Systolic and Diastolic Blood Pressure, Incident Cardiovascular Events, and Death in Elderly Persons
The Role of Functional Limitation in the Cardiovascular Health Study

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Abstract—Whether limitation in the ability to perform activities of daily living (ADL) or gait speed can identify elders in whom the association of systolic and diastolic blood pressure (DBP) with cardiovascular events (CVDs) and death differs is unclear. We evaluated whether limitation in ADL or gait speed modifies the association of systolic blood pressure or DBP with incident CVD (n=2358) and death (n=3547) in the Cardiovascular Health Study. Mean age was 78±5 and 21% reported limitation in ≥1 ADL. There were 778 CVD and 1289 deaths over 9 years. Among persons without and those with ADL limitation, systolic blood pressure was associated with incident CVD: hazard ratio [HR] (per 10-mm Hg increase) 1.08 (95% confidence interval, 1.03, 1.13) and 1.06 (0.97, 1.17), respectively. ADL modified the association of DBP with incident CVD. Among those without ADL limitation, DBP was weakly associated with incident CVD, HR 1.04 (0.79, 1.37) for DBP >80, compared with <65 mm Hg. Among those with ADL limitation, DBP was inversely associated with CVD: HR 0.65 (0.44, 0.96) for DBP 66 to 80 mm Hg and HR 0.49 (0.25, 0.94) for DBP >80, compared with DBP ≤65. Among people with ADL limitation, a DBP of 66 to 80 had the lowest risk of death, HR 0.72 (0.57, 0.91), compared with a DBP of ≤65. Associations did not vary by 15-feet walking speed. ADL can identify elders in whom diastolic hypotension is associated with higher cardiovascular risk and death. Functional status, rather than chronologic age alone, should inform design of hypertension trials in elders. (*Hypertension*. 2014;64:472-480.)

Key Words: activities of daily living ■ aged ■ hypertension

Elderly people ≥75 years represent the fastest growing age group in the United States, and ≈2/3 are living with high blood pressure (BP).[1] Optimal management of hypertension in elderly people remains a subject of active debate.[2–6] Some studies show that high BP is a risk factor for cardiovascular events (CVDs) and death in elderly people.[7,8] Other studies have shown that higher BP is associated with lower risk of death in some elders, particularly those >75 years.[9,10] A meta-analysis of trials including people aged ≥80 years reported reduction of cardiovascular risk, but not death, from lowering BP.[11] However, trial participants may not be representative of the general elderly population, where there is large heterogeneity of health status.[12] Reliable identification of elders in whom high BP is associated with increased risk of CVDs and death, and who are thus most likely to benefit from treatment, remains difficult. We recently showed that walking speed of a 6-meter (20 feet) walk, a measure of functional status, can differentiate subgroups of elders in whom the association of systolic BP (SBP) with death is incremental, null or reversed.[13] Whether measures of health

or functional status modify the association of BP with incident CVDs remains uncertain.

Additional concern over excessive lowering of BP, particularly diastolic blood pressure (DBP), in elderly people poses another major challenge. Isolated systolic hypertension (high SBP with normal or low DBP) is the most common form of hypertension in the elderly.[14] Some, but not all, studies including elderly people have shown associations of lower DBP with higher risk of CVDs and death.[7,15–17] Whether measures of functional status can identify the elders in whom low DBP is associated with increased risk CVDs and death has not been well established.

We designed this analysis to evaluate whether limitations in activities of daily living (ADL) and a short test for gait speed (15 feet) modify the association of SBP or DBP with CVDs and death among elders participating in the Cardiovascular Health Study (CHS). We hypothesized that higher SBP and DBP would be associated with higher risk of incident CVD and death among healthy elders, but not among elders with functional limitations.

Methods

Participants

We included participants who completed the seventh follow-up visit of the CHS. Briefly, CHS initially recruited community-dwelling Black and White individuals aged >65 years from Medicare eligibility lists in 4 US communities (Forsyth County, NC; Sacramento County, CA; Washington County, MD; and Pittsburgh, PA), in 2 waves from 1989 to 1993. At enrollment, participants were excluded if they were not expected to remain in the current community for 3 years or longer, were receiving treatment for cancer, or were unable to provide informed consent.[18] For these analyses, the seventh follow-up visit was considered the baseline visit to maximize inclusion of people aged >75 years. For analyses of all-cause death, we included all individuals with year 7 measures of BP for a total sample size of 3547. For analyses considering incident cardiovascular disease as the outcome, we excluded 1189 people with prevalent CVD[19] or heart failure, for a total sample size of 2358. All participants provided written informed consent; the institutional review boards of the University of Washington and the affiliated clinical centers approved the study.

SBP and DBP

Participants were asked to fast for 8 to 12 hours overnight prior to the study visit. Trained study personnel obtained 3 seated BP readings, and the average of the last 2 readings was recorded using standardized procedures.

Outcomes

Our first outcome of interest was incident CVD for 10 years. Incident CVD was defined as having myocardial infarction, cardiac arrest, stroke, or cardiovascular death among people without a known history of CVD or heart failure. All events were adjudicated by a CHS outcome-assessment committee. Cases of CVD events were ascertained from hospital records that included clinical histories, elevated cardiac enzyme levels, electrocardiographic changes, and brain imaging studies. More details on event adjudication have been previously published.[18,19] The second outcome of interest was death from all causes. Deaths were identified by a review of obituaries, medical records, death certificates, and the Centers for Medicare and Medicaid Services health care–utilization database for hospitalizations and from household contacts; 100% complete follow-up for ascertainment of mortality status was achieved.

Effect Modifiers

Self-report of limitations in the ability to perform ADL and walking speed using a 15-feet walk were chosen a priori as potential effect modifiers. Difficulty with ADL and slow gait speed has been previously shown to be strong predictors of adverse outcomes.[20,21] Ability to perform ADLs was ascertained by questionnaire by asking whether the participant had difficulty with eating, transferring from bed to chair, mobility inside the home, dressing, bathing, and using the toilet.[22] We categorized people into those without limitation and those who reported limitation of ≥1 ADL. The time (in 0.1-second increments) required for participants to walk 15 feet at their usual pace was recorded using a stopwatch, during the CHS visit at each field center. Walking speed was recorded in meters per second (m/s). We categorized people as fast (≥1.0 m/s), medium (0.60–0.99 m/s), or slow (<0.60 m/s) walkers based on clinically relevant cut points and based the distribution of gait speed in CHS.

Covariates

Covariate data were obtained concomitantly with BP measures. Age, sex, race, income, education, and past or present smoking were

Table 1.   Characteristics of 3547 Elders in Cardiovascular Health Study by Ability to Perform ADL

Characteristic	Total	No Limitation in ADL	Limitation in ≥1 ADL
n	3547	2792	755
Age	78 (5)	78 (5)	80 (6)
Female	2150 (61%)	1622 (58%)	528 (70%)
Black	584 (17%)	430 (15%)	154 (20%)
Education			
None to grade 9	555 (16%)	392 (14%)	163 (22%)
HS graduate	1317 (37%)	1053 (38%)	264 (35%)
Professional	1667 (47%)	1344 (48%)	323 (43%)
Smoking			
Former	1536 (44%)	1220 (45%)	316 (43%)
Current	259 (8%)	209 (8%)	50 (7%)
Physical activity kcal/wk*	675 (183, 1598)	795 (270, 1755)	296 (0, 945)
BMI, kg/m^2	26.9 (4.7)	26.6 (4.4)	28.3 (5.5)
SBP	137 (21)	137 (21)	138 (21)
DBP	70 (11)	70 (11)	70 (12)
Treated with antihypertensives	2074 (59%)	1588 (57%)	486 (65%)
Diabetes mellitus	529 (16%)	382 (14%)	147 (22%)
Total cholesterol	202 (40)	201 (40)	204 (40)
Cystatin C	1.16 (0.41)	1.14 (0.37)	1.27 (0.53)
History of CHD†	885 (25%)	656 (24%)	229 (30%)
History of CHF†	354 (10%)	218 (8%)	136 (18%)

ADL indicates activities of daily living; BMI, body mass index; CHD, coronary heart disease; CHF, congestive heart failure; DBP, diastolic blood pressure; HS, high school; and SBP, systolic blood pressure.

*Median (interquartile range).

†Excluded for the incident cardiovascular event analyses.

ascertained by questionnaire. Height and weight were measured with participants wearing light clothing and no shoes. Body mass index was calculated as weight in kilograms divided by height in meters squared. Physical activity was estimated as kilocalories per week and assessed by self-report. Fasting blood was collected and stored at −70°F until needed for the appropriate assays, including high-density lipoprotein cholesterol, triglycerides, glucose. Low-density lipoprotein cholesterol was calculated using the Friedewald equation. Cystatin C was measured by means of a particle-enhanced immunonephelometric assay (N Latex Cystatin C, Dade Behring) with a nephelometer (Behring Nephelometer II Analyzer, Dade Behring) and calibrated to international standard. Diabetes mellitus was defined as a self-report of diabetes mellitus, the use of insulin or oral hypoglycemic agents, or a fasting glucose of ≥126 mg/dL. Prevalent cardiovascular disease was defined as having a history of coronary heart disease, heart failure, or stroke, and these have been previously validated in CHS.[19] Use of antihypertensive medication was ascertained by a medication inventory interview.

Analyses

We first evaluated the characteristics of participants overall and by reported difficulty with ADL. We used the *t* test or the χ^2 test, as appropriate. We then evaluated the distributions of SBP and DBP separately, stratified by ADL status. We investigated the association of SBP and DBP (separately) with incident CVDs, modeling the predictors as continuous (per standard deviation increase) and in categories to allow modeling of nonlinear associations, using multivariable Cox regression. Categories of SBP and DBP were established based on clinically relevant cut points and the distribution of the data in CHS. We examined events during 10 years of follow-up. Nested models

are presented as demographic adjusted (age, sex, race, education), followed by full adjustment for potential confounders and treatment with antihypertensive medications. We evaluated effect modification by stratifying a priori by ADL status and walking speed categories (slow, intermediate, fast) and calculating strata-specific hazard ratios. We also tested for a statistical interaction of SBP and DBP categories by ADL and walking speed (separately) for incident CVD, using the likelihood ratio test in fully adjusted models. As an exploratory analysis, we estimated incident CVD event rates stratified by both ADL status and antihypertensive treatment.

We were then interested in understanding the associations of combinations of SBP and DBP with risk of incident CVD. We categorized participants into 4 mutually exclusive categories that represent clinically relevant cut points for elderly people and to mirror the categorizations above: (1) SBP ≥150 and DBP >65, (2) SBP ≥150 and DBP ≤65, (3) SBP <150 and DBP ≤65, and (4) SBP <150 and DBP >65. We evaluated the age-adjusted rates of events in each category. We then compared the association of each category with the referent (SBP <150 and DBP >65) for incident CVD using Cox proportional hazards, adjusting for demographic variables and confounders, stratified by ADL status. As secondary analyses, we also evaluated the association of pulse pressure with incident CVD, stratified by ADL status.

Results

Participant Characteristics
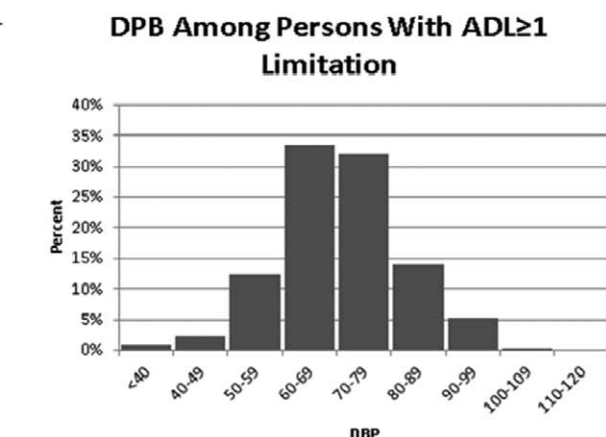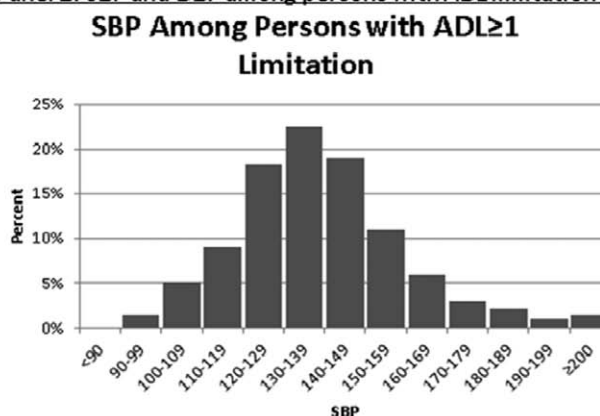
Among 3547 elderly participants, the mean age was 78±5 years, 61% were women, and 17% were black. Approximately 21% (n=755) of people reported limitation in ≥1 ADL. In
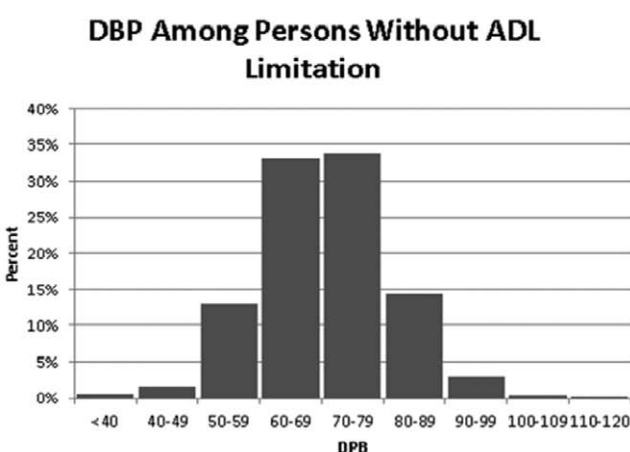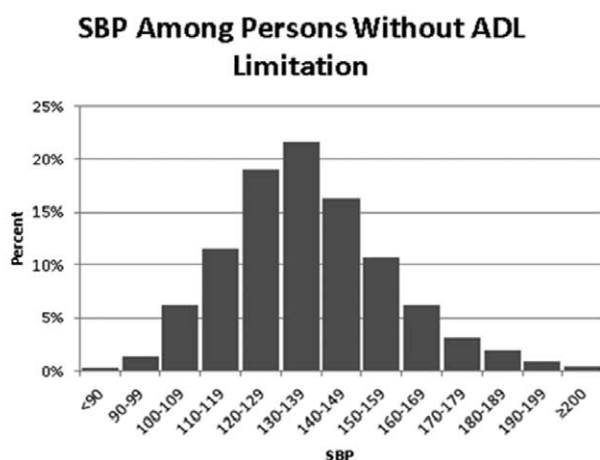
Figure 1. Distribution of systolic blood pressure (SBP) and diastolic blood pressure (DBP) among 3547 Cardiovascular Health Study Participants without (**A**) and with (**B**) activities of daily living (ADL) limitation.

Table 2.   The Association of SBP and DBP With Incident Cardiovascular Event Stratified by ADL

BP	n	Rate per 1000 PY	Demo Adjusted* HR (95% CI)	Adjusted† HR (95% CI)
SBP				
Without ADL limitation				
SBP (per 10-mm Hg increase)	1943	44.5	1.08 (1.04, 1.12)‡	1.08 (1.03, 1.13)‡
SBP				
≤120	380	34.3	1.00	1.00
121–150	1146	43.1	1.24 (0.99, 1.57)	1.20 (0.94, 1.52)
>150	417	58.7	1.54 (1.19, 2.01)§	1.48 (1.11, 1.98)§
With ADL limitation				
SBP (per 10-mm Hg increase)	415	56.9	1.03 (0.95, 1.13)	1.06 (0.97, 1.17)
SBP				
≤120	71	39.4	1.00	1.00
121–150	240	56.3	1.38 (0.81, 2.33)	1.62 (0.94, 2.79)
>150	104	72.7	1.45 (0.80, 2.63)	1.72 (0.91, 3.26)
DBP				
Without ADL limitation				
DBP (per 10-mm Hg increase)	1946	30.4	1.07 (0.99, 1.15)	1.00 (0.93, 1.09)
DBP				
≤65	602	43.8	1.00	1.00
66–80	1028	41.9	1.02 (0.85, 1.23)	0.94 (0.7, 1.14)
>80	313	55.1	1.26 (0.99, 1.61)	1.04 (0.79, 1.37)
With ADL limitation				
DBP (per 10-mm Hg increase)	415	56.9	0.87 (0.74, 1.02)	0.85 (0.73, 1.00)
DBP				
≤65	134	71.7	1.00	1.00
66–80	211	51.8	0.70 (0.48, 1.03)	0.65 (0.44, 0.96)§
>80	70	45.5	0.60 (0.33, 1.09)	0.49 (0.25, 0.94)§

ADL indicates activities of daily living; BP, blood pressure; CI, confidence interval; DBP, diastolic blood pressure; HR, hazard ratio; PY, person years; and SBP, systolic blood pressure.

*Adjusted for age, sex, race, and education.

†Further adjusted for smoking, physical activity, body mass index, diabetes mellitus, total cholesterol, cystatin C, use of anti-hypertension medication, and SBP or DBP. *P* value for interactions SBP×ADL=0.23 and DBP×ADL=0.18.

‡*P*<0.001.

§*P*<0.05.

general, participants who reported having a limitation in ADL were older, more likely to be female, black, and have a lower level of education. People with ADL limitations were more likely to have known coronary heart disease and heart failure (Table 1). The distributions of SBP and DBP were similar among people with and those without limitations in ADL (Figure 1). In the subcohort of people included in the incident CVD analyses (n=2459), the prevalence of ADL limitation was 18%. Similar to the larger cohort, people with ADL limitation in this subset were also older, more likely to be women, and had a higher prevalence of comorbidities.
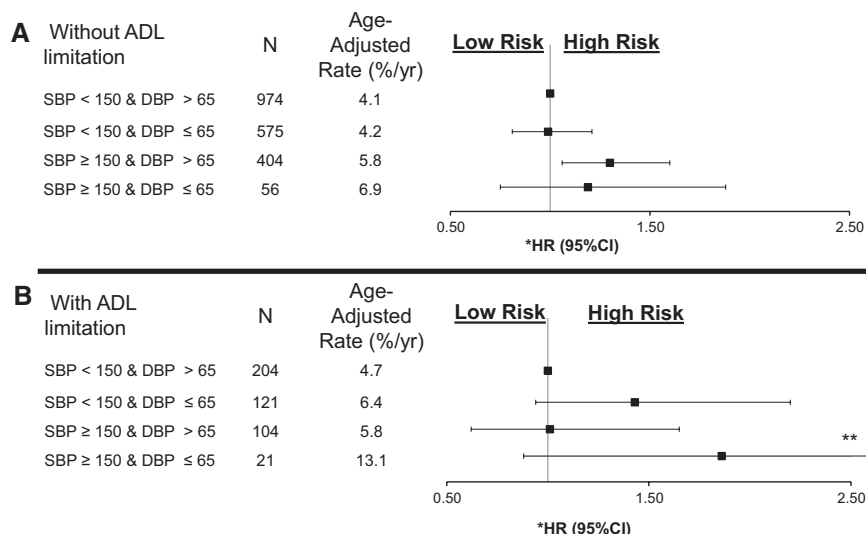
Association of SBP and DBP With Incident CVD Among People Without and Those With ADL Limitation

Over a median follow-up time of 8.5 years, there were 631 and 147 incident CVD events in people without and those with ADL limitation, respectively.

Among people without and those with ADL limitation, a higher SBP was incrementally associated with incident CVD, and the hazard ratios were similar among the 2 groups (Table 2). Findings were similar when we used alternative cut points for SBP. For example, among people without ADL limitation, the age-adjusted incident CVD rates were 34.4, 40.2, 50.3, and 58.9 for SBP <120, 120 to 139, 139 to 149, and ≥150, respectively.

When we examined the association of DBP with incident CVD, we found evidence of effect modification by ADL status. Among people with no ADL limitation, higher DBP was associated with higher CVD risk, but results were not statistically significant after full adjustment. In contrast, among people with ADL limitation, DBP was inversely associated with incident CVD. Compared with people with a DBP of <65 mm Hg, those with a DBP of >80 and 66 to 80 mm Hg had a 51% and 35% lower adjusted risk of incident CVD, respectively (Table 2).

A Without ADL limitation

	N	Age-Adjusted Rate (%/yr)
SBP < 150 & DBP > 65	974	4.1
SBP < 150 & DBP ≤ 65	575	4.2
SBP ≥ 150 & DBP > 65	404	5.8
SBP ≥ 150 & DBP ≤ 65	56	6.9

B With ADL limitation

	N	Age-Adjusted Rate (%/yr)
SBP < 150 & DBP > 65	204	4.7
SBP < 150 & DBP ≤ 65	121	6.4
SBP ≥ 150 & DBP > 65	104	5.8
SBP ≥ 150 & DBP ≤ 65	21	13.1

Figure 2. The association of combined systolic blood pressure (SBP) and diastolic blood pressure (DBP) categories without (**A**) and with (**B**) activities of daily living (ADL) limitation. *Adjusted for age, sex, race, and education; **95% confidence interval (CI), 0.88–3.93. HR indicates hazard ratio.

We then examined the association of combinations of SBP and DBP with incident CVD in people with and those without ADL limitation. People with an SBP of <150 and a DBP of >65 had the lowest rates of incident CVD across both ADL strata (Figure 2). Approximately 3.5% (n=125) of participants had very wide pulse pressures, with an SBP of ≥150 and a DBP of ≤65. Although a relatively small group, these people with widest pulse pressures had the highest age-adjusted rates of incident CVD within each strata of ADL (Figure 2A and 2B).

Among people without ADL limitation, a DBP of ≤65 did not confer any additional risk in people with an SBP of <150, compared with people with an SBP of <150 and a DBP of >65 (Figure 2A). However, among people with ADL limitation, a DBP of ≤65 was associated with a higher risk of incident CVD, whether the SBP was ≤ or >150, compared with the lowest risk group. People with an SBP of >150 and a DBP of >65 were at similar risk of incident CVD compared with people with an SBP of <150 and a DBP of >65 among those with ADL limitation (Figure 2B).

Finally, we examined the association of pulse pressure with incident CVD by ADL strata. Among people without ADL limitation, there was no significant association between pulse pressure and incident CVD (hazard ratio, 1.00 [0.92, 1.08] per 10-mm Hg increase in PP). Among people with ADL limitation, higher PP was significantly associated with higher risk of incident CVD, hazard ratio 1.17 (1.01, 1.34) per 10-mm Hg increase in PP, *P* value for interaction 0.37.

As an exploratory analysis, we estimated incident CVD rates for each BP category, stratified by both ADL status and antihypertensive treatment. People with higher SBP had higher rates of incident CVD, regardless of ADL limitation or treatment status. Among people without ADL limitation, people with a DBP of >80 had the highest rates of incident CVD, and the rates were similar for a DBP of ≤65 and 66 to 80 mm Hg in both treated and untreated people. In contrast, among people with ADL limitation, there was an inverse gradient of DBP with incident CVD among those on treatment; the incident CVD rates were 96.6, 57, and 42.7, respectively, for DBP ≤65, 66 to 80, and >80 mm Hg. Among people with

limitation and not on treatment, rates were 47.6 and 41.8 for DBP ≤65 and 66 to 80, respectively. There were too few people (n=11) with a DBP of >80 mm Hg in this group for precise comparisons.

Association of SBP and DBP With Mortality in People With or Without ADL Limitation

There were 1289 and 498 deaths among participants without and those with limitation in ADL, respectively. We did not appreciate strong associations between SBP and mortality, and findings did not vary by ADL status (Table 3).

Among people without limitation in ADL, a higher DBP was modestly associated with increased risk of death. Among people with limitation in ADL, compared with people with a DBP of ≤65, those with a DBP of 66 to 80 had a 28% lower risk of death. People with a DBP of >80 had similar risk compared with people with a DBP of ≤65 (Table 3).

Association of BP With Incident CVD and Mortality by Walking Speed

The association of SBP and DBP with incident CVD did not vary by strata of walking speed (Table 4). Findings did not vary by walking speed for the total mortality outcome (all *P* values >0.20). Only 206 people (5.8%) had missing data on walking speed. There was no association between SBP or DBP with either outcome among people with missing gait speed (data not shown).

Discussion

In this cohort of community-dwelling elders, we found that ADL status modifies some of the associations between BP components and incident CVD and death. Specifically, among people who do not report limitation in ADL, a higher SBP and DBP were associated with a higher risk of incident CVD. Among people with ADL limitation, a high SBP remained associated with higher risk of incident CVD, whereas the association of DBP with CVD was inverted. Moreover, among people with ADL limitation, the combination of a high SBP and a low DBP conferred the highest risk of incident CVD, and pulse pressure was significantly

Table 3.   The Association of SBP and DBP With All-Cause Mortality Stratified by ADL

BP	n	Rate per 1000 PY	Demo Adjusted* HR (95% CI)	Adjusted† HR (95% CI)
SBP				
Without ADL limitation				
SBP (per 10-mm Hg increase)	2792	58.5	0.99 (0.96, 1.02)	0.97 (0.94, 0.99)‡
SBP				
≤120	587	60.8	1.00	1.00
121–150	1587	56.2	0.87 (0.75, 1.00)	0.88 (0.76, 1.03)
>150	618	62.3	0.90 (0.76, 1.07)	0.83 (0.68, 1.00)
With ADL limitation				
SBP (per 10-mm Hg increase)	755	102.9	1.01 (0.96, 1.06)	1.01 (0.96, 1.06)
SBP				
≤120	130	107.5	1.00	1.00
121–150	450	93.7	0.83 (0.62, 1.10)	0.94 (0.70, 1.25)
>150	175	125.4	1.07 (0.77, 1.48)	1.12 (0.80, 1.58)
DBP				
Without ADL limitation				
DBP (per 10-mm Hg increase)	2792	58.5	0.98 (0.93, 1.03)	1.07 (1.01, 1.14)‡
DBP				
≤65	941	63.6	1.00	1.00
66–80	1425	55.0	0.94 (0.83, 1.07)	1.11 (0.97, 1.27)
>80	426	59.4	0.99 (0.83, 1.18)	1.30 (1.06, 1.61)‡
With ADL limitation				
DBP (per 10-mm Hg increase)	755	102.9	0.93 (0.84, 1.02)	0.97 (0.88, 1.07)
DBP				
≤65	258	120.8	1.00	1.00
66–80	366	86.7	0.68 (0.54, 0.86)‡	0.72 (0.57, 0.91)‡
>80	131	120.7	0.87 (0.63, 1.20)	0.87 (0.61, 1.24)

ADL indicates activities of daily living; BP, blood pressure; CI, confidence interval; DBP, diastolic blood pressure; HR, hazard ratio; PY, person years; and SBP, systolic blood pressure.

*Adjusted for age, sex, race, and education.

†Further adjusted for smoking, physical activity, body mass index, diabetes mellitus, total cholesterol, cystatin C, use of anti-hypertension medication, and SBP or DBP. P value for interaction SBP×ADL=0.55 and DBP×ADL=0.23.

‡$P<0.05$.

and incrementally associated with CVD risk. A low DBP was also associated with a higher risk of death among people with ADL limitation. Our findings suggest that functional status, assessed by ADL limitation, can inform understanding associations of BP components with incident CVD and death in elderly people.

This study extends our prior reports showing that markers of functional status modify the association between BP and death in elderly people.[13,23] In addition, our findings shed light on the reasons for the inconsistent reports and current controversy on optimal BP levels in elderly people. Observational studies have been conflicting on the association of high BP with adverse outcomes in elderly people.[7–10,24] A recent meta-analysis of randomized trials showed that treated elders had lower cardiovascular risk compared to untreated people. However, there was large heterogeneity in the trials, and trial participants are unlikely to represent the general population of elders.[11,12] Our findings that a high SBP is significantly and incrementally associated with higher cardiovascular risk in people without ADL limitation support the notion that lowering of SBP is beneficial in nonfrail elders[6,25] and question the need for higher targets in this population.

The findings that the associations of DBP with CVD and death were inverted among people with ADL limitation are noteworthy. Isolated systolic hypertension (high SBP with low or normal DBP) is the most common form of hypertension in elders. The Systolic Hypertension in Elderly Program showed a benefit of lowering SBP in people with isolated systolic hypertension.[26] However, some studies have documented a J-shaped association of DBP with death and cardiovascular outcomes, but the importance of diastolic hypotension has been inconsistent across studies.[15,16,27] These findings have led to concern that attempts to lower SBP can result in excessive DBP lowering and increased risk of adverse events in elderly people. Our findings suggest that ascertaining limitation in ADL, rather than relying on chronologic age alone, can identify the subgroup of elders in whom a low DBP is associated with a significantly higher risk of incident CVD and death.

Table 4.   Association of SBP and DBP With Incident Cardiovascular Event Across Strata of Walking Speed

BP	n	Rate per 1000 PY	Demo Adjusted* HR (95% CI)	Adjusted† HR (95% CI)
SBP				
Walking speed <0.60				
SBP (per 10-mm Hg increase)	303	81.6	1.07 (0.97, 1.18)	1.06 (0.96, 1.17)
SBP				
≤120	56	66.7	1.00	1.00
121−150	174	80.8	1.26 (0.69, 2.32)	1.25 (0.67, 2.35)
>150	73	97.6	1.49 (0.79, 2.92)	1.43 (0.69, 2.93)
Walking speed 0.60−0.99				
SBP (per 10-mm Hg increase)	1391	52.2	1.10 (1.05, 1.15)‡	1.10 (1.05, 1.16)‡
SBP				
≤120	243	41.7	1.00	1.00
121−150	826	48.2	1.19 (0.91, 1.57)	1.30 (0.97, 1.73)
>150	322	71.5	1.67 (1.23, 2.25)‡	1.81 (1.30, 2.51)‡
Walking speed ≥1.00				
SBP (per 10-mm Hg increase)	717	37.8	1.06 (1.00, 1.13)	1.07 (0.99, 1.16)
SBP				
≤120	163	28.3	1.00	1.00
121−150	412	40.7	1.43 (0.98, 2.07)	1.37 (0.94, 2.04)
>150	142	41.0	1.38 (0.88, 2.16)	1.36 (0.82, 2.24)
DBP				
Walking speed <0.60				
DBP (per 10-mm Hg increase)	303	81.6	1.01 (0.84, 1.21)	0.94 (0.79, 1.13)
DBP				
≤65	108	71.3	1.00	1.00
66−80	138	90.1	1.27 (0.81, 1.99)	1.07 (0.66, 1.72)
>80	57	81.1	0.93 (0.48, 1.81)	0.66 (0.31, 1.38)
Walking speed 0.60−0.99				
DBP (per 10-mm Hg increase)	1391	52.2	1.04 (0.95, 1.13)	0.99 (0.90, 1.08)
DBP				
≤65	433	55.1	1.00	1.00
66−80	752	46.9	0.89 (0.73, 1.10)	0.85 (0.68, 1.05)
>80	117	66.0	1.29 (0.99, 1.69)	1.09 (0.80, 1.48)
Walking speed ≥1.00				
DBP (per 10-mm Hg increase)	717	37.8	1.00 (0.88, 1.14)	0.93 (0.80, 1.07)
DBP				
≤65	213	41.9	1.00	1.00
66−80	387	36.6	0.93 (0.68, 1.27)	0.81 (0.58, 1.14)
>80	117	34.9	0.83 (0.54, 1.28)	0.62 (0.37, 1.03)

BP indicates blood pressure; CI, confidence interval; DBP, diastolic blood pressure; HR, hazard ratio; PY, person years; and SBP, systolic blood pressure.

*Adjusted for age, sex, race, and education.

†Further adjusted for smoking, physical activity, body mass index, diabetes mellitus, total cholesterol, cystatin C, use of anti-hypertension medication, and SBP or DBP. *P* value for interaction SBP×walk=0.70 and DBP×walk=0.59.

‡*P*<0.001.

Our report that people with ADL limitation and widest pulse pressure had the highest risk of incident CVD highlights the need for further investigation on the importance of the combined association of SBP and DBP with CVD risk and death in frail elders.

Reasons why limitation in ADL may modify the association of DBP with incident CVD are not known. Some have suggested that elders with ADL limitation may represent a subgroup of ill people who already have lower DBP, a marker of poor cardiovascular function. However, we found that DBP

distributions did not vary by ADL limitation, and adjustment for confounders did not explain observed differences. It is also possible that limitation in ADL identifies people with poor vascular tone and high degrees of vascular stiffness and who may be more susceptible to adverse effects of treatment. Adjustment for treatment did not affect our findings. Some, but not all, reports from randomized trials have suggested that on-treatment diastolic hypotension is associated with higher risk of CVD and death.[15,16,27] Few studies have examined whether existing vascular dysfunction in frail elders explains the association of diastolic hypotension with adverse outcomes.[28] Finally, some suggest that differences in functional status may identify the elders who are aging successfully versus those who are dying.[29] It is possible that aggressive attempts to lower SBP in a dying elder may increase the risk of adverse outcomes associated with diastolic hypotension. Future studies are needed to describe the associations of BP trajectories with CVD and mortality risk.

Our report represents a large, heterogeneous, well-characterized cohort of community-dwelling elders. Our study is observational in nature, and thus limited in inferring causality. However, no large randomized trials including frail elderly people have been conducted to accurately investigate benefits and harms of lowering SBP or DBP in this group. We have limited power to explore specific treatment effects as additional effect modifiers. We are also limited in our ability to explore a larger number of combinations of SBP and DBP. However, our findings using clinically relevant cut points support those observed for each BP component alone. We found that speed to complete a 15-feet walk did not modify the association of BP with outcomes. Longer walk distances may be required to elucidate relevant subgroups.[13] Our findings highlight the urgency of including frail elders in trials of hypertension treatment. Our data suggest that patient characteristics (such as functional and health status) may be more informative in ascertaining optimal BP levels in elderly people, rather than chronologic age alone.

Perspectives

We found that knowledge of an elder's ability to perform ADLs may improve our understanding of the association of SBP and DBP with CVD risk and death. Among people without ADL limitation, a lower SBP is associated with lower cardiovascular risk, and a wider range of DBP (and thus pulse pressure) may be acceptable. In contrast, among people with limitation in ADL, the benefit of a lower SBP may need to be weighed against the associations of diastolic hypotension with higher risk of CVD and death. Future research is necessary to determine benefits and harms of lowering each BP component in frail adults and the role of vascular stiffness in explaining these observations.

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Disclosures

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Novelty and Significance

What Is New?

- Functional disability may affect the importance of blood pressure levels for cardiovascular risk.

What Is Relevant?

- Hypertension is common in elderly people.
- Best management strategies for hypertension in elderly people are not well known.

Summary

Reporting limitations in activities of daily living can identify elders in whom low diastolic blood pressure is associated with higher cardiovascular risk and death.

Hypertension

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Systolic and Diastolic Blood Pressure, Incident Cardiovascular Events, and Death in Elderly Persons: The Role of Functional Limitation in the Cardiovascular Health Study

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