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A Population-Based Cohort Study

Blood Pressure, Gait Speed, and Mortality in Very Old Individuals: A Population-Based Cohort Study

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A total of 806 participants in the population-based prospective Umeå 85+:GERDA study aged 85, 90, and 95 years or older.

Keywords: Gait speed, blood pressure aged, 80 and older mortality residential facilities prospective studies

Objective: Clinical trials and observational studies have produced contradictory results regarding the association of blood pressure (BP) and mortality in people aged 80 years or older. Gait speed at usual pace has been shown to moderate this association in a population of noninstitutionalized people aged 65 years or older. The aims of this study were to investigate the association of BP with all-cause mortality in a representative sample of people aged 85 years or older and to assess whether gait speed moderates this association.

Design, Setting, and Participants: A total of 806 participants in the population-based prospective Umeå 85+:GERDA study aged 85, 90, and 95 years or older.

Measurements: Gait speed at usual pace was measured over 2.4 m. The main outcome was hazard ratios (HRs) for all-cause mortality according to systolic and diastolic BP categories in the total sample and in faster-walking (≥0.5 m/s, n = 312) and slower-walking (<0.5 m/s, n = 433) subcohorts; the latter also included habitually nonwalking participants. Comprehensive adjustments were made for sociodemographic and clinical characteristics associated with death.

Results: Mean age and baseline systolic and diastolic BP were 89.6 ± 4.6 years, 146.8 ± 23.9 mm Hg, and 74.8 ± 11.1 mm Hg, respectively. Most (n = 561 [69%]) participants were women, 315 (39%) were care facility residents, and 566 (70%) were prescribed BP-lowering drugs. Within 5 years, 490 (61%) participants died. In the total sample and slower-walking subcohort, systolic BP appeared to be inversely associated with mortality, although not independent of adjustments. Among faster-walking participants, mortality risk after adjustment was more than 2 times higher in those with systolic BP of 140 to 149 mm Hg (HR = 2.25, 95% confidence interval [CI] = 1.03–4.94) and 165 mm Hg or higher (HR = 2.13, 95% CI = 1.01–4.49), compared with systolic BP of 126 to 139 mm Hg. Mortality risk was also independently higher in faster-walking participants with diastolic BP higher than 80 mm Hg, compared with diastolic BP of 75 to 80 mm Hg (HR = 1.76, 95% CI = 1.07–2.90).

Conclusion: The gait speed threshold of 0.5 m/s may be clinically useful for the distinction of very old people with and without increased all-cause mortality risk due to elevated systolic and diastolic BP.

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Very Elderly Trial (HYVET), the largest double-blind, placebo-controlled trial to examine this issue, found that antihypertensive therapy markedly reduced total mortality in people aged 80 years or older. Because the level of comorbidity in the HYVET sample was low in comparison with that of the general population of very old individuals, the applicability of this study’s findings to the latter remains unclear.

Gait speed, measured over a short distance, is an integrative measure of health and functional abilities that has been shown to predict adverse outcomes and mortality risk. Using gait speed to divide a population of noninstitutionalized adults aged 65 years or older into subcohorts, Odden et al found that hypertension was associated with all-cause mortality only in participants whose usual pace was 0.8 m/s or faster. In slower-walking participants, including those who were physically unable to complete the walk, BP was not associated with mortality. Gait speed thus appears to distinguish groups of older people with and without increased mortality risk related to hypertension. However, the mean age of participants in the study by Odden et al was 74 years, and its results remain to be confirmed in the very old population. The cutoff value of 0.8 m/s for gait speed has been well supported in the scientific literature for younger old populations, but a lower threshold may be more suitable for very old, and generally slower-walking, people.

This study was conducted to investigate the association between BP and mortality in a representative sample of very old people and to assess whether gait speed at usual pace could moderate this association.

Methods
Setting and Design

This study was based on data from the Umeå 85+/GERontological Regional DAtabase (GERDA) population-based cohort study by Umeå University, Sweden. Half of inhabitants aged 85 years (selected from a randomized starting point) and all of those aged 90 and 95 years or older in 8 municipalities of northern Sweden and western Finland were selected from national tax and population registers for participation in the Umeå 85+/GERDA study. The objective of the study was to increase knowledge of the living conditions of very old people, increase quality of life, and provide data to support planning of future eldercare. Data collection commenced in 2000, 2002, 2005, and 2007; in 2005 it was conducted in collaboration with Åbo Akademi University and the University of Vaasa, Finland. The study design has been described in detail elsewhere. Eligible participants were invited by mail to participate in the study and subsequently contacted by telephone to obtain informed consent. For participants with cognitive impairment, a close relative also provided oral consent, when appropriate. Trained assessors visited all participants at their homes or institutions to conduct standardized interviews and tests. Relatives and/or health care professionals were interviewed when needed and the medical records of all consenting participants were reviewed. The Umeå 85+/GERDA study has been approved by the Regional Ethical Review Board in Umeå (99-326, 05-063M) and the Ethics Committee of Vaasa Central Hospital (registration number 05-87).

Participants

Of 1310 eligible Umeå 85+/GERDA study participants, 115 died before contact and 347 declined home visits (Figure 1). All participants whose BP was measured (n = 806; 67.4% participation rate) were included in the present study. The 389 nonparticipants who declined home visits or for whom no BP measurement was obtained did not differ significantly from participants in age (P = .636) or sex (P = .136). For persons who participated in more than one round of data collection, the earliest dataset was used. Gait speed was assessed in 609 participants, who were included in gait speed analyses and subcohorts. Of 197 participants who were unable to complete the gait speed test, 136 participants were included in a gait-speed subcohort because they were considered to have habitual physical impairment of gait function (habitually nonwalking), which may reflect mortality risk in this population. Sixty-one of those who were unable to complete the gait speed test were excluded from gait speed analyses and subcohorts because of recent fracture preventing gait speed assessment, failure to understand instructions, severe visual or hearing impairment, environmental limitation, or other reasons not related to a habitual physical impairment of gait function. In total, 745 participants were included in gait speed subcohorts.

Measures

Dates of death were collected from death certificates, electronic medical records, and population registers for the 5 years after the date of study inclusion. Information on participants’ age, sex, living conditions, education, and smoking status was collected during interviews. BP was measured using a calibrated manual sphygmomanometer and stethoscope with participants supine after 5 minutes of...
rest. In 51 participants, BP measurements were registered in a seated position; in 11 cases, measurements were obtained from medical records of recent health clinic visits because of missing values. Systolic BP was classified in quintiles (≤125, 126–139, 140–149, 150–164, and ≥165 mm Hg) and diastolic BP was classified in quartiles (<70, 70–74, 75–80, and ≥80 mm Hg) because its distribution was narrower than that of systolic BP. Gait speed over a distance of 2.4 m²0.21 was measured twice and a mean value was calculated. When only one gait speed measurement was obtained, it was included in the analysis. Starting from a standing still position, the participants were instructed to walk past a mark on the floor at their usual pace and were timed using a digital stopwatch. Walking aids were permitted, but no personal assistance or support from nearby structures was allowed. Gait speed was dichotomized to form 2 gait speed subcohorts. Few (n = 53) participants had gait speeds of 0.8 m/s or faster, preventing subcohort formation on this basis. An alternative cutoff value of 0.5 m/s, which has been shown to distinguish between higher and lower mortality risk in very old individuals, was thus used to form a faster-walking (>0.5 m/s) and slower-walking (<0.5 m/s) subcohort; the latter also included habitually nonwalking participants. Body mass index was calculated by dividing weight (in kilograms) by the square of height (in meters). The Mini-Mental State Examination (MMSE) was used to assess cognition on a scale of 0 to 30, with higher scores indicating better cognitive function. Dependency in activities of daily living (ADLs) was assessed using the Barthel ADL Index on a scale of 0 to 20, with a score of 20 indicating total independence in personal ADLs.²²

Information on participants’ medical history and drug prescriptions was collected during interviews and verified using medical records. Diagnoses of dementia, depression, and angina pectoris were based on previous diagnoses and current drug prescription. Assessment scores also were applied to diagnose dementia and depression according to Diagnostic and Statistical Manual of Mental Disorders, Fourth edition, criteria.²³ A specialist in geriatric medicine reviewed and confirmed all diagnoses. A covariate of all BP-lowering drugs was defined to include prescriptions of angiotensin-converting enzyme (ACE) inhibitors, beta-blockers (excluding eye drops), calcium channel blockers, diuretics (except in patients with concurrent heart failure), and other BP-lowering drugs, irrespective of indication.

Statistical Analysis

Differences in 5-year mortality and gait speed subcohorts according to sociodemographic and clinical characteristics were assessed using Student t-test and Pearson χ² test. Differences in 5-year mortality according to age (85, 90, and ≥95 years) and gait speed groups (slower- and faster-walking, habitually nonwalking, and excluded nonwalking) were examined using the Pearson χ² test. Differences in mean gait speed, systolic BP, and diastolic BP according to age and gait speed groups were assessed using 1-way analyses of variance. Correlations were tested between all baseline covariates, and the ADL score covariate was removed from the analyses due to strong (r > 0.6) correlations with the care facility residency, MMSE score, diagnosis of dementia, and gait speed covariates. The diagnosis of dementia covariate was removed due to strong correlation with MMSE score. The antidepressant prescription covariate was removed to reduce the risk of an overlapping effect with the diagnosis of depression covariate.

Associations between all-cause mortality and categorized systolic and diastolic BP, respectively, were analyzed using Cox proportional hazard regression models. In the total sample, model 1 was adjusted for age and sex, and model 2 was adjusted for age, sex, and all baseline variables from Table 1 associated with mortality at a significance level of P ≤ .15 in univariate analyses. Proportionality of hazards was tested using Schoenfeld residuals.²⁵ Assumptions were not fulfilled for the age and education covariates, which were adjusted for using time-dependent variables in an extended Cox proportional hazard regression model. An interaction term was entered in both models to test for any interaction effect between systolic BP and gait speed. The association of BP with mortality also was analyzed in gait speed subcohorts. To reduce the number of covariates used to examine gait speed subcohorts, which were characterized by fewer events (deaths within 5 years),²⁶ only variables from model 2 in the total sample that were associated with mortality at a significance level of P ≤ .05 in multivariate analysis (age, age × follow-up time, sex, congestive heart failure, atrial fibrillation, myocardial infarction, cancer, depression, angina pectoris, body mass index, and MMSE score) were included in this model. To control for the influence of early death, analyses using both models were repeated with the exclusion of data from participants who died in the first year after data collection. Statistical analyses were performed using SPSS statistics software (version 20.0; IBM Corporation, Armonk, NY). All analyses were 2-tailed and P < .05 was considered significant.

Results

Table 1 shows the baseline characteristics of the study population with respect to survival status and gait speed subcohort. In the study population (n = 806), the mean age was 89.6 years. A total of 490 (61%) participants died within 5 years (mean, 3.34 years) after study inclusion. Approximately two-thirds (n = 561) of participants were women, most (63%) of whom had gait speeds slower than 0.5 m/s (slower-walking subcohort, also including habitually nonwalking participants). The slower-walking subcohort included 3 times as many women as men. Almost two-fifths (39%) of study participants were living in a residential care facility, and few (16%) of these participants were assigned to the faster-walking subcohort. BP-lowering drugs were prescribed to 70% of participants. ACE inhibitor and diuretic prescriptions were significantly more prevalent in the slower-walking subcohort (20% and 54%, respectively) and among those who died within 5 years of study inclusion (21% and 52%, respectively) than in other groups. High age, care facility residency, living alone, congestive heart failure, atrial fibrillation, cerebrovascular disease, dementia, hip fracture, depression, and angina pectoris also were significantly more prevalent among those who died within 5 years of study inclusion and those in the slower-walking subcohort. Gait speed and BP were lower among those who died within 5 years than among those who lived (gait speed [mean ± standard deviation], 0.46 ± 0.20 vs. 0.58 ± 0.21 m/s, P < .001; systolic BP, 142.7 ± 23.9 vs. 153.3 ± 22.4 mm Hg, P < .001; diastolic BP, 73.7 ± 11.3 vs. 76.5 ± 10.4 mm Hg, P < .001).

Table 2 presents mean gait speed, BP, and survival status according to age and gait speed groups. Gait speed and BP showed decreasing trends with increasing age. BP also showed decreasing trends with decreasing gait speed, while the proportion of deaths increased.

Hazard ratios (HRs) for death in the total sample and according to gait speed subcohort are presented for systolic BP in Table 3 and diastolic BP in eTable 1. Survival curves based on Cox proportional hazard regression models are shown for systolic BP in Figure 2 and diastolic BP in eFigure 1. In initial age- and sex-adjusted analysis of the total sample (model 1), compared with systolic BP ≤ 125 mm Hg, mortality risk decreased with increasing BP category (126–139 mm Hg: HR 0.70, 95% confidence interval [CI] 0.53–0.93; 140–149 mm Hg: HR 0.63, 95% CI 0.48–0.83; 150–164 mm Hg: HR 0.59, 95% CI 0.45–0.76; ≥ 165 mm Hg: HR 0.50, 95% CI 0.38–0.66; Table 3, Figure 2A). None of these associations was significant in the fully adjusted model for the total sample (model 2). For diastolic BP, mortality risk was significantly increased in the quartile of BP lower than 70 mm Hg in model 1 (HR 1.42, 95% CI 1.11–1.81) and in the
Data are presented as n (%) or mean ± SD. Total number is presented after characteristics with some missing data.

*Comprises participants with gait speeds <0.5 m/s and those unable to complete the walking test due to habitual impairment of gait function.

**NSAIDs, opioids, and paracetamol.

*Calculated only for participants who completed the gait speed test.

The association of BP with mortality differed among gait speed subcohorts. In the slower-walking subcohort, patterns of association were similar to those of the total sample (Table 3, Figure 2B, eFigure 1B). In age- and sex-adjusted analysis, interaction effects between gait speed subcohort and BP in the association with mortality were significant for systolic BP (P = .031), but not for diastolic BP (P = .283). Interaction effects were not significant for systolic BP (P = .327) or diastolic BP (P = .272) in the fully adjusted model.

Repeated analyses with the exclusion of data from participants who died in the first year of study inclusion produced essentially the same results (data not shown).

### Discussion

In this study of a representative sample of very old individuals, low systolic and diastolic BP were significantly associated with increased mortality risk in initial age- and sex-adjusted analyses, but not in analyses adjusted for all covariates, including previous disease. Similar patterns of association were observed in the total sample and the slower-walking subcohort (which also included habitually
nonwalking individuals). In the faster-walking subcohort, higher BP categories were significantly and independently associated with higher mortality risk, compared with intermediary systolic (126–139 mm Hg) and diastolic (75–80 mm Hg) BP categories.

Similar to the findings of Odden et al in noninstitutionalized people with a mean age of 74 years, our results indicate that greater gait speeds at usual pace is likely to also identify people in the multimorbid very old population, including care facility residents, with increased mortality risk due to high BP. Despite substantial differences in disease burden, these results in the faster-walking subcohort are analogous to those of the HYVET intervention study, in which treatment of hypertension to a target systolic BP of 150 mm Hg reduced mortality rates in comparatively healthy people aged 80 years or older. In contrast, BP was not independently associated with mortality in the slower-walking subcohort, which is also congruent with the findings of Odden et al. The gait speed threshold of 0.5 m/s used in the present study appears to adequately distinguish groups of very old people with and without increased mortality risk due to elevated systolic and diastolic BP. These findings indicate that this threshold was suitable for the present study population of very old individuals. Moreover, mean gait speeds of those who lived and those who died within 5 years after study inclusion fell on either side of this threshold (Table 1), further supporting its relevance. The cutoff value of 0.8 m/s used by Odden et al in a somewhat younger population may be difficult to implement in those aged 85 years or older because few of these individuals have gait speeds >0.8 m/s. Further population-based studies are needed to investigate the role of gait speed in the development of other complications of hypertension, such as stroke and dementia.

In line with several previous observations in very old individuals, BP was not found to be an independent risk factor for mortality in the total sample of the present study. However, some previous studies have found low BP to be independently associated with higher mortality, although resembling the present study in other regards, these studies adjusted for fewer covariates, which may account for the difference in results. Results from the total sample of the present study suggest the existence of an inverse association between BP and mortality that is independent of age and sex, but dependent on other factors, such as disease. A similar association was observed in the slower-walking subcohort (majority of the sample), which may account in part for the association observed in the total study sample. The slower-walking subcohort represents a portion of the very old population with lower overall organ-system function.

Table 3

<table>
<thead>
<tr>
<th>Gait Speed Subcohort</th>
<th>n</th>
<th>Total Sample</th>
<th>HR (95% CI)</th>
<th>Gait Speed &lt;0.5 m/s</th>
<th>HR (95% CI)</th>
<th>Gait Speed &gt;0.5 m/s</th>
<th>HR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitually nonwalking</td>
<td>136</td>
<td>433</td>
<td>1</td>
<td>0.78 (0.56–1.08)</td>
<td>0.14</td>
<td>1</td>
<td>0.78 (0.56–1.08)</td>
</tr>
<tr>
<td>Excluded nonwalking</td>
<td>61</td>
<td>312</td>
<td>1</td>
<td>0.60 (0.40–0.80)</td>
<td>0.001</td>
<td>0.50 (0.38–0.66)</td>
<td>0.001</td>
</tr>
<tr>
<td>Model 2</td>
<td>698</td>
<td>311</td>
<td>1</td>
<td>0.59 (0.45–0.76)</td>
<td>0.001</td>
<td>0.50 (0.38–0.66)</td>
<td>0.001</td>
</tr>
<tr>
<td>model 1</td>
<td>806</td>
<td>433</td>
<td>1</td>
<td>0.70 (0.53–0.93)</td>
<td>0.014</td>
<td>0.50 (0.38–0.66)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Blood pressure reference category was chosen based on graphical interpretation of initial age- and sex-adjusted analyses in the total sample and in each gait speed group. Model 1 was adjusted for age and sex. Model 2: In gait speed subcohorts adjusted for age, sex, follow-up time, sex, congestive heart failure, atrial fibrillation, myocardial infarction, cancer, depression, angina pectoris, body mass index, and MMSE score; in total sample also adjusted for care facility residency, living alone, education, education follow-up time, cerebrovascular disease, hip fracture, angiotensin-converting enzyme inhibitors, calcium channel blockers, diuretics, benzodiazepines, neuroleptics, warfarin, analgesics, statins, number of drugs, and gait speed subcohort.

*Calculated using Cox proportional hazard regression models.

Comprises participants with gait speeds <0.5 m/s and those unable to complete the walking test due to habitual impairment of gait function.

Because model 2 included more covariates in the total sample than in the gait speed subcohorts, more participants were excluded in the total sample than in gait speed subcohorts due to missing values.

Table 2

<table>
<thead>
<tr>
<th>Gait Speed Subcohort</th>
<th>n</th>
<th>Gait speed, m/s</th>
<th>Systolic BP, mm Hg</th>
<th>Diastolic BP, mm Hg</th>
<th>Deceased Within 5 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group, y 806</td>
<td>348</td>
<td>0.57 ± 0.21 (n = 304)</td>
<td>152.3 ± 23.0</td>
<td>76.5 ± 10.5</td>
<td>490</td>
</tr>
<tr>
<td>&lt;95 260</td>
<td>0.50 ± 0.21 (n = 198)</td>
<td>&lt;0.001</td>
<td>146.5 ± 24.0</td>
<td>&lt;0.001</td>
<td>151 (43.4)</td>
</tr>
<tr>
<td>Gait speed group, m/s 745</td>
<td>198</td>
<td>0.43 ± 0.19 (n = 107)</td>
<td>137.8 ± 22.4</td>
<td>71.9 ± 11.1</td>
<td>174 (87.9)</td>
</tr>
<tr>
<td>&lt;0.5 312</td>
<td>0.68 ± 0.16</td>
<td>&lt;0.001</td>
<td>154.3 ± 22.4</td>
<td>&lt;0.001</td>
<td>118 (37.8)</td>
</tr>
<tr>
<td>&lt;0.5 297</td>
<td>0.35 ± 0.10</td>
<td>&lt;0.001</td>
<td>146.9 ± 23.5</td>
<td>&lt;0.001</td>
<td>199 (67.0)</td>
</tr>
<tr>
<td>Excluded nonwalking 61</td>
<td>—</td>
<td>133.3 ± 23.3</td>
<td>71.0 ± 11.2</td>
<td>&lt;0.001</td>
<td>124 (91.2)</td>
</tr>
<tr>
<td>Data are presented as n (%) or mean ± SD. Differences between groups were examined using 1-way analyses of variance and Pearson χ² test.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2. Survival curves based on Cox proportional hazard regression models of systolic blood pressure categories in the total sample (A, n = 806) and by gait speed subcohort; <0.5 m/s (B, n = 433) and ≥0.5 m/s (C, n = 312). The <0.5 m/s gait speed subcohort comprises participants with gait speeds <0.5 m/s and those unable to complete the walking test due to habitual impairment of gait function. Model 1 was adjusted for age and sex. Model 2: In gait speed subcohorts adjusted for age, sex, congestive heart failure, atrial fibrillation, myocardial infarction, cancer, depression, angina pectoris, body mass index, and MMSE score; in total sample also adjusted for care facility residency, living alone, education, cerebrovascular disease, hip fracture, angiotensin-converting enzyme inhibitors, calcium channel inhibitors, diuretics, benzodiazepines, neuroleptics, warfarin, analgesics, statins, number of drugs, and gait speed subcohort.
higher disease burden, collectively more medication use, and higher risk of adverse outcomes, which may be correlated more strongly than hypertension with mortality. In many patients, these effects could reflect imminent heart failure. In contrast, the faster-walking subcohort had longer-than-average life expectancy and may have been exposed to the pathologic effects of sustained hypertension, such as death. As gait speed decreases with age in a group of very old people, the association between hypertension and mortality may cease to exist merely in comparison with the overall rising mortality rate.

The present population-based study involved home visitation of very old people, enabling participation of the frailest individuals and care facility residents. Standardized face-to-face interviews, in combination with data from medical records, provided extensive information on comorbidities that was incorporated in the fully adjusted regression model. The division of BP values into 4 or 5 categories allowed for interpretation of nonlinear associations. Despite these strengths, the present study has some limitations. Although mortality data were reliable, information on cause of death was not collected. The study was representative of people in the studied geographic area aged 85, 90, and 95 years or older, and its results may not apply to a general population of very old individuals. Furthermore, BP was measured while participants were supine, which impedes comparison with other studies. Because of the high prevalence of orthostatic hypotension in very old people, the measurement of BP with participants in a seated position might have produced a wider distribution of BP values and lower mean values. Each participant’s BP was measured only once during a home visit, which may limit the reliability of this measurement. However, data quality seemed to be acceptable for group-level comparison, as BP was measured using a calibrated manual sphygmomanometer according to a standardized procedure. Finally, the statistical power of some subcohort analyses may have been limited.

Conclusions

In conclusion, the association of BP with mortality differed in gait speed subcohorts. High systolic and diastolic BP seem to be independently associated with increased mortality risk among very old people with gait speeds of 0.5 m/s or faster. In slower-walking and habitually nonwalking individuals, BP does not appear to be independently associated with mortality. Low systolic and diastolic BP may be markers of increased mortality risk in very old people with lower gait speed, possibly secondary to failing health. Future studies should aim to investigate the risks of other complications of hypertension in very old people, with respect to gait speed. The gait speed threshold of 0.5 m/s may be clinically useful for the distinction of very old people with and without increased mortality risk due to elevated systolic and diastolic BP.

Supplementary Data

Supplementary Data related to this article can be found online at http://dx.doi.org/10.1016/j.jamda.2014.09.004.

References