High blood pressure (BP), a major established predictor of cardiovascular disease, is the leading risk factor for mortality worldwide. Both systolic BP (SBP) and diastolic BP (DBP) have continuous, independent relations with the risk of cardiovascular disease; however, considerable uncertainty persists about the relative importance of SBP, DBP, and their combination in predicting cardiovascular risk.

**Significance of SBP and DBP**

Given the stronger prognostic value of SBP compared with DBP and the prominent role of aortic stiffening as a predictor of cardiovascular outcomes, a simplified definition of hypertension has been proposed. According to this view, the thresholds for diagnosing and treating hypertension should be based on SBP only, and DBP values should be discarded, at least in individuals 50 years of age or older. A number of other undisputed theoretical and practical reasons support this position. SBP tends to rise continuously throughout life, whereas DBP rises up to approximately 50 years of age, then levels off and tends to decrease after the age of 60. As a consequence thereof, elevated SBP is more prevalent than DBP in populations with increasing life expectancy. Moreover, poor SBP control is much more common than poor DBP control. Also, measurement of SBP is more accurate than that of DBP. Finally, a single number is simpler to communicate in public health initiatives and may be an easier target to focus on for physicians.

In the current issue of *Circulation*, Franklin et al shed new light on the debated issue of which BP components best capture the BP-associated cardiovascular risk. The authors took advantage of the prospectively collected database of the Framingham Heart Study. In 9657 adults who were free from cardiovascular disease and without antihypertensive therapy, the authors confirmed that SBP is a stronger risk factor for cardiovascular disease than DBP. More importantly, they demonstrated that the combined evaluation of SBP and DBP improves cardiovascular risk prediction over the 2 individual components. The model that included both SBP and DBP was significantly better than the models that included a single BP component (SBP or DBP) in predicting cardiovascular risk, although the increase in the area under the receiver operating characteristic curve of the SBP-plus-DBP model compared with the SBP model was lower in the multivariate-adjusted than in the unadjusted model, which suggests that some of the incremental prognostic information provided by DBP may already be included in the other commonly accepted risk markers. These data are in agreement with an earlier analysis of the Multiple Risk Factor Intervention Trial that showed that the addition of DBP to SBP improved prediction of cardiovascular mortality in middle-aged men.

What added value can the evaluation of DBP convey beyond that of SBP in cardiovascular risk stratification? First, isolated diastolic hypertension was a cardiovascular risk factor in the study by Franklin et al. Subjects with isolated diastolic hypertension represented 14% of the hypertensive population, and their cardiovascular risk was found to be about twice that of the subjects with normal BP. It must be recognized that in the setting of the Framingham Heart Study, subjects with isolated diastolic hypertension also tend to have a cluster of markers of cardiovascular risk, including male sex, smoking, and higher body mass index, which may explain in part the risk associated with high DBP. However, the increased cardiovascular risk among subjects with isolated diastolic hypertension was confirmed in a multivariate-adjusted model. Moreover, a recently published analysis of a large, nationwide Chinese database also confirmed that isolated diastolic hypertension is an independent risk factor for cardiovascular disease. Overall, these data suggest that the view of isolated DBP elevation as a low-risk condition should be reconsidered. Second, DBP was...
Significance of Mean and Pulse Pressure

BP traditionally has been measured in terms of peak (systolic) and trough (diastolic) values, but a more physiologically appropriate interpretation considers the BP waveform as being composed of a steady component (mean arterial pressure) on which cyclic oscillations, represented by pulse pressure, are superimposed. Mean arterial pressure is generally regarded as a measure of cardiac output and peripheral resistance, whereas pulse pressure is mainly determined by the distensibility of the large arteries and by the timing and intensity of reflected waves, the pattern of ventricular ejection, and heart rate. In their study, Franklin et al.11 found that the model based on mean and pulse pressures had the same value as the traditional approach based on SBP and DBP in predicting cardiovascular disease. In fact, the 2 models had exactly the same predictive power as expressed by the Akaike information criterion. On a mathematical basis, this should not come as a surprise; given that mean and pulse pressures are derived entirely from SBP and DBP, no improvement in the overall goodness-of-fit can be expected. The “resistance-stiffness” model based on mean and pulse pressures has relevant pathophysiological implications, however. In contrast to DBP, which displayed a quadratic relation with cardiovascular risk, both mean and pulse pressure had a linear, independent relation with risk. These data, in agreement with previous reports,16,17 show that arterial resistance (represented approximately by mean arterial pressure) and large-artery stiffness (witnessed by pulse pressure) have joint adverse effects on the subsequent risk of cardiovascular disease.

The present study should be considered within the context of its limitations. It has been suggested that stroke might preferentially be predicted by mean arterial pressure, whereas pulse pressure could have a stronger impact on coronary heart disease.18 Unfortunately, the analysis by Franklin et al.11 only considered overall cardiovascular end points (largely because of a power issue) and did not take into account coronary and cerebrovascular outcomes separately. Moreover, to maximize the number of person-observations and to utilize the information provided by multiple BP measurements obtained over the years in a given individual, the observation time was divided into serial 4-year intervals, each of which was treated as an independent observation (despite coming from the same individual), and the different BP components obtained at the beginning of each 4-year period and their combinations were related to the occurrence of cardiovascular events over the next 4 years. Thus, despite the 50-year-long duration of the Framingham Heart Study, the present analysis only considered short-term cardiovascular risks. This might explain in part why the authors could not replicate their previous findings based on long-term observations16,17 show that arterial resistance (represented approximately by mean arterial pressure) and large-artery stiffness (witnessed by pulse pressure) have joint adverse effects on the subsequent risk of cardiovascular disease.

What are the clinical and public health implications of these findings? It is unquestionable that SBP is able to capture most of the prognostic significance of BP, especially in subjects above the age of 50 years; however, it is not yet time to discard DBP. The results of this large prospective study11 and other observations18 suggest that isolated diastolic hypertension should not be regarded as a benign entity. These findings support the recommendation of the Seventh Joint National Committee to consider both SBP and DBP in the definition and management of hypertension.20 Moreover, the combination of high SBP and low DBP represents a condition of particularly high cardiovascular risk, which has been emphasized appropriately in the 2007 European guidelines on high blood pressure management21 and deserves to be better highlighted in forthcoming releases of the Joint National Committee recommendations.

Disclosures

References


Table. Evolving Definition of Hypertension in Adults According to the Joint National Committee Guidelines

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Publication Year</th>
<th>BP Criterion</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>JNC 1</td>
<td>1976</td>
<td>DBP</td>
<td>≥90 mm Hg</td>
</tr>
<tr>
<td>JNC 2</td>
<td>1980</td>
<td>DBP</td>
<td>≥90 mm Hg</td>
</tr>
<tr>
<td>JNC 3</td>
<td>1984</td>
<td>DBP</td>
<td>≥90 mm Hg</td>
</tr>
<tr>
<td>JNC 4</td>
<td>1988</td>
<td>DBP + isolated systolic hypertension</td>
<td>≥90 mm Hg</td>
</tr>
<tr>
<td>JNC 5</td>
<td>1993</td>
<td>SBP and/or DBP</td>
<td>≥140/90 mm Hg</td>
</tr>
<tr>
<td>JNC 6</td>
<td>1997</td>
<td>SBP and/or DBP</td>
<td>≥140/90 mm Hg</td>
</tr>
<tr>
<td>JNC 7</td>
<td>2003</td>
<td>SBP and/or DBP</td>
<td>≥140/90 mm Hg</td>
</tr>
</tbody>
</table>

JNC indicates Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.

None.

"Resistance-stiffness" model based on mean and pulse pressures has relevant pathophysiological implications, however. In contrast to DBP, which displayed a quadratic relation with cardiovascular risk, both mean and pulse pressure had a linear, independent relation with risk. These data, in agreement with previous reports, show that arterial resistance (represented approximately by mean arterial pressure) and large-artery stiffness (witnessed by pulse pressure) have joint adverse effects on the subsequent risk of cardiovascular disease.

The present study should be considered within the context of its limitations. It has been suggested that stroke might preferentially be predicted by mean arterial pressure, whereas pulse pressure could have a stronger impact on coronary heart disease. Unfortunately, the analysis by Franklin et al. only considered overall cardiovascular end points (largely because of a power issue) and did not take into account coronary and cerebrovascular outcomes separately. Moreover, to maximize the number of person-observations and to utilize the information provided by multiple BP measurements obtained over the years in a given individual, the observation time was divided into serial 4-year intervals, each of which was treated as an independent observation (despite coming from the same individual), and the different BP components obtained at the beginning of each 4-year period and their combinations were related to the occurrence of cardiovascular events over the next 4 years. Thus, despite the 50-year-long duration of the Framingham Heart Study, the present analysis only considered short-term cardiovascular risks. This might explain in part why the authors could not replicate their previous findings based on long-term observations from the Framingham Heart Study. In that study, a progressive shift from DBP to SBP and then to pulse pressure was found with increasing age, whereas in the present short-term analysis, no significant effect of age was documented.

What are the clinical and public health implications of these findings? It is unquestionable that SBP is able to capture most of the prognostic significance of BP, especially in subjects above the age of 50 years; however, it is not yet time to discard DBP. The results of this large prospective study and other observations suggest that isolated diastolic hypertension should not be regarded as a benign entity. These findings support the recommendation of the Seventh Joint National Committee to consider both SBP and DBP in the definition and management of hypertension. Moreover, the combination of high SBP and low DBP represents a condition of particularly high cardiovascular risk, which has been emphasized appropriately in the 2007 European guidelines on high blood pressure management and deserves to be better highlighted in forthcoming releases of the Joint National Committee recommendations.

Disclosures

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Key Words: Editorials | blood pressure | cardiovascular diseases | prognosis
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Circulation. 2009;119:210-212
doi: 10.1161/CIRCULATIONAHA.108.827931

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