# All things blood pressure: from measurement to management

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**Table 6. Categories of BP in Adults***

| BP Category | SBP | | DBP |
|---|---|---|---|
| Normal | <120 mm Hg | and | <80 mm Hg |
| Elevated | 120–129 mm Hg | and | <80 mm Hg |
| Hypertension | | | |
| Stage 1 | 130–139 mm Hg | or | 80–89 mm Hg |
| Stage 2 | ≥140 mm Hg | or | ≥90 mm Hg |

*Individuals with SBP and DBP in 2 categories should be designated to the higher BP category.

Blood pressure is one of the most significant factors influencing both our healthspan and lifespan. Often referred to as the “silent killer,” high blood pressure (hypertension) can cause extensive organ damage, often without any noticeable symptoms. It is a widespread issue, affecting a staggering one in three people in the world (more than a billion individuals),[1] many of whom are unaware of their condition. The consequences of untreated hypertension are severe, contributing to cardiovascular disease, kidney failure, cognitive decline, and even sexual dysfunction.

However, the good news is that blood pressure is a manageable condition. Through accurate monitoring and proactive steps, individuals can lower their blood pressure and significantly reduce their risk of life-threatening complications. In this piece, we will explore how to measure blood pressure, the consequences of hypertension, and the interventions available to manage it effectively.

## What is blood pressure and how do we measure it?

Blood pressure refers to the force that circulating blood exerts against the walls of blood vessels, particularly the arteries, in the systemic circulation. It is measured in millimeters of mercury (mmHg) and consists of two readings: systolic and diastolic pressure.

- Systolic Pressure: This is the pressure in the arteries when the left ventricle of the heart contracts, pumping oxygenated blood into the aorta and throughout the body.
- Diastolic Pressure: This is the pressure in the arteries when the heart is resting between beats, allowing the ventricles to refill with blood.

A typical blood pressure reading is expressed as systolic pressure over diastolic pressure (e.g., 120/80 mmHg, where 120 is the systolic pressure and 80 is the diastolic pressure).

Organizations such as the American Heart Association and American College of Cardiology have set guidelines for classifying different blood pressure levels to help determine the appropriate treatment plan. The most recent guidelines, revised in 2017, define the following categories.eatment plan. The most recent guidelines, revised in 2017, define the following categories.

**Table 1**. **Current blood pressure categorizations (last revised in 2017).** Credit: ACC/AHA Task Force.[2]

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## Hypertension: the “silent killer”

Approximately half of all American adults have some form of high blood pressure,[3] including many young adults (roughly 12.5% of individuals aged 20-40).[4] The condition has numerous deleterious effects on health, and in the US alone, essential hypertension and hypertensive kidney diseaseare responsible for more than 40,000 deaths (~13 deaths per 100,000 people),[5] while hypertension is either a primary or *contributing* cause for almost 686,000 deaths[5,6] (a little over 200 deaths per 100,000). The most common causes of death to which hypertension is a contributing factor are cardiovascular events like stroke, heart attack, and heart failure.

Indeed, organs that are highly sensitive to blood flow – such as the heart, brain, and kidneys – are particularly susceptible to the effects of hypertension. Each 20/10 mmHg increase in blood pressure *doubles* the risk of cardiovascular mortality,[7] and, compounding the issue, hypertension also exacerbates the excess risk to heart health imposed by other risk factors such as smoking and high cholesterol. In addition, hypertension accelerates kidney damage and can cause end-stage renal disease (ESRD).[8] High blood pressure is also linked to cognitive impairment, including memory loss and an increased risk of dementia, as chronic hypertension can lead to damage of the small blood vessels in the brain and thus impair cognitive function over time.[9] Further, the effects of hypertension are not limited to these major organ systems; excessively high blood pressure can also cause issues like vision problems and sexual dysfunction.[10] (For details about the biological mechanisms through which hypertension causes various disorders, see my “Ask Me Anything” (AMA) podcast on blood pressure.)

Despite the widespread effects that hypertension has on the body, it often shows no symptoms until significant damage has already occurred. For this reason, it is often referred to as a “silent killer,” and indeed, about half of US adults with uncontrolled hypertension are unaware of their condition.[3] Yet without awareness of hypertension, we cannot take proactive measures to curb the damage it causes, which is why it’s crucial for everyone, even those who feel perfectly healthy, to monitor their blood pressure regularly and take steps to lower it if elevated.

## How to measure blood pressure accurately

Accurate blood pressure measurement is essential for proper diagnosis and management, but measuring blood pressure is a bit of an art as well as a science. Readings can generate variable results depending on the protocol used and other variables such as time of day and body position, so ensuring the most accurate picture of one’s blood pressure requires taking multiple readings over several weeks.

Of course, visiting a doctor’s office a dozen or more times in rapid succession is hardly ideal, so the ability to measure blood pressure at home is invaluable for generating a sufficient number of data points to fully understand where we stand. Home readings also have the advantage of circumventing potential sources of inaccuracy related to the medical facility itself – for instance, some patients experience a phenomenon known as “white coat syndrome,” in which anxiety about being in a medical setting causes temporary spikes in blood pressure. Further, medical staff often do not consider space-specific issues such as the patient just having climbed stairs to get to the office, and different staff members may vary in their level of diligence with respect to proper positioning of the patient’s arm and use of an appropriate cuff size. All of these factors reinforce the importance of home readings.

### Guidelines for accurate home measurement

For accurate blood measurements in a home setting, you must first choose the right equipment. Use a validated blood pressure monitor, preferably one that is manual rather than automatic. (Automatic cuffs are not directly measuring blood pressure. They typically measure mean arterial pressure and then impute systolic and diastolic values, often overestimating by as much as 10 to 15 mmHg. Thus, manual measurements are the gold standard.) You must also ensure that you have the appropriate cuff size for your arm, as cuffs that are too large can result in significant underestimation, while too-small cuffs can overestimate blood pressure.[11] To determine your proper cuff size, measure your arm circumference about halfway along your bicep (between your elbow and shoulder). The length of the inflatable cuff bag should be about 80% of your arm circumference and the width at least 40%.[12]

**Table 2. Recommended Cuff Size by Arm Circumference.** Chart from Smith 2005,[13] based on data from Pickering et al. 2005.[12]

## Recommended Cuff Sizes for Accurate Measurement of Blood Pressure

| *Patient* | *Recommended cuff size* |
|---|---|
| **Adults (by arm circumference)** | |
| 22 to 26 cm | 12 × 22 cm (small adult) |
| 27 to 34 cm | 16 × 30 cm (adult) |
| 35 to 44 cm | 16 × 36 cm (large adult) |
| 45 to 52 cm | 16 × 42 cm (adult thigh) |

Many parameters can affect the accuracy of blood pressure readings, including caffeine, physical activity, time of day, and body position, some of which are summarized in **Figure 1** below. (For instance, blood pressure drops at night by about 10–20% when you are in a horizontal position.[14]) Therefore, to get the most accurate reading, you should avoid caffeine, exercise, and smoking for at least 30 minutes prior to blood pressure measurement and empty your bladder. Rest at least five minutes beforehand and do not talk or engage in activities while taking the measurement. Sit with your back supported, feet flat on the floor, and arm supported at heart level.

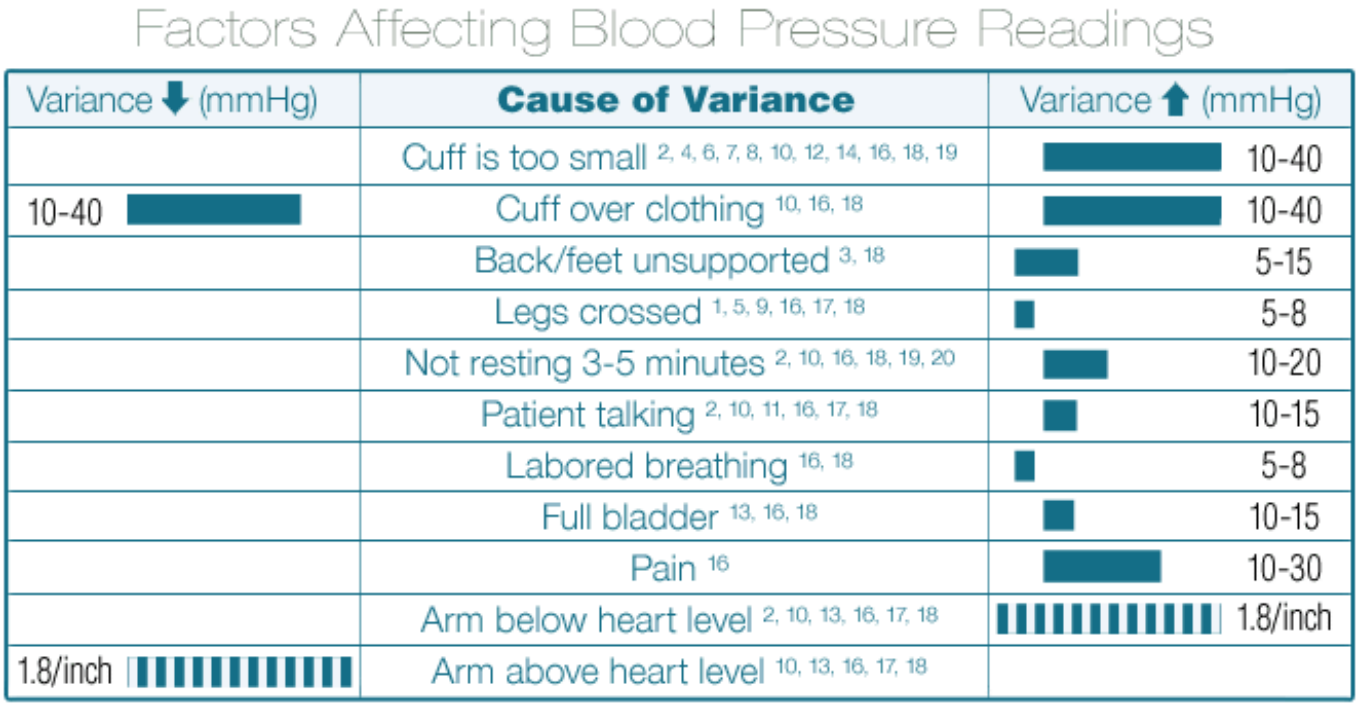


**Figure 1. Factors affecting blood pressure readings.** Credit: American Diagnostic Corporation.[15]

Regardless of whether you choose to use a manual or automatic cuff, place the cuff on bare skin, not over clothing, positioning it about an inch above the crease in your elbow. Take at least two readings, roughly one minute apart, and average the results. As you repeat this process over separate days or weeks, it can be helpful to keep a log of your blood pressure readings to share with your healthcare provider.

**Manual cuff**: When using a manual cuff, you will also need a stethoscope. The first step is to find your brachial artery: put your palm up and your hand in the area where your arm bends, then bend your arm in towards your body and you'll feel a pulse. Place the stethoscope on the pulsing artery, then inflate

the cuff (with the stethoscope still in place) until you feel the loss of that pulse. Continue to inflate the cuff to about 30 mmHg higher, and then slowly release the valve of the cuff.

When you hear the first tapping/thudding sound, that is the systolic reading (enough pressure has been released to allow blood through). As the pressure slowly releases further, the sounds will change from a murmur into a “swooshing” sound. When the sound stops, that is the diastolic number (the cuff pressure is now below the minimum pressure at which the artery detects expansion).

(There is also an online video demonstrating how to use a manual monitor[16] if you would find it helpful.)

**Automated cuff:** Automated cuffs have their own algorithms and can be good alternatives for those who find manual measurement to be too challenging. Automated cuffs vary widely and the instructions will be specific to each model. (There is an online video available[17] demonstrating how to use a basic automated model.)

## Benefits of lowering blood pressure

Of course, being aware of our blood pressure is only the first step. To improve health trajectories, we need to act on this information by making efforts to keep blood pressure within healthy ranges – or to bring it *back* to a healthy range if elevated.

Early research, such as the Framingham Heart Study, indicated that reducing blood pressure below the then-standard threshold of 140/90 mmHg could reduce the risk of stroke and cardiovascular disease.[18] More recent evidence indicates that even more aggressive BP targets may further reduce risk; in the Systolic Blood Pressure Intervention Trial (SPRINT), participants who were treated to reduce systolic blood pressure to below 120 mmHg experienced a 25% reduction in cardiovascular mortality after just one year relative to participants treated to a systolic target of 140 mmHg. (In fact, the difference was so great that the study was discontinued out of ethical concerns for the <140 mmHg group.)[19] Likewise, the 2021 STEP (“Chinese SPRINT”) study found that lowering systolic BP to <130 mmHg rather than <150 mmHg reduced composite cardiovascular outcomes by 26%.[20] Studies like these have shifted medical guidelines, emphasizing the importance of aiming for a systolic blood pressure below 120 mmHg in high-risk individuals to achieve optimal cardiovascular and cognitive health.

The primary message from these studies is that reducing blood pressure – even in those already diagnosed with hypertension – can significantly reduce the risk of heart disease, stroke, and other serious health conditions. While preventing elevated blood pressure in the first place is ideal, the results from these trials demonstrate that reducing blood pressure after it has already exceeded optimal ranges offers enormous benefits for cardiovascular health.

## Non-modifiable risk factors for hypertension

As we’ve stated earlier, hypertension is incredibly common across the entire adult population of the US and beyond. No one has the luxury of assuming they are “too healthy” to be at risk of high blood pressure and thus neglect regular monitoring. This message is all the more important for certain populations which, *regardless of lifestyle and general health status*, are at above-average risk. Non-modifiable factors such as age, sex, racial background, and family history have significant implications for risk of hypertension, and understanding these associations therefore empowers us to assess more accurately our own level of risk and take appropriate action.

## Age

Blood pressure tends to increase with age because blood vessels lose elasticity over time, hormonal changes affect the balance of fluids and salts, and the consequences of lifelong unhealthy habits begin to accrue. While about 19% of women ages 20–44 have hypertension, the prevalence skyrockets to 85% of women 75 or older (comparable numbers for men are 30% and 79% respectively).[2] Thus, as you age, you should increase the frequency of blood pressure monitoring so that you are aware if yours begins to rise and can then seek appropriate medical support. You may also need to adapt your diet and exercise habits to accommodate age-related changes.

## Sex

At younger ages, hypertension is more prevalent in men than women, but the numbers tend to converge above the age of about 65. The figure below illustrates how the rates of hypertension rise with age in both sexes.

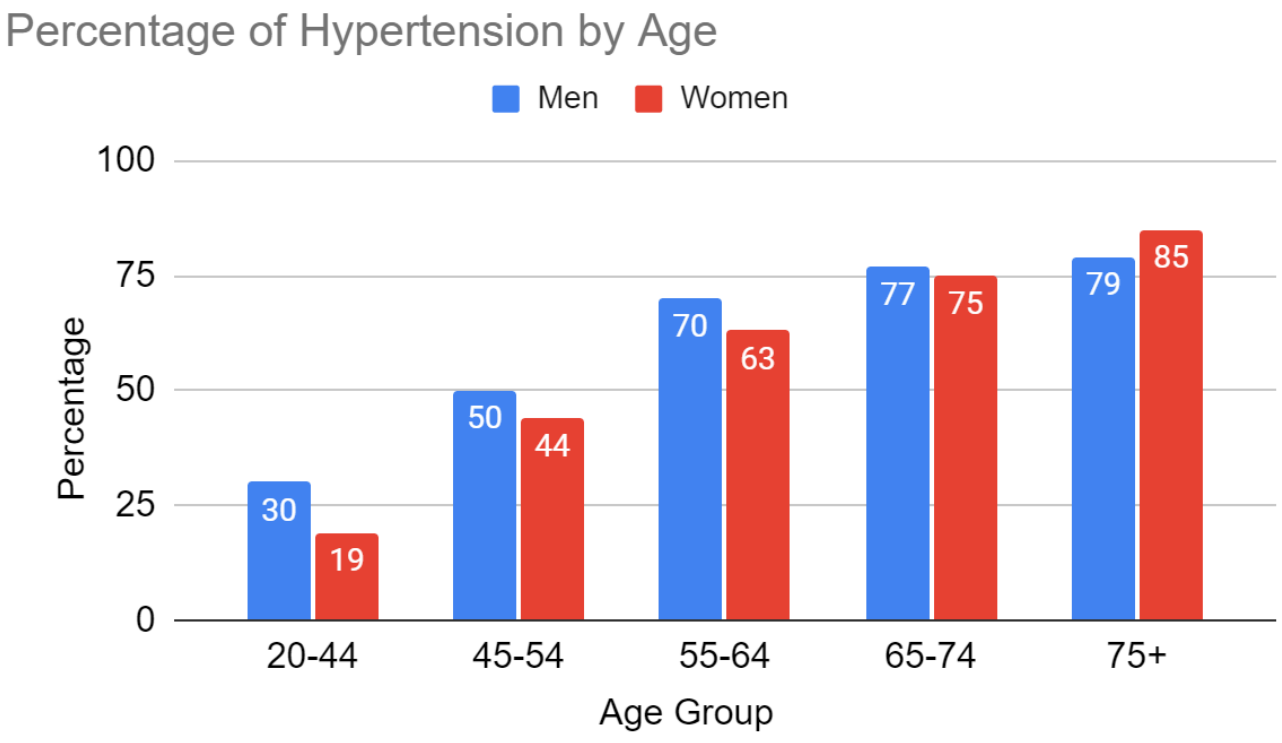


**Figure 2. Age-specific prevalence of hypertension.** Graph created in house using data from ACC/AHA Task Force.[2]

Sex differences in rates of hypertension at younger ages are related to the protective effects of estrogen in pre-menopausal women;[21] rates of hypertension increase in post-menopausal women[22,23] and in women whose ovaries are removed prior to natural menopause.[21,23] However, estrogen has vasoconstrictive as well as vasodilatory properties, as evidenced by higher blood pressure in women taking oral contraceptives and during the last trimester of pregnancy, and the mechanisms of these effects are poorly understood.[23] Likewise, the effect of treating post-menopausal women with exogenous estrogen via hormone replacement therapy (HRT) on hypertension is not straightforward and appears to differ based on when HRT is started and stopped, which type is used, the dose, and how it is administered.[22]

## Race

As we've discussed in a past newsletter, race is a very imperfect proxy for a number of poorly defined genetic and lifestyle factors that may have significance for health. And yet, because we don't fully understand the specific impact of countless genetic, socioeconomic, cultural, or other factors on blood pressure, the known associations between racial background and hypertension risk serve as valuable stand-ins for these other variables (and their complex interactions) when it comes to risk assessments.

African Americans have substantially higher risk of developing hypertension than other races (**Figure 3**). Indeed, the discrepancy is large enough that even African-American *women* – who, as we've just seen, are at lower risk than men when all else is equal – have higher rates of hypertension than *men* of other races. Given the increased risk, Black patients of both sexes should be particularly proactive about starting to monitor their blood pressure at a relatively young age and adopting lifestyle changes that might mitigate risks.

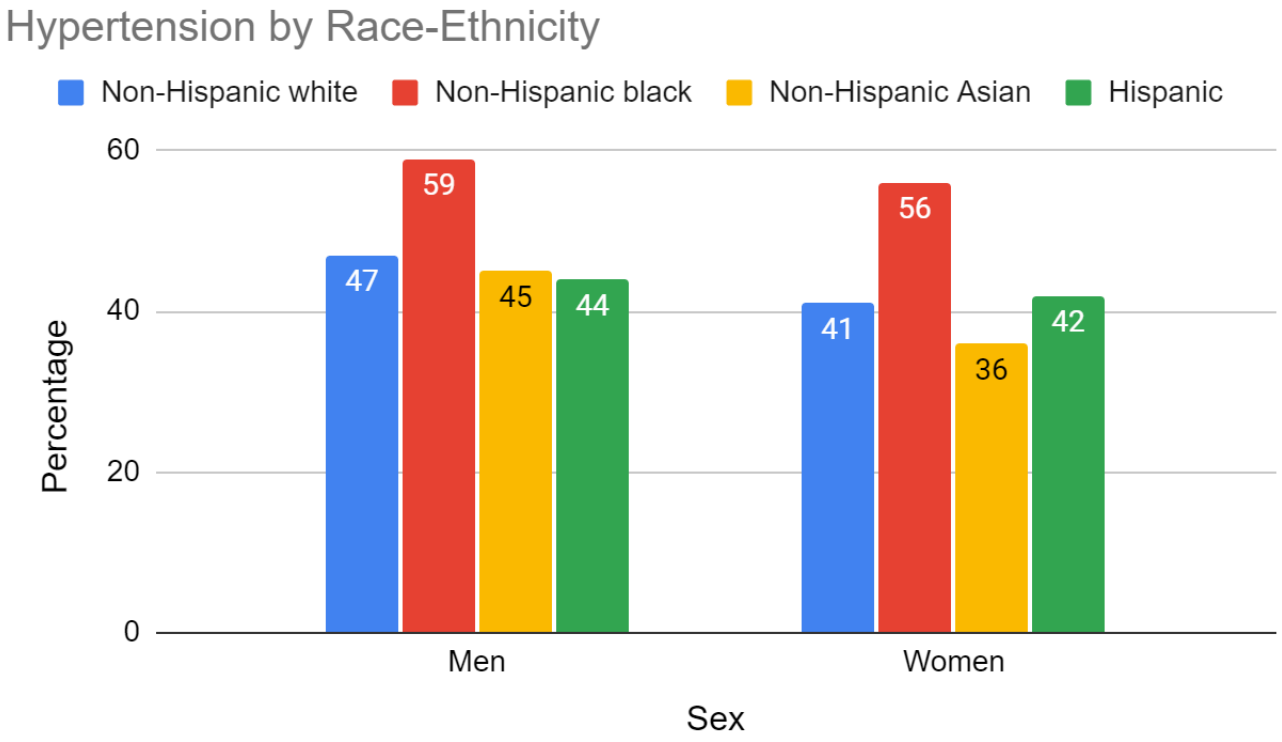


**Figure 3**. **Race-specific prevalence of hypertension.** Graph created in house using data from ACC/AHA Task Force.[2]

Other races are more similar in risk level, though Asian females exhibit lower risk than other groups. However, despite having lower rates of hypertension than African Americans, individuals of Hispanic or Asian backgrounds who *do* have hypertension are reportedly less likely to be *aware* of their condition and receive treatment, underscoring the fact that no one can afford to ignore their blood pressure.[24]

## Family history and genetics

If your parents or close relatives have/had high blood pressure, you may also be at increased risk. Variants in many genes are known to affect blood pressure, both alone and in combination. Research suggests that having a large number of variants with small effects on increasing BP can accelerate age-related hypertension in individuals. Current data suggest that the heritability of variation in blood pressure is about 50%,[25] and having a family history of high blood pressure makes an individual's risk

of developing hypertension about four times as high as someone without a family history.[26] As of now, researchers have found more than 800 different loci (specific places on chromosomes where genes are located) that have an effect on blood pressure.[25] It is estimated that each of these influences less than 1 mmHg of blood pressure differences, and most of the associated responsible genes have not been identified, emphasizing the scope and complexity of genetic inheritance of blood pressure levels.[25]

While more research is needed to better understand the relationship between genetics and hypertension, genetic predisposition warrants frequent monitoring and you should know your family's medical history and keep track of updates as your relatives age. The good news is that having a family history of hypertension does not prevent you from pursuing lifestyle modifications that are within your control and can make a big difference.

## Modifiable risk factors for hypertension

Lifestyle modifications often offer effective, non-pharmacological ways to control or reduce blood pressure, sometimes with results comparable to medications. A large proportion of hypertension in Americans is caused by an unhealthy diet (and the related risk factor of obesity), a lack of exercise, and excess alcohol consumption (or some combination of these).[2]

### Obesity

One of the most effective lifestyle changes for controlling blood pressure is weight loss. Excess body weight can strain the heart and promote insulin resistance, both of which contribute to increased blood pressure. Research shows a consistent and direct relationship between body mass index (BMI) and hypertension, and large-scale studies have found that obesity may cause anywhere from 40–78% of hypertension cases.[2] Even modest weight loss can have significant benefits for blood pressure reduction, as indicated by the results of a 2003 meta-analysis of 25 randomized controlled trials (RCTs) of adults generally in the overweight or obese ranges of BMI. The analysis found that for every kilogram of body weight lost, systolic blood pressure decreased by about 1 mmHg and diastolic blood pressure by 0.92 mmHg.[27] Weight loss can be achieved through caloric restriction, intermittent fasting, or dietary changes, with the best approach depending on what is most sustainable for the given individual.

### Diet

A healthy diet plays a critical role in blood pressure management, with certain nutrients – most notably sodium and potassium – having more direct effects than others.

Conventional wisdom holds that a low-sodium diet is key for keeping blood pressure in check, and indeed, various studies and meta-analyses have observed positive correlations between sodium intake and both systolic and diastolic blood pressure.[28] Reductions in sodium intake have accordingly been shown to reduce blood pressure – an effect which was strongest for those with hypertension at baseline but persisted even among those with normal baseline blood pressure.[29,30]

However, the relationship between dietary sodium, hypertension risk, and overall health and lifespan is more complex than may first meet the eye. Certain individuals and groups are more sensitive to the effects of salt on blood pressure than others – meaning that a given increase in sodium intake results in a disproportionately large increase in blood pressure among these susceptible individuals. People who are more likely to be "salt sensitive" include African Americans, older adults, and individuals with

diabetes, chronic kidney disease, or pre-existing hypertension, and these groups should therefore make special efforts to reduce their sodium intake from the current US average of around 3,000–3,500 mg per day[31] down closer to about 2,000 mg/day or lower.[32]

While some groups advocate for even more drastic sodium restriction across the entire adult population (e.g., the American Heart Association, which recommends an upper limit of 1,500 mg/day[33]), it's important to note that a very low sodium intake may also cause problems. Epidemiological evidence has shown that sodium intake is positively associated with life expectancy and *inversely* correlated with all-cause mortality risk in a dose-dependent manner.[34,35] Although these associations are purely observational, it is plausible that they represent an increase in health risks that are sufficient to overcome any benefits of blood pressure reduction. In addition to symptoms such as headaches, changes in mental status, lethargy, muscle cramps, and nausea/vomiting, low blood sodium can lead to dehydration and excessively *low* blood pressure, which may increase risk of falls and injury – a major contributor to morbidity and mortality among older adults.[36] Thus, we recommend modest reductions in sodium for individuals at low risk of salt-attributable elevations in blood pressure, whereas more aggressive reductions may be necessary for more "salt sensitive" groups.

While *reducing* sodium can help lower blood pressure, *increasing* consumption of potassium – a mineral essential for muscle contraction, kidney function, and vasodilation – may do the same. Among hypertensive adults, numerous studies have shown that potassium supplementation can reduce systolic and diastolic blood pressure by about 3-6 mmHg and 1-4 mmHg, respectively.[37,38] (In the absence of baseline hypertension, it's unclear whether supplementation reduces blood pressure or lowers risk of BP elevations.[39]) As potassium helps to promote sodium excretion, the positive impact of potassium on blood pressure help to counteract sodium's negative effects, as evidenced by the finding that potassium supplementation leads to greater reductions in blood pressure in subjects with a high sodium intake. Likewise, the effect is also greater among individuals with low baseline potassium levels,[38] and some evidence suggests that the *ratio* of sodium to potassium may be more important for blood pressure regulation than the absolute concentration of either mineral in isolation.[40] Thus, consuming potassium-rich foods like bananas, potatoes, and beans is a good bet for controlling blood pressure, particularly for those with high salt intake.

Salt substitutes that replace sodium chloride with potassium chloride may be a simple way to help manage blood pressure. A Chinese study found that replacing salt (100% sodium chloride) with a salt substitute mixture of 75% sodium chloride and 25% potassium chloride reduced rates of stroke (14% fewer per 1000 person-years), major cardiovascular events (13% fewer per 1000 person-years), and death (12% fewer per 1000 person-years).[41] A 2024 review article advocated for an official recommendation that all patients with hypertension use a salt substitute (unless they have a contraindication like advanced kidney disease).[42] A 2023 WHO Report mentioned potassium-enriched salt as an inexpensive way to prevent cardiovascular events and reduce blood pressure.[43] This is a practical option, as salt substitutes cost more than salt but less than many other foods and less than high-end brand salts.[44]

## Physical activity and exercise

Physical activity has profound effects on both short-term and long-term blood pressure management. Regular exercise strengthens the heart, improves vascular health, and helps regulate weight. During exercise, systolic blood pressure rises to meet the increased demand for oxygen, while diastolic blood pressure often decreases or remains stable due to improved arterial elasticity. In the long term, though, regular aerobic exercise like walking, running, and cycling can lower blood pressure by improving heart efficiency and reducing systemic vascular resistance. A meta-analysis of RCTs lasting at least four

weeks found that endurance exercise was an effective way to lower blood pressure.[45] Another study found that the most physically fit people at ages 18-30 had half the risk of having hypertension 15 years later compared to those who were the least physically fit at the same ages.[46] For individuals with hypertension, starting an exercise program under medical supervision is crucial. Both aerobic and resistance exercises are beneficial, though aerobic exercise generally provides more significant reductions in blood pressure.

## Alcohol

Mounting evidence supports a clear, causal link between alcohol consumption and elevated blood pressure, and reducing alcohol intake can lead to substantial blood pressure improvements. As we've discussed in a past newsletter, research utilizing Mendelian randomization (a means of inferring causality from observational data) has shown that risk of hypertension rose *exponentially* with progressive levels of alcohol intake over a decade-long follow-up period. The greatest increase in risk were thus among very heavy drinkers, for whom each one-drink increase in daily consumption elevated hypertension risk by 160% (OR=2.6; 95% CI: 1.6-4.2; $P<0.001$), but importantly, the association persisted even at *low* levels of intake, for which each additional daily drink corresponded to a 30% increase in hypertension risk relative to complete abstinence (OR=1.3; 95% CI: 1.1-1.5; $P=0.003$) These data demonstrate that, despite flawed epidemiological findings to the contrary, *any* level of alcohol consumption increases the likelihood of high blood pressure, though the effect is most dramatic for heavy drinkers. Fortunately, as we have covered in the past, even for those with a history of heavy drinking, reducing intake can attenuate the added risk of hypertension and drastically improve cardiovascular health trajectories more broadly.[47,48]

## Other factors that may impact hypertension

**Sleep:** Poor sleep, including both sleep deprivation and insomnia, has been linked to elevated blood pressure. A 2019 meta-analysis found that both inadequate sleep (≤5 hours) and excessive sleep (≥9 hours) were positively associated with hypertension, as were other sleep-related concerns such as obstructive sleep apnea and snoring.[49] Indeed, another meta-analysis demonstrated that the association was dose dependent according to a U-shaped pattern, meaning that the risk for hypertension increased with progressively *shorter* durations of sleep below seven hours/day as well as with progressively *longer* durations of sleep above nine hours/day.[50] While these findings all derive from observational studies, the dose-response relationship would support a causal link between poor sleep and elevated blood pressure, and a number of plausible mechanisms for such an effect have been proposed. Though future studies are needed to investigate these mechanisms and provide more specific insights as to the phases and patterns of sleep which might be most relevant for hypertension risk, at present we can still be confident that ensuring adequate, high-quality sleep is essential for maintaining healthy blood pressure levels.

**Stress:** Chronic stress is a significant contributor to hypertension, though it can be challenging to manage. Stress can elevate blood pressure through the activation of stress hormones like cortisol, which increase heart rate and blood vessel constriction. Unhealthy coping mechanisms, such as overeating, smoking, or alcohol consumption, may exacerbate the impact of stress on blood pressure. Strategies for stress reduction include mindfulness, meditation, deep breathing exercises, and physical activity. Studies have shown that behavioral approaches like using relaxation techniques[51] and biofeedback can lower blood pressure by a small amount in some patients.[52]

**Caffeine:** Caffeine can raise blood pressure, particularly in individuals who are not regular consumers, though the increase is temporary. One study found that, although both systolic and systolic readings increase after consuming caffeine, the elevation was not sustained with regular consumption and had no effect on ECG measure of heart function.[53] Another small study found that systolic BP increased only in subjects who do not regularly drink caffeine.[54] Therefore, although regular caffeine consumption does not appear to be a major factor in hypertension, people who do not regularly drink caffeinated beverages should be aware that a sudden increase in caffeine consumption could cause their blood pressure to spike. However, despite these acute effects, the preponderance of evidence does not indicate that regular, long-term consumption of caffeine results in chronic blood pressure elevations or an increased risk of hypertension.[55]

**Insulin resistance:** I have often discussed the five metrics of metabolic syndrome, two of which are high blood pressure and elevated glucose levels (the other three are truncal obesity, elevated triglyceride levels, and low HDL cholesterol). High blood pressure accompanied by high glucose levels can be a proxy for insulin resistance. Insulin resistance, which is often a precursor to type II diabetes, reduces the bioavailability of nitric oxide,[56] a molecule involved in the dilation of blood vessels. Thus, insulin resistance can contribute to higher blood pressure, underscoring the importance of managing both conditions simultaneously to improve long-term health outcomes.

## Medications for blood pressure management

While lifestyle changes are essential for blood pressure management, medications may be necessary for some individuals. There are several classes of medications commonly used to control hypertension, including **angiotensin converting enzyme (ACE) inhibitors**, **angiotensin II receptor blockers (ARBs)**, **thiazide diuretics (THZs)**, and **calcium channel blockers (CCBs)**. For primary hypertension, all first-line medications are roughly equivalent in efficacy, reducing systolic pressure by about 12–15 mmHg and diastolic by about 9–11 mmHg. These drug classes also appear largely comparable in their effectiveness in reducing risk of major adverse cardiovascular events, as reported in a 2019 analysis of data from nearly five million patients.[57] However, it is worth noting ACE inhibitors and ARBs are frequently found to be less effective in reducing blood pressure specifically among Black individuals than CCB or THZ alternatives.[58,59]

The optimal choice of medication is specific to each patient. In addition to the consideration of racial background, the decision depends on variables such as co-existing conditions and tolerability of various side effects. For instance, most CCBs are contraindicated for patients with heart failure with reduced ejection fraction, while THZs are often considered to be less desirable options for patients with diabetes or prediabetes due to exacerbation of metabolic dysregulation.[60] ACE inhibitors and ARBs, meanwhile, should be avoided during pregnancy, though these medications are otherwise typically associated with fewer side effects relative to CCBs and THZs.

A summary of these first-line drug classes is shown in the Table below. (Other antihypertensive drugs include β-adrenergic blockers (commonly known as beta blockers) and, less commonly, α-adrenergic blockers, but they are no longer considered first-line options.) Tolerability and potential side effects are also important considerations, and in some cases, combination therapy may be used to enhance effectiveness while minimizing side effects. Decisions about which medication to use should be made in consultation with a physician who has been informed of all co-existing conditions, and in all cases, the use of blood-pressure medications should be accompanied by BP-lowering lifestyle interventions. While medications are more effective than any single lifestyle factor, the sum total of all lifestyle interventions can have benefits at least on par with what medications can accomplish.

**Table 3. The four first-line hypertension drug categories.**

| Drug class | Mechanism | Examples | Contraindications |
|---|---|---|---|
| ACE Inhibitors | Decrease blood vessel constriction | Lisinopril, enalapril | Pregnancy, hyperkalemia, bilateral renal artery stenosis |
| Angiotensin II receptor blockers (ARBs) | Decrease blood vessel constriction | Losartan, valsartan | Pregnancy, hyperkalemia, bilateral renal artery stenosis |
| Thiazide Diuretics (THZ) | Promote renal elimination of sodium and water | Hydrochlorothiazide, chlorthalidone | Gout<br>May also exacerbate impaired glycemic control |
| Calcium Channel Blockers (CCB) | Promote blood vessel relaxation | Amlodipine, diltiazem | Heart failure with reduced ejection fraction |

## Secondary hypertension

While most cases of high blood pressure are classified as “primary” hypertension, around 5-10% of cases are instead “secondary” hypertension – meaning the elevation in blood pressure results from another underlying medical condition. Secondary hypertension is considered correctable with proper treatment of the underlying cause,[61] but it can be more complex and resistant to standard treatments than primary hypertension.

Secondary hypertension is not always easily recognizable, as it shares many symptoms with primary hypertension. However, one of the first indicators is if the hypertension does not respond well to conventional blood pressure medications. Likewise, if a patient’s hypertension was previously controlled with medication but becomes resistant over time or if blood pressure readings exceed 180 mmHg systolic, secondary hypertension should be considered. Additionally, the sudden onset of high blood pressure or a significant increase in already elevated blood pressure can be indicative of an underlying condition.

Age is another important factor. Secondary hypertension should be suspected in younger individuals who do not have other typical risk factors for high blood pressure, as well as in individuals over age 55 when the hypertension appears for the first time. If hypertension is diagnosed before the age of 30 or after age 55, a more thorough investigation for secondary causes is warranted to ensure appropriate intervention.

### Causes of secondary hypertension

Several medical conditions can lead to secondary hypertension. These conditions affect various systems in the body, often disrupting the regulation of blood pressure.[61]

1. **Kidney disease and renal hypertension**: The kidneys play a crucial role in regulating fluid and sodium balance, both of which are essential for controlling blood pressure. Impaired kidney function, such as from the narrowing of arteries supplying the kidneys, can lead to fluid retention and elevated blood pressure.

2. **Adrenal gland dysfunction**: The adrenal glands, located above the kidneys, secrete hormones that influence blood pressure. Hyperaldosteronism, a condition in which the adrenal glands overproduce aldosterone (a hormone that regulates blood levels of sodium and potassium), can cause elevations in blood pressure. In rare cases, adrenal gland hypoplasia (when the adrenal gland is functioning below normal capacity) can also result in secondary hypertension. Also rarely, tumors called pheochromocytomas, which secrete “fight or flight” hormones called catecholamines, can lead to spikes in blood pressure.
3. **Obstructive sleep apnea**: This common condition, characterized by breathing interruptions during sleep, can raise blood pressure through various accompanying changes such as increased sympathetic nervous system activity.
4. **Medications**: Certain drugs, including birth control pills, decongestants, over-the-counter pain relievers, and chemotherapeutic drugs can elevate blood pressure. Physicians should review patients’ medications to rule them out as possible causes of secondary hypertension.

**Less common causes include:**

1. **Thyroid problems**: Both hyperthyroidism (overactive) and hypothyroidism (underactive) can cause fluctuations in blood pressure. Thyroid hormones influence heart rate and vascular tone, making thyroid dysfunction a potential cause of secondary hypertension.
2. **Cushing syndrome:** This syndrome is typically caused by steroid drug use (or, in rare cases, by an adrenal tumor). It results from excess levels of the hormone cortisol.
3. **Aorta abnormalities**: A congenital condition in which the aorta is narrowed can also cause secondary hypertension and requires surgical intervention for correction.

### Managing Secondary Hypertension

Treatment for secondary hypertension focuses on addressing the root cause. Unlike primary hypertension, where lifestyle changes and medication are the mainstay of treatment, secondary hypertension requires specific interventions tailored to the underlying condition.

If medications are the cause of secondary hypertension, switching or discontinuing the use of the offending drugs may be sufficient to restore normal blood pressure. For example, substituting birth control pills or decongestants with alternatives that do not raise blood pressure can have a significant impact. In cases of renal artery narrowing or adrenal tumors, surgical procedures may be necessary. In cases of sleep apnea, using a continuous positive airway pressure (CPAP) machine to improve breathing during sleep can help lower blood pressure.

## Low blood pressure (hypotension)

While much of the focus in blood pressure management is on reducing *high* blood pressure, blood pressure that is too *low* (hypotension) can also be problematic. As a general guideline, a blood pressure below 90/60 mmHg would probably be considered low. However, unlike hypertension, low blood pressure is defined less by a specific numerical threshold than by the presence of symptoms, which can vary depending on the underlying cause and severity.[62] Common symptoms include dizziness, fainting, blurred vision, nausea, fatigue, and dehydration, though some also experience cold, clammy, pale skin, and shallow breathing. These symptoms are typically more concerning when they occur suddenly or are accompanied by a sharp drop in blood pressure, as opposed to blood pressure that has been stable at a low level.

Low blood pressure can be caused by a number of factors. Dehydration is a common cause, as reductions in blood volume can result in a drop in blood pressure. Prolonged bed rest can also contribute, as it leads to reduced muscle tone and blood volume. Hypotension can also arise due to deficiencies in vitamin B12 and folate, which can hamper production of red blood cells. Finally, certain medications – especially those used to treat *high* blood pressure or various cardiovascular conditions – have the potential to lower blood pressure *too* much, often leading to orthostatic hypotension (a condition in which blood pressure suddenly drops when you stand up from a lying or sitting position), which in turn can cause lightheadedness and fainting.

Importantly, low blood pressure can also result from other underlying health conditions. Heart problems such as bradycardia (slow heartbeat), heart valve issues, and heart failure can reduce blood pressure, as can endocrine disorders such as underactive thyroid or adrenal insufficiency. Thus, those with hypotensive symptoms should work with their healthcare provider to identify the cause.

Even if more serious underlying conditions are ruled out, identifying the cause of low blood pressure is necessary for determining how best to manage it. For instance, fluid and electrolyte replacement will help to address hypotension caused by dehydration, while adjustments in antihypertensive medications may be necessary for those whose blood pressure is too low due to treatment for hypertension or heart disease.[62] For individuals with persistent hypotension, wearing compression stockings can help prevent blood from pooling in the legs, thus improving circulation. Avoiding sudden changes in body position, such as standing up quickly, can also help to prevent dizziness or fainting in hypotensive individuals.

## The bottom line

Hypertension is implicated in hundreds of thousands of deaths each year in the US, most often through its contributions to cardiovascular events and kidney disease.[5,6] Diagnosis, prevention, and management of hypertension can thus have enormous impacts on health and lifespan, as apparent by the fact that each 20/10 mmHg increase in blood pressure doubles the risk of cardiovascular mortality – ergo, each 20/10 mmHg *decrease* in blood pressure can halve this risk.[7]

> The diagnosis of hypertension requires accurate blood pressure measurements, but many variables can affect the results, so readings should be taken multiple times over several weeks. In addition, factors like cuff size, body position, and even time of day can affect readings, so following proper protocol is important to ensure consistent and accurate measurements.
>
> The first step in treating hypertension should be to address modifiable factors. The most important factors under our control that causally impact blood pressure are an unhealthy diet/obesity, a lack of exercise, and excess alcohol consumption, roughly in that order.
>
> If, after these factors have been addressed, patients are still unable to reach their goals, the currently available antihypertensive medications are very effective at reducing blood pressure without significant side effects.
>
> First-line antihypertensive medications include angiotensin converting enzyme (ACE) inhibitors, angiotensin II receptor blockers, thiazide diuretics, and calcium channel blockers. β-adrenergic blockers and, less commonly, α-adrenergic blockers, are considered second-line options.

Few health parameters have larger impacts on healthspan and lifespan than blood pressure, yet few are as simple to monitor or have as many options for management. By taking an active role in our own blood pressure oversight and management, we can drastically reduce our chances of ending up on the wrong side of hypertension statistics.

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