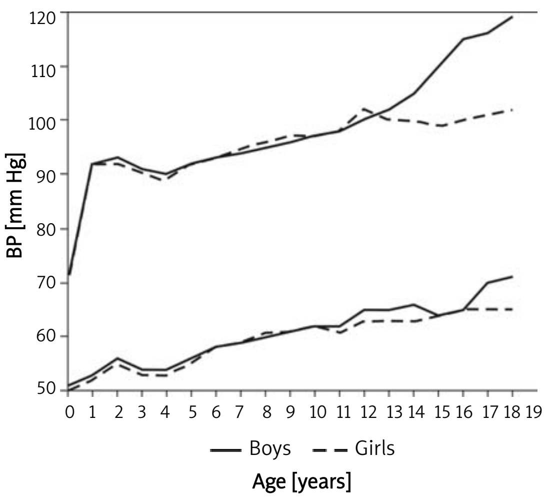


Figure 6. Mean systolic (above) and diastolic (below) blood pressure of boys (bold line) and girls (dotted line) from birth to 18 years. Diastolic blood pressure reflects the use of Phase IV Korotkoff sounds. Adapted from ref. [33]

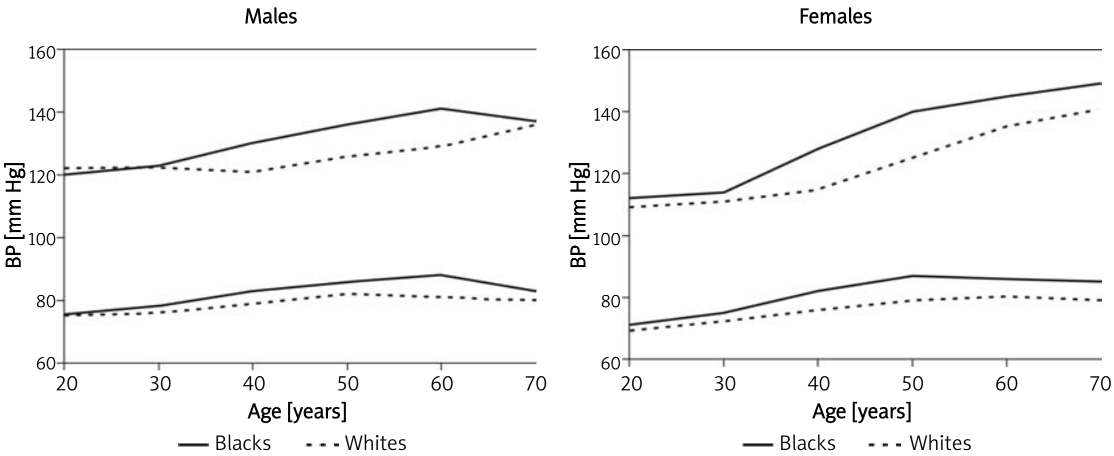


Figure 7. Age-blood pressure relationship by race and sex for systolic (above) and diastolic (below) blood pressure in the general population of the United States, 1976-1980. Adapted from ref. [35]

is 10 mm Hg higher than that of girls, with the respective difference between both sexes in diastolic BP being 5 mm Hg. No systematic differences have been reported for different ethnicities (blacks, Caucasians, Hispanic Americans) in childhood and adolescence.

The Second Task Force on Blood Pressure Control in Children was updated in 1996 [34]. The main change was the recommendation to adjust BP not only for the child's sex and age, but also height, which became the third criterion for BP assessment. This new criterion helps eliminate bias in assessing BP in children with extreme body height values, i.e., in those small and tall for age. The recommendation for recording of Phase V Korotkoff sounds was extended to include children up to 13 years of age.

Adulthood and old age

In adulthood, systolic and diastolic BP tends to rise with age. The increase is somewhat greater in systolic BP, rising up to 80 to 90 years of life, whereas diastolic BP remains almost unaltered from age 50 years upward. Ageing results in a progressive increase in pulse pressure (difference between systolic and diastolic pressure). In adults, systolic and diastolic BP is higher in men than in women (e.g., 120-130/75-80 mm Hg in 20-year-old men and 110-120/70-75 mm Hg in women of the same age). However, the BP rise in adulthood is steeper in women compared with men (0.6-0.8 mm Hg/year in women and 0.33-0.5 mm Hg/ year in men between ages 20 and70 years). As a result, systolic BP of women aged 70 and over is equal to or higher than that of men. Data regarding BP in the elderly are limited. However, several studies of questionable reliability have suggested that systolic BP of women in their late 80s or 90s is 10-20 mm Hg higher compared with their male counterparts. The gender difference may be partly explained by different survival rates. Male hypertensives are more likely to die from CVD.

As mentioned above, both blacks and whites show similar BP levels in childhood and adolescence. Among 20- to 30-year olds, mean BP is higher in blacks compared with whites, and the difference continues to grow in the ensuing 10-year periods. The National Health and Nutrition Examination Survey I reported mean differences of 4.1-10.6/3.5-7.0 mm Hg and 5.3-17.7/3.4-10.9 between 30- and 70-year old males and females, respectively (Figure 7) [35].

Blood pressure tracking

Several longitudinal studies have shown that essential hypertension in adults is associated with high BP levels in childhood. The concept that BP rank is established early in childhood has received increasing attention since early detection and prevention of high BP levels in childhood may reduce the incidence of adult hypertension. The tendency for individuals to stay roughly in the same rank of the BP distribution as they age is known as "tracking". It means that individuals from the lower part of the distribution curve tend to have the smallest BP increases with age (i.e., they continue to remain in the lower part of the distribution curve).

While BP tracking is generally believed to exist within populations, long-term prediction for a specific individual is fairly unreliable [36].

Blood pressure tracking is most relevant in childhood, as it allows identification of individuals likely to develop hypertension during their lifetime.

The age-related rise in systolic BP is primarily responsible for the increase in both the incidence and prevalence of hypertension with increasing age [37]. The impressive increase in BP to hypertensive levels with age is also illustrated by Framingham data indicating that the four-year rates of progression to hypertension are 50% for those 65 years and older with BP in the 130-139/85-89 mm Hg range, and 26% for those with BP in the 120-129/80-84 mm Hg range [38].

Populations with low blood pressure

A constant finding in all populations which do not develop hypertension and whose mean BP does not tend to rise with age is a low salt intake. The relationship seems to be a causal one. A case in point is some African tribes retaining their original lifestyle without exposure to excessive salt intake. Changes in lifestyle and eating habits are usually associated with a higher prevalence of all risk factors for hypertension (increase in BMI, increased salt intake, and decreased potassium intake).

It is generally believed that BP levels and hypertension prevalence are lower in the rural population, as compared with the urban one forced to quit its hitherto traditional, simple lifestyle. A substantially greater rise in BP occurs during migration to another continent (Japanese to Hawaii and further on to the USA, blacks migrating to Europe) [39].

Age and gender differences

Global estimates of BP by age, sex, and subregion show considerable variation in estimated levels (analyses based on data from about 230 surveys including 660,000 participants) [40]. Age-specific mean systolic BP values ranged from 114 to 164 mm Hg for females, and from 117 to 153 mm Hg for males. Females typically had lower systolic BP levels than males in the 30- to 44-year age groups but, in all subregions, systolic BP levels rose more steeply with age for females than males. Therefore, systolic BP levels in those aged ≥60 years tended to be higher in females.

Prevalence of hypertension

Whenever comparing the prevalence of hypertension, one should be aware that this is heavily dependent on the definition of hypertension, population examined, number of BP readings taken on each occasion and, finally, on the number of visits.

The prevalence of hypertension reported by Kearney et al. [1] varies widely, with rates as low as 3.4% in rural Indian men and as high as 72.5% in Polish women. In developed countries, the prevalence of hypertension ranges between 20 and 50%.

Regional differences

Inter-continental and within-Europe differences

Subregions with consistently high mean systolic BP levels include parts of Eastern Europe and Africa. Mean systolic BP levels are the lowest in south-east Asia and parts of the western Pacific.

A comparative analysis of hypertension prevalence and BP levels in six European countries, the US and Canada, based on the second BP reading, showed a 60% higher prevalence of hypertension in Europe compared with the US and Canada in population samples aged 35-64 years [41]. There were also differences in the prevalence of hypertension among European countries, with the highest rates in Germany (55%), followed by Finland (49%), Spain (47%), England (42%), Sweden (38%), and Italy (38%). Prevalences in the US and Canada were half the rates in Germany (28 and 27%, respectively). The differences in prevalence cannot be explained by differences in BMI (North America 27.1 kg/m^2, Europe 26.9 kg/m^2).

Findings from the WHO MONItoring Trends and Determinants in CArdiovascular Diseases (MONICA) Project showed a remarkably higher prevalence of hypertension in Eastern Europe, and virtually no difference in the rates of controlled hypertension among Eastern and Western populations [42].

Regional differences within a country

Regional differences in BP levels have been observed in a number of developed countries. Differences were reported between urban and rural populations, with a tendency towards higher BP levels in urban areas. In a number of areas, regional variations in BP levels are closely related to cardiovascular mortality. This is the case, e.g., of Japan, where mean BP levels are the highest in the north-east part of the largest island (Tohoku), also known for high stroke-related mortality rates.

Minor differences in mean BP levels have been reported in the US, being the highest in the south, and the lowest in the west. This is consistent with regional differences in stroke-related mortality [43].

Marked geographic differences in CV mortality have also been noted in the United Kingdom. The lowest rates of death from CVD and stroke have been reported in south-east and eastern England. Cardiovascular mortality tends to rise west- and northward, reaching the highest rates in the valleys of southern Wales, northern England, and Scotland. The results of the British Regional Heart Study [44] and the Nine Towns Study documented geographic variation related to different CV mortality rates. While some of the variations could be attributed to factors such as body weight and alcohol, and sodium-potassium intake, most of the variations remain unexplained [45].

Ethnic differences

Prevalence of hypertension varies among different racial groups within the population. An excellent database is provided by NHANES (National Health and Nutrition Examination Survey), which used stratified multistage probability samples of the civilian non-institutionalized US population. The age-adjusted prevalence of hypertension is the highest in non-Hispanic blacks, followed by non-Hispanic whites, and Mexican Americans [46].

Trends in the prevalence of hypertension

The prevalence of hypertension in the US declined uniformly across all population groups between NHANES I and NHANES II, with an additional and greater decline between NHANES I and the first two phases of NHANES III. However, the NHANES survey of 1999-2000 reported an increase in the prevalence of hypertension [47]. No significant increase in the overall prevalence of hypertension was detected at the last survey performed in 2003-2004 [46].

A significant decrease in the prevalence of hypertension was reported in Australia with three surveys performed as part of the National Heart Foundation's Risk Factor Prevalence Study 1980, 1983, and 1989 [48].

Two Health Surveys for England conducted in 1994 and 1998 reported a similar prevalence of hypertension (38 and 37%) [49], which was also the case of Greece, where surveys were performed between 1979 and 1983, and in 1997 [50, 51].

A significant decline in the prevalence of hypertension was found in the Belgian [52], Finnish [53] and Czech [54] populations, whereas a slight increase was observed in the MONICA Augsburg Project in Germany [55].

An increase in the prevalence of hypertension was reported in China [56], Singapore [57], and India [58-62].

In conclusion, over the past one to two decades, the prevalence has remained stable or decreased in developed countries, and has increased in developing countries.

Awareness and treatment of hypertension

Awareness and treatment of hypertension varies considerably between countries and regions [1]. In developed countries, there are approximately one half to two thirds of hypertensives in the general population aware of their diagnosis, and one third to one half receiving treatment. The levels of awareness and treatment in most developing countries tend to be lower than those reported in developed countries.

Trends in awareness and treatment of hypertension

There are only a few countries having data on longitudinal trends reported. During the 12-year interval between NHANES II and III, the proportion of hypertensive patients aware of their condition increased from 51 to 73% [47]. Increases in awareness were higher for women than for men, among both blacks and whites. The Health Survey for England reported increased hypertension awareness and treatment from 46.0 and 31.6% in 1994 to 52.2 and 38.0% in 1998 [49]. In Germany, from 1984/85 to 1994/95, awareness remained at 50% in men and 60% in women. The proportion of hypertensives receiving drug treatment increased by 7.9% in men, and 4.1% in women [63].

An enormous increase in awareness of hypertension was reported in Finland (from 54.5 to 75.9% in men and from 72.8 to 84.3% in women) between 1982 and 1997 [53]. In the Czech Republic, there was an increase in the awareness (from 49.5 to 67.2%) and treatment (from 29.3 to 49.3%) of hypertension from 1985 to 2000/01 [54].

Hypertension control

Hypertension is poorly controlled worldwide, with less than 25% controlled in developed countries, and less than 10% in developing countries [1]. Hypertension control rates also vary within countries by age, gender, race/ethnicity, socio-economic status, education, and quality of health care [64]. While awareness of hypertension has improved in the US and other Western countries over the past decade, hypertension control remains inadequate as only a proportion of those who are aware of their diagnosis are treated, and an even smaller number of those receiving treatment are treated adequately. Sadly, however, the most important parameter likely to have an impact on public health is neither the number of those who are aware of their hypertension nor the number taking steps to improve it but, rather, the percentage of those whose BP is under control [65].

Environmental factors

Air temperature and seasonal variation in blood pressure

A number of reports have pointed out that a lower air temperature is associated with a higher mean BP. As air temperature in Scotland and northern England is lower than in southern England, the differences in air temperature may be theoretically responsible for some regional differences in BP across the United Kingdom.

A seasonal effect on BP was first described by Rose [66] while analyzing measurements in 56 men observed for 1-3 years at a clinic for ischaemic heart disease. The Medical Research Council's trial of mild hypertension found that systolic and diastolic BP levels were higher in winter than in summer. The seasonal variation in BP was greater in older than in younger individuals and was highly significantly related to maximum and minimum daily air temperature measurements, but not to rainfall [67].

Social status

The British Regional Heart Study and the Nine Towns Study reported a lower systolic BP in white-collar workers compared with unskilled blue-collar workers [68, 45]. Individuals with a lower level of education also show a higher prevalence of other risk factors, in particular obesity and lower physical activity. An inverse relationship between education and BP has been found in many adult populations [69]. In the less educated, BMI levels and more adverse intake patterns of multiple macro- and micronutrients account substantially for their higher BP levels [70].

Body weight and physical activity

Blood pressure and body mass index (BMI) are closely interrelated. The relative risk (odds ratio) for the development of hypertension rises markedly with increasing BMI [71]. The importance of this relationship is reinforced by the high and increasing prevalence of overweight and obesity worldwide [72-74].

A variety of epidemiological studies have documented an inverse correlation between the level of physical activity and BP levels. Prospective cohort studies have reported a higher incidence of hypertension in individuals with lower levels of physical activity and lower cardiorespiratory fitness [75]. Randomized controlled studies have furnished evidence of a beneficial effect of physical activity on BP. A meta-analysis of controlled interventional studies concluded that adequate dynamic physical training contributes significantly to BP control. The training-induced decrease in BP averaged 2.6/1.8 mm Hg in normotensives and 7.4/5.8 mm Hg in hypertensives [76, 77].

Sodium and potassium intake

There is a correlation in most populations between normal dietary sodium intake (usually expressed as 24-h urinary sodium excretion) and mean BP [78]. However, 24-h urinary sodium output is biased by large intra-individual variability. In most populations, the age-related rise in BP is significantly associated with sodium intake [79].

There are major differences in the individual response by BP to salt intake. Afro-Americans, the middle-aged, elderly, those with diabetes and hypertension respond more sensitively to changes in salt intake compared with the general population. These groups tend to have a less responsive renin-angiotensin-aldosterone system [80]. The recommended adequate sodium intake has been recently reduced from 2.4 to 1.5 g/day (65 mmol/day) [81], corresponding to 3.8 g/day sodium chloride, which may be difficult to achieve.

Individuals on a predominantly vegetarian diet show lower BP levels and their BP rises less with increasing age compared with those on diets of plant and animal origin [82]. Vegetarians have lower BP levels compared with the non-vegetarian population even in developed countries [83]. The lowest levels of BP in industrialized nations were reported in strict vegetarians not consuming virtually any products of animal origin. Their diet includes whole-grain products, lots of green-leaved vegetables, pumpkins, and root vegetables. A diet rich in potassium and polyunsaturated fats and containing little starch, saturated fats and cholesterol correlates inversely with BP levels in a large population of US males [84]. Over the past decade, increased potassium intake and dietary patterns based on the DASH trial (a diet rich in fruit, vegetables and low-fat dairy products, with a reduced content of dietary cholesterol as well as saturated and total fat) [85] have emerged as effective strategies that also lower BP.

Alcohol consumption

Observational studies and clinical trials have documented a direct, dose-dependent relationship between alcohol intake and BP, particularly as the intake of alcohol increases above approximately two drinks per day [86, 87]. Importantly, this relationship has been shown to be independent of potential confounders such as age, obesity, and salt intake [88]. Although some studies have shown that the alcohol-hypertension relationship also extends into the light drinking range (≤2 drinks per day), this is the range in which alcohol may reduce CHD risk.

A meta-analysis of 15 randomized controlled trials reported that decreased consumption of alcohol (median reduction in self-reported alcohol consumption, 76%; range, 16-100%) reduced systolic and diastolic BP by 3.3 and 2.0 mm Hg, respectively. The BP reductions were similar in normotensive and hypertensive individuals; there was a dose-dependent relationship between reduction in alcohol consumption and decline in BP [87].

A reduction in alcohol consumption is associated with a decrease in BP (a decrease in alcohol consumption by one alcoholic drink will result in decreases in both systolic and diastolic BP by about 1 mm Hg).

Women and lean individuals absorb larger amounts of ethanol than men [89]; consequently, their daily consumption should not exceed 20 ml of ethanol.

Excessive alcohol intake is a major risk factor for the development of hypertension and may be responsible for resistance to antihypertensive therapy [90].

Dietary factors with limited or uncertain effect on blood pressure

Several predominantly small clinical trials and meta-analyses of these trials [91-93] have docu-

Table I. Rates of progression to hypertension in Framingham Heart Study. Adapted from ref. [38]

Blood pressure, category	Percentage of 4-year progression to hypertension			
	Men, age 35-64 years	Men, age 65-74 years	Women, age 35-64 years	Women, age 65-74 years
Optimal	5	15	5	16
Normal	18	25	12	26
High normal	37	47	37	49

mented that high-dose omega-3 polyunsaturated fatty acid (commonly called fish oil) supplements can lower BP in hypertensive individuals with BP reductions occurring at relatively high doses (≥3 g/day). In hypertensive individuals, average systolic and diastolic BP reductions were 4.0 and 2.5 mm Hg, respectively [93].

Overall, data are insufficient to recommend an increased intake of fibre alone [94, 95], supplemental calcium or magnesium [96, 97] as means to lower BP. Additional research is warranted before specific recommendations can be made about the amount and type of carbohydrate [98, 99] to affect BP.

Incidence of hypertension

There are much fewer data about the incidence, i.e., newly developed cases, of hypertension than about its prevalence. The incidence of hypertension in the Framingham cohort over 4 years was directly related to the prior level of BP and to age, with similar rates in men and women [38]. Obesity and weight gain also contributed to progression of hypertension. A 5% weight gain after 4 years was associated with 20% increased odds of hypertension (Table I). Another longitudinal database is provided by the NHANES study, which found minimal differences in the incidence of hypertension between men and women for all age groups. Incidence rates for blacks were at least twice the rates of whites for almost every age-sex group [100].

Short-term incidence rates of hypertension are available for middle-aged adults in Korea, confirming again only minor differences in the crude two-year incidence of hypertension between males and females. Incidence rates were markedly increased (two or five times higher) in individuals with higher BP at baseline. Older age and overweight were also major predictors for hypertension [101].

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