

# Differential Impact of Systolic and Diastolic Blood Pressure Level on JNC-VI Staging

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**Abstract**—The sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure classifies blood pressure into stages on the basis of both systolic (SBP) and diastolic (DBP) blood pressure levels. When a disparity exists between SBP and DBP stages, patients are classified into the higher stage (“up-staged”). We evaluated the effect of disparate levels of SBP and DBP on blood pressure staging and eligibility for therapy. We examined 4962 Framingham Heart Study subjects between 1990 and 1995 and determined blood pressure stages on the basis of SBP alone, DBP alone, or both. After the exclusion of subjects on antihypertensive therapy ( $n=1306$ ), 3656 subjects (mean age  $58 \pm 13$  years; 55% women) were eligible. In this sample, 64.6% of subjects had congruent stages of SBP and DBP, 31.6% were up-staged on the basis of SBP, and 3.8% on the basis of DBP; thus, SBP alone correctly classified JNC-VI stage in  $\approx 96\%$  ( $64.6\% + 31.6\%$ ) of the subjects. Among subjects  $>60$  years of age, SBP alone correctly classified 99% of subjects; in those  $\leq 60$  years old, SBP alone correctly classified 95%. Of 1488 subjects with high-normal blood pressure or hypertension, who were potentially eligible for drug therapy, 13.0% had congruent elevations of SBP and DBP, 77.7% were up-staged on the basis of SBP, and 9.3% were up-staged on the basis of DBP; SBP alone correctly classified 91%, whereas DBP alone correctly classified only 22%. SBP elevation out of proportion to DBP is common in middle-aged and older persons. SBP appears to play a greater role in the determination of JNC-VI blood pressure stage and eligibility for therapy. Given these results, combined with evidence from hypertension treatment trials, future guidelines might consider a greater role for SBP than for DBP in determining the presence of hypertension, risk of cardiovascular events, eligibility for therapy, and benefits of treatment. (*Hypertension*. 1999;34:381-385.)

**Key Words:** hypertension, detection and control ■ risk factors ■ epidemiology ■ guidelines

Hypertension has been firmly established as a risk factor for cardiovascular diseases, including stroke, coronary heart disease, congestive heart failure, and peripheral arterial disease.<sup>1</sup> Historically, elevated diastolic blood pressure (DBP) was thought to confer a greater risk for cardiovascular events than elevated systolic blood pressure (SBP), which resulted in classification systems and treatment recommendations that placed greater emphasis on the treatment of diastolic hypertension.<sup>2–5</sup> However, mounting evidence from prospective epidemiological investigations indicates that elevated SBP is at least as important a risk factor as elevated DBP.<sup>6–9</sup> In addition, more recent clinical trials<sup>10–12</sup> have demonstrated a reduction in cardiovascular events with the treatment of elevated SBP.

The sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-VI) was published in November 1997.<sup>13</sup> This report, like its predecessor,<sup>14</sup> classifies patients into blood pressure stages on the basis of the levels of both their SBP and DBP. JNC-VI also proposes a new algorithm for

treatment of elevated blood pressure with a risk-stratification component based not only on level of blood pressure but also on the presence or absence of other coincident cardiovascular disease risk factors, target organ damage, or clinical cardiovascular disease.

In clinical practice, SBP and DBP levels are often disparate, leading to a phenomenon known as “up-staging.”<sup>15</sup> For example, a patient with a blood pressure of 150/80 mm Hg would be classified as Stage 1 hypertension<sup>13</sup> on the basis of his SBP, despite having a normal DBP; such a patient is up-staged in the classification scheme because of a SBP elevation out of proportion to the DBP. The prevalence of disparate levels of SBP and DBP has not been reported in a general population. Examination of blood pressure disparity may point to a differential effect of SBP versus DBP in determining blood pressure stage and eligibility for therapy. Such data may assist clinicians, researchers, and policy makers in understanding the potential impact of JNC-VI guidelines on clinical practice and public health. We sought to determine the proportion of untreated subjects in a

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community-based sample who have elevated blood pressure on the basis of SBP, DBP, or both and to determine the effect of disparate levels on blood pressure up-staging.

## Methods

### Study Sample

The Framingham Heart Study was established in 1948 when 5209 residents of Framingham, Massachusetts, aged 28 to 62 years, were enrolled in a prospective epidemiological cohort study to evaluate potential risk factors for coronary heart disease. Members of this cohort have received follow-up evaluations every 2 years with medical histories and physical examinations, as well as selected laboratory tests, including fasting lipid levels and 12-lead electrocardiograms. In 1971, 5124 additional subjects (offspring of original cohort subjects and their spouses) were enrolled into the Framingham Offspring Study. These participants have received follow-up evaluations every 4 years. Study design and entry criteria for both cohorts have been detailed elsewhere.<sup>16–19</sup> All exams and procedures have been approved by the Institutional Review Board of Boston University School of Medicine.

The present study sample included 1164 subjects from the original Framingham Heart Study cohort who participated in examination cycle 22 (1990–1994) and 3798 participants from the Framingham Offspring Study who participated in examination cycle 5 (1991–1995). Because we wanted to determine the effect of SBP and DBP on JNC-VI staging in untreated individuals, we excluded from the main analyses all subjects who were receiving antihypertensive therapy (including diuretics,  $\alpha_1$ -agonists,  $\alpha_2$ -blockers,  $\beta$ -blockers, calcium channel-blockers,  $\alpha$ -methyl dopa, angiotensin-converting enzyme inhibitors, and peripheral vasodilators) at the time of their examination.

### Blood Pressure Measurement

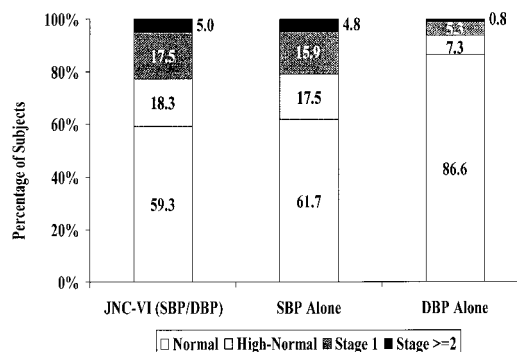
At each examination, blood pressure was measured twice in the left arm with a mercury column sphygmomanometer by an examining physician after the patient had rested  $\geq 5$  minutes in the seated position. The SBP level was defined as the first appearance of sound (Korotkoff phase 1), and the DBP level was defined as the disappearance of sound (phase 5). Measurements were separated by  $\geq 2$  minutes. The means of the 2 separate SBP and DBP measurements were then calculated to derive the reported blood pressure for that examination.

### Blood Pressure Staging

Blood pressure stages were classified according to the following JNC-VI criteria<sup>13</sup>: normal (SBP <130 and DBP <85 mm Hg); high-normal (SBP 130 to 139 mm Hg or DBP 85 to 89 mm Hg); stage 1 hypertension (SBP 140 to 159 mm Hg or DBP 90 to 99 mm Hg); stage 2 hypertension (SBP 160 to 179 mm Hg or DBP 100 to 109 mm Hg); or stage 3 hypertension (SBP  $\geq 180$  mm Hg or DBP  $\geq 110$  mm Hg). To determine the prevalence of disparate levels of SBP and DBP and the differential effect of SBP and DBP in determining the JNC-VI blood pressure stage, subjects were also staged according to the levels of their SBP alone or DBP alone. Blood pressure stages 2 and 3 were combined into a stage  $\geq 2$  category for all analyses because of the low prevalence of stage 3 hypertension ( $n=35$ ).

### Statistical Analysis

The number and percentage of subjects in each SBP stage, DBP stage, and JNC-VI stage were then determined. In addition, the percentage of subjects within each JNC-VI stage who had disparate or congruent levels of SBP and DBP was determined. These analyses were performed for the entire study sample and repeated for subjects with JNC-VI high-normal blood pressure or hypertension. To assess the effect of age on SBP and DBP and blood pressure staging, we stratified the study sample into 2 groups *a priori* (those  $>60$  and those  $\leq 60$  years of age) and repeated the analyses. In a secondary analysis, subjects who received antihypertensive therapy and were therefore excluded from the main analyses were classified according



**Figure 1.** Distribution of blood pressure stages in 3656 untreated subjects on the basis of JNC-VI criteria, SBP alone, or DBP alone.

to their on-treatment blood pressure. All analyses were performed with SAS statistical software (SAS Corp).<sup>20</sup>

## Results

During the study period, 4962 subjects were examined. A total of 1306 subjects were excluded because they were receiving antihypertensive therapy; this left 3656 subjects in the study sample. The mean age of the study sample was  $58 \pm 13$  years; 55% were women.

Figure 1 shows the percentage of subjects in each blood pressure stage on the basis of JNC-VI criteria with the use of both SBP and DBP, the systolic stage only, or the diastolic stage only. In the entire study sample, 59% of subjects had normal blood pressure, 18% had high-normal blood pressure, 18% had stage 1 hypertension, and 5% had stage  $\geq 2$  hypertension. These percentages were quite similar when subjects were classified on the basis of their SBP only but were markedly different for DBP. Nearly 40% of subjects had an elevated (high-normal or hypertensive) SBP, whereas only 13% had elevated DBP. Therefore, blood pressure staging by JNC-VI criteria, which accounts for both SBP and DBP, more closely reflected the distribution of SBP than DBP.

Table 1 shows the number of subjects who were classified into each JNC-VI SBP and DBP category. The numbers on the diagonal (shown in bold) represent subjects in our study sample with congruent levels of SBP and DBP by JNC-VI classification. The numbers below and to the left of the diagonal represent subjects with SBP that was elevated out of proportion to DBP or subjects who were up-staged on the basis of their SBP. The numbers above and to the right of the diagonal represent subjects who were up-staged on the basis of their DBP. In all, 1295 subjects (35%) were classified above or below the diagonal, indicating that they had disparate levels of SBP and DBP.

Among the entire sample, 64.6% of subjects had congruent levels of blood pressure, 31.6% were up-staged on the basis of SBP, and only 3.8% were up-staged on the basis of DBP. Therefore, knowledge of the SBP alone correctly classified the JNC-VI stage in 96% (64.6%+31.6%) of subjects, whereas knowledge of the DBP alone correctly classified only 68% (64.6%+3.8%) of subjects.

### High-Normal and Hypertensive Subjects

There were 1488 subjects who had high-normal blood pressure or hypertension. This group is of particular interest

**TABLE 1. Number of Subjects in Each JNC-VI Blood Pressure Stage on the Basis of SBP and DBP levels**

SBP, mm Hg	DBP, mm Hg				Row Total
	Normal <85	High-Normal 85–89	Stage 1 90–99	Stage $\geq 2$ $\geq 100$	
Normal (<130)	<b>2168</b>	74	14	0	2256
High-Normal (130–139)	518	<b>75</b>	45	0	638
Stage 1 (140–159)	394	92	<b>95</b>	6	587
Stage $\geq 2$ ( $\geq 160$ )	86	27	39	<b>23</b>	175
Column Total	3166	268	193	29	<b>3656</b>

Numbers in boldface indicate congruent levels of SBP and DBP.

because they are potentially eligible for initial drug therapy under JNC-VI recommendations. There was an even more striking disparity in SBP and DBP levels among this subgroup (Figure 2): 94% had an elevated SBP, whereas only 33% had an elevated DBP. Fully two thirds of the subjects had a normal DBP despite being in a high-normal or hypertensive JNC-VI stage. Again, the JNC-VI stage reflected the effect of up-staging on the basis of SBP. In subjects with high-normal, stage 1, and stage  $\geq 2$  levels, 11%, 15%, and 13%, respectively, were classified on the basis of both SBP and DBP; 78%, 76%, and 84% were classified on the basis of SBP alone; and 11%, 9%, and 3% were classified on the basis of DBP alone (Table 2).

Of the 1488 subjects with high-normal blood pressure or hypertension, 13.0% were staged on the basis of congruent elevations of SBP and DBP, 77.7% were up-staged on the basis of SBP elevation out of proportion to DBP, and 9.3% were up-staged on the basis of DBP. Therefore, knowledge of the SBP alone correctly classified JNC-VI stage in 91%, whereas knowledge of the DBP alone correctly classified only 22% of subjects.

### Affect of Age

To examine whether age affected the proportion of subjects who were up-staged on the basis of SBP or DBP in the study sample, we stratified subjects according to age  $>60$  years ( $n=1366$ ) or age  $\leq 60$  years ( $n=2290$ ). In the older group, 46% had congruent levels of SBP and DBP, 53% were up-staged on the basis of SBP, and only 1% were up-staged on the basis of DBP. Therefore, knowledge of only the SBP correctly classified the JNC-VI stage in 99% of subjects (versus 47% for DBP alone). In the younger age group,

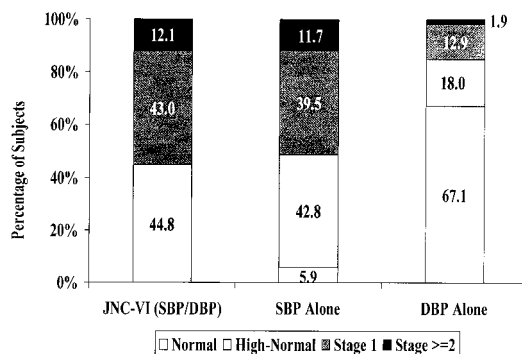
76% had congruent levels of SBP and DBP, 19% were up-staged on the basis of SBP, and 5% were up-staged on the basis of DBP. Knowledge of only the SBP correctly classified JNC-VI stage in 95% of subjects (versus 81% for DBP alone).

### Treated/Excluded Subjects

Bias may have been introduced into our results if subjects with diastolic hypertension were more likely to be treated by their physicians. To examine this possibility, we measured on-treatment blood pressures in the 1306 subjects excluded from the study sample because they were receiving antihypertensive therapy. When we classified subjects into JNC-VI stages on the basis of these on-treatment blood pressures, 35% had congruent levels of SBP and DBP, 62% were up-staged on the basis of SBP, and 3% were up-staged on the basis of DBP. After we restricted the analysis to subjects without a history of myocardial infarction or congestive heart failure who were receiving antihypertensive therapy ( $n=1162$ ), these percentages were identical.

### Discussion

In our predominantly middle-aged sample, we observed that disparate levels of SBP and DBP were common and occurred in 35.4% of untreated subjects. Consequently, when we applied the JNC-VI classification of blood pressure values, we found that subjects were classified more often on the basis of SBP elevation out of proportion to DBP rather than in the opposite situation. Among all untreated subjects, 31.6% were up-staged on the basis of SBP and 3.8% were up-staged on the basis of DBP. In subjects with high-normal blood pressure or hypertension, who were potentially eligible for initial drug therapy, 77.7% were up-staged on the basis of SBP and 9.3% were up-staged on the basis of DBP. In this group, knowledge



**Figure 2.** Distribution of blood pressure stages in 1488 subjects with high-normal blood pressure or hypertension on the basis of JNC-VI criteria, SBP alone, or DBP alone.

**TABLE 2. Percentage of Subjects Within Each JNC-VI Blood Pressure Stage who Were Staged on the Basis of SBP Versus DBP Levels**

SBP, mm Hg	DBP, mm Hg			
	Normal <85	High-Normal 85–89	Stage 1 90–99	Stage $\geq 2$ $\geq 100$
Normal (<130)	<b>100</b>	11.1	2.2	0
High-Normal (130–139)	77.7	<b>11.2</b>	7.0	0
Stage 1 (140–159)	61.6	14.4	<b>14.8</b>	3.3
Stage $\geq 2$ ( $\geq 160$ )	47.5	14.9	21.5	<b>12.7</b>

of only the SBP was able to classify JNC-VI stage correctly in 91% of subjects versus 22% for DBP.

In the treatment algorithm as recommended by JNC-VI, all patients with high-normal blood pressure or hypertension should attempt lifestyle modification. Patients with stage  $\geq 2$  hypertension, stage 1 hypertension with target organ damage or cardiovascular disease, or high-normal blood pressure with diabetes, nephropathy, or congestive heart failure are eligible for initial drug therapy. Our data indicates that SBP plays a greater role than DBP in determining both blood pressure stage and eligibility for therapy.

### Risk of Elevated SBP Versus DBP

Epidemiological data suggests that elevated SBP is at least as strong a risk factor as elevated DBP for the development of cardiovascular disease. Previous reports from the Framingham Heart Study and Multiple Risk Factor Intervention Trial (MRFIT) have highlighted the relative risk associated with an increased SBP both in subjects with isolated systolic hypertension<sup>7,8</sup> as well as in those with elevated SBP and DBP.<sup>9</sup> Data from nearly 348 000 men who were free of coronary heart disease, between the ages of 35 and 57 years, and screened for MRFIT indicate that the relative risk of coronary heart disease mortality for subjects in the highest decile versus those in the lowest decile of SBP was 3.82 as opposed to 2.90 for those in the highest versus lowest decile of DBP. The relative risk for each SBP decile was consistently higher than that for comparable DBP deciles.<sup>9</sup>

In addition, elevated SBP appears to confer a greater absolute risk of cardiovascular disease than does elevated DBP,<sup>6,9</sup> especially with advancing age. As age increases, mean blood pressure levels tend to rise and the prevalence of hypertension increases. After age 60, however, mean diastolic pressures tend to plateau or fall, whereas systolic pressures continue to increase.<sup>21,22</sup> Because the majority of coronary heart disease events and cardiovascular morbidity occur in older individuals, the result is that there is also a greater attributable risk conferred by SBP elevation than by DBP elevation.<sup>8</sup>

Further evidence of the importance of systolic hypertension comes from 2 clinical trials. The SHEP<sup>10</sup> and Syst-Eur<sup>11</sup> trials were both double-blind, placebo-controlled studies that evaluated the treatment of isolated systolic hypertension in elderly patients. Both studies demonstrated significant reductions in stroke and other cardiovascular endpoints with active treatment versus placebo.

Despite evidence from trials that indicate that the benefits of blood pressure reduction in hypertensive individuals and the dissemination of national guidelines recommending greater treatment, the rates of hypertension treatment and control to goal blood pressure ( $<140/90$  mm Hg) in the United States are suboptimal. In the latest National Health and Nutrition Examination Survey (NHANES III, phase 2), conducted in 1991–1994, only 53.6% of hypertensive adults aged 18 to 74 years were receiving treatment and only 27.4% had reached goal blood pressure.<sup>13</sup> Clinicians appear especially reluctant to treat older patients,<sup>22</sup> perhaps because of perceived lower benefits among the elderly and risk of side effects. Yet, it is precisely the older patients who are at highest absolute risk for developing the sequelae of uncon-

trolled hypertension: stroke, coronary heart disease, congestive heart failure, renal disease, and other vascular complications. The historical focus on DBP may have created the misperception that treatment of hypertension requires only control of the diastolic component. If this is the case, older patients with elevated SBP, in whom the mean diastolic pressure often is normal, may be undertreated because they are perceived to be “controlled.” Further emphasis in national guidelines should therefore be placed on the prevalence, associated risks, and the benefits of controlling elevated SBP.

### Changes in JNC Classification

In the first 4 JNC reports,<sup>2–5</sup> blood pressure stage was defined principally by DBP level. As a result of evidence that had accumulated, JNC-V,<sup>14</sup> published in 1993, proposed a major revision in the classification of blood pressure stages by use of both SBP and DBP. The blood pressure staging system has remained largely unchanged in JNC-VI, the most recent report.<sup>13</sup>

Pogue et al<sup>15</sup> examined the phenomenon of up-staging among 1158 hypertensive patients who participated in the High Blood Pressure Program at Harlem Hospital. The use of JNC-V criteria (incorporating SBP and DBP) compared with JNC-IV criteria (using DBP alone) to classify these hypertensive patients resulted in more than half of them being up-staged.

In an analysis similar to our present study, the MRFIT Investigators examined the prevalence of SBP and DBP elevation according to the JNC-V classification scheme. They observed that, in their younger male population, 32.4% of high-normal and hypertensive individuals were classified into their blood pressure stage on the basis of SBP alone, 39.7% were classified on the basis of DBP alone, and 27.9% had congruent levels of SBP and DBP.<sup>9</sup> These proportions differ from our results in the 398 men  $\leq 60$  years with high-normal or hypertensive levels (53.0%, 24.6%, and 22.4%, respectively). The discrepancy may be due to the MRFIT blood pressure measurement protocol, which used trained observers, rather than physicians to measure blood pressure. The discrepancy may also reflect the different ethnic composition or selection bias in the group of patients who were screened for the MRFIT cohort. That is, young men with diastolic hypertension may have been preferentially referred to the centers that participated in the MRFIT trial. The MRFIT data are limited in that they include only men 35 to 57 years of age, thus excluding women and the largest hypertensive group, the elderly. Further studies of blood pressure staging are therefore warranted in general populations with broader age ranges. In the present study, women comprised 55% of the sample and subjects ranged in age from 26 to 101 years.

In our sample, as in MRFIT screenees, DBP appeared to have a greater relative impact in determining blood pressure stage in younger individuals, but it was still far less useful than SBP. Among those  $>60$  years of age (the group that includes the majority of hypertensives in the population), the SBP alone correctly predicted JNC-VI stage in nearly all (99%) subjects.

In our secondary analysis of subjects receiving antihypertensive therapy, we again observed a marked preponderance of subjects with on-treatment SBP elevated out of proportion to DBP. The antihypertensive therapy may have decreased levels of SBP and DBP differentially, thereby affecting the



relative contributions of SBP and DBP to JNC-VI staging. However, large-scale clinical trials have typically documented equal or greater reductions in SBP compared with DBP during antihypertensive therapy.<sup>23,24</sup> Hence, if anything, we may have underestimated the pretreatment contribution of SBP in determining blood pressure stage in this group. This would argue against any potential selection bias derived from preferential treatment of subjects with elevated DBP.

### Potential Limitations

These results should be interpreted in the context of their limitations. First, the Framingham Heart Study cohort is composed almost exclusively of white individuals. Examination of the disparity of SBP and DBP in other populations and ethnicities would be useful to determine whether SBP remains as strong a determinant of blood pressure staging and eligibility for therapy. Second, our study sample comprised middle-aged and older individuals. SBP tends to rise with advancing age, whereas DBP plateaus in the sixth decade, after which it tends to fall.<sup>21,22</sup> Therefore, a younger sample might include more subjects with diastolic elevations out of proportion to SBP. However, the vast majority of hypertensive individuals are middle-aged or older, so the findings of our study likely pertain to hypertensive individuals as a population. In the subgroup of individuals <60 years of age in our sample, more subjects had congruent levels of SBP and DBP, but knowledge of just the SBP still correctly classified 95% of subjects. Finally, the JNC-VI report recommends that blood pressure stage should be assigned on the basis of the average of  $\geq 2$  readings taken at each of  $\geq 2$  visits after an initial screening.<sup>13</sup> We used the average of 2 blood pressures measured during a single visit to assign blood pressure stage. It is possible that some subjects may have been classified into a different stage had we measured blood pressure on 3 separate visits within a short period of time. However, such data were not available.

### Conclusions

SBP elevation out of proportion to DBP caused many subjects to be up-staged by use of JNC-VI criteria. Therefore, SBP appears to play a greater role in determining blood pressure stage and eligibility for therapy. Given these results, combined with evidence from hypertension treatment trials, future guidelines might consider acknowledging a greater role for SBP than for DBP in determining blood pressure stage, risk of cardiovascular events, eligibility for therapy, and benefits of treatment.

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