Original Article

High Morning Home Blood Pressure Is Associated with a Loss of Functional Independence in the Community-Dwelling Elderly Aged 75 Years or Older

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To elucidate the relationship between home systolic blood pressure (SBP) and functional impairment in the elderly 75 years or older, 461 community-dwelling subjects (192 men, 269 women, mean age: 80 years) were studied. Home blood pressure was measured twice in the morning and twice in the evening for 5 consecutive days with an automatic cuff-oscillometric device. Total/high-density lipoprotein cholesterol and several functional assessments were evaluated. A subject was determined to exhibit a loss of independence according to the activities of daily living (ADL) score in a study conducted in 2001. Based on the mean home SBPs (mSBP) and morning–evening SBP differences (dSBP), the subjects were classified into 4 groups as follows: hypertensive/morning-dominant (HM; mSBP≥135 mmHg, dSBP≥15 mmHg), hypertensive/sustained (HS; mSBP≥135 mmHg, dSBP<15 mmHg), normotensive/morning-dominant (NM; mSBP<135 mmHg, dSBP≥15 mmHg), and normotensive/controlled (NC; mSBP<135 mmHg, dSBP<15 mmHg). There were no differences in sex, cholesterol levels, history of stroke, other cardiovascular diseases (CVDs), and cognitive function, but there were significant differences in age, antihypertensive medications, the neurobehavioral test scores, and ADL scores. There were no significant differences in terms of mortality and CVD events. In the survivors, HM and HS were independent risk factors for a loss of independence, after adjustments were made for onset of stroke, age, antihypertensive therapy, history of CVD, as well as neurobehavioral test scores and ADL scores (odds ratio [OR]: 12.2 and 3.78, respectively). After the same adjustments as those mentioned above were made, HM and HS were found to be negative determinants of survival and maintenance of independence (OR: 0.082, 0.270, respectively). In conclusion, high home SBP (≥135 mmHg) and high dSBP (≥15 mmHg) were found to be important in determining the levels of disability for the very elderly. (*Hypertens Res* 2005; 28: 657–663)

***Key Words*: home blood pressure, elderly, morning hypertension, independence, successful aging**

Introduction

Recently there have been rapid increases in both the population and life span of the elderly in developed countries, which has resulted in a considerable increase in the number of frail elderly people. “The project to reduce the number of dependent elderly persons” has been promoted as an important

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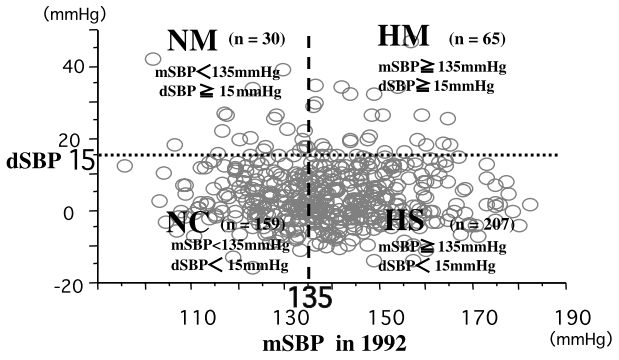

Fig. 1. *Classification of four groups according to the distribution of mean home SBP (mSBP) and morning–evening home SBP differences (dSBP). HM, hypertensive/morning-dominant; HS, hypertensive/sustained; NM, normotensive/morning-dominant; NC, normotensive/controlled.*

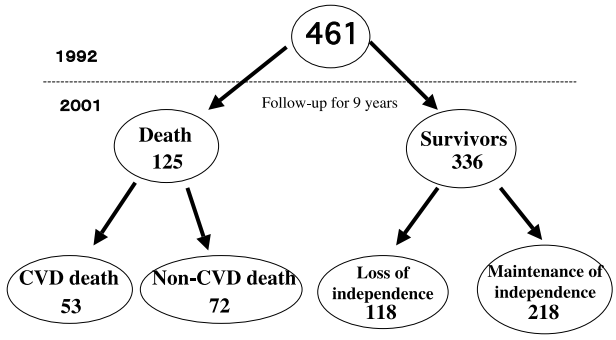

Fig. 2. *Outcome after a 9-year follow-up period. CVD, cardiovascular disease, including stroke.*

issue not only from the medical, but also from the socioeconomic point of view. This project should be considered a top priority, and appropriate measures should be taken to improve the current situation (*1*). Although stroke is a major cause of mortality and disability in the elderly (*2–4*), the management of hypertension in the community has contributed to an outstanding reduction in the incidence of stroke (*5*, *6*).

In many previous epidemiological studies on blood pressure (BP) in the elderly, the mortality and morbidity associated with stroke and other cardiovascular diseases (CVDs) have been selected as the endpoint (*7–9*). There have been also several epidemiological studies of the relationship between hypertension and dementia (*10*, *11*). However, assessments of functional abilities, the most important factor for elderly persons and their caregivers, have been rarely conducted.

Improving the management of BP for the prevention of stroke and other CVDs has led to the popularization of home BP monitoring devices among the general public (*12*, *13*). However, there have been few reports concerning home BP values in the elderly. Increased BP in the morning is considered as a strong risk factor for stroke and other CVDs (*14–17*). It remains to be clarified whether such an elevation in BP in the morning is also a risk factor for a loss of functional independence in the elderly.

In the present study, we recruited community-dwelling elderly people 75 years of age or older, and conducted medical and functional assessments. We followed the subjects for 9 years. The purpose of our study was to clarify the relationship between home BP values and functional disabilities, as well as that between home BP and the mortality/incidence of stroke. Furthermore, we studied morning–evening home BP differences in this very elderly sample.

Methods

Subjects

The study subjects were elderly people, aged 75 years or older, who resided in Kahoku Town, Kochi Prefecture, Japan in 1992. All subjects applied to participate in the home BP monitoring program. Subjects with atrial fibrillation were excluded because of the potential inaccuracy of their home BP measurements. A total of 461 people were recruited as the subjects of our study (192 men, 269 women, mean age: 81 years).

Home BP Measurement

Home BP was measured in 1992 with an automatic device (HEM-755C; OMRON Life Science Co., Ltd., Kyoto, Japan) based on the cuff-oscillometric method. The validity of BP measurement according to this method has been reported in several studies (*18–20*). The subjects and their caregivers were taught by community nurses how to measure the BP at home using this device. According to a previously reported method (*21*), BP was measured in the non-dominant arm after taking at least a 5-min rest in a sitting position, twice in the morning (6–7 AM) and twice in the evening (8–9 PM), for 5 consecutive weekdays.

We obtained the data regarding the total mean systolic BP (mSBP), morning and evening systolic BP (SBP), morning and evening diastolic BP (DBP) and pulse rates (PR). The mean morning–evening SBP differences (dSBP) were calculated. We defined subjects with mSBP≥135 mmHg as hypertensive or poorly controlled subjects, according to the Japanese Society of Hypertension (JSH) Guidelines for the Self-Monitoring of Blood Pressure at Home (*12*). We also divided our subjects into two groups by using mean+1SD of the dSBP. There were no subjects whose mean DBP values alone exceeded 85 mmHg.

Table 1. Basic Characteristics (1992)

	NC (n=159)	NM (n=30)	HS (n=207)	HM (n=65)
Age (years)*	80.3±4.5	81.5±5.1	80.5±5.1	81.4±5.3
Men (n [%])	74 (46.5)	13 (43.3)	79 (38.1)	26 (40.0)
SBP (mmHg)**	125±8	124±8	148±11	150±10
DBP (mmHg)**	72±7	73±9	80±11	81±9
PR(/min)*	68±8	67±7	69±8	68±12
Morning SBP (mmHg)**	126±9	135±9	149±12	162±11
Evening SBP (mmHg)**	123±9	113±9	148±12	138±11
Total cholesterol (mg/dl)	190±35	210±39	186±38	195±42
HDL cholesterol (mg/dl)	48±14	56±10	45±13	44±12
ADL (full score: 21)	20.4±1.9	20.8±0.8	20.2±2.6	20.2±1.9
MMSE (full score: 30)	27.2±4.4	28.4±2.2	27.3±3.2	27.5±3.2
Up and Go test (s)	13.0±3.2	13.0±2.8	14.1±4.6	14.9±5.4
Antihypertensive drugs** (Yes, n [%])	38 (23.9)	10 (33.3)	89 (43.0)	40 (61.5)
History of CVD (Yes, n [%])	16 (10.0)	1 (3.3)	13 (6.3)	4 (8.1)

NC, normotensive/controlled; NM, normotensive/morning-dominant; HS, hypertensive/sustained; HM, hypertensive/morning-dominant; SBP, systolic blood pressure; DBP, diastolic blood pressure; PR, pulse rate; HDL, high-density lipoprotein; ADL, activities of daily living; MMSE, mini-mental state examination; CVD, cardiovascular disease, including stroke. *ANOVA, $p<0.05$, **ANOVA, $p<0.01$.

Annual Self-Administered Questionnaire

In the baseline survey (1992), the self-administered questionnaire was addressed to the study subjects to obtain information about characteristics potentially related to their BP, mortality, and disability; the data collected included a history of stroke, heart disease, and bone disease or arthropathy, antihypertensive medications, current and past cigarette smoking, current intake of alcohol, and activities of daily living (ADL). All of the response sheets submitted by the subjects were reviewed by community nurses to ascertain their information.

Assessment of ADL, Cognitive Function, Neurobehavioral Function, Mood and Serum Lipid Analysis

The questionnaire regarding the ADL was conducted in 1992 and 2001 in the same manner as was used in our previous study (*22*). Briefly, ADL were assessed with respect to the following seven items: walking, ascending and descending stairs, feeding, dressing, using the toilet, bathing, and grooming. Each ADL item was scored on a 0–3 scale: 0 = completely dependent, 1 = needs a lot of help, 2 = needs some help, and 3 = completely independent. The scores for these seven items were summarized to obtain a total ADL score ranging from 0 to 21. When a subject did not maintain a score of 21 or 20 points in 2001, he or she was defined as a person that was losing independence.

The mini-mental state examination (MMSE) was used to evaluate each subject's level of cognitive functioning (*23*). The Up and Go test was used to evaluate neurobehavioral function (*24*). This latter test measures, in s, the time it takes the subject to stand up from an armchair, walk a distance of 3 m, walk back to the chair, and sit down again. This simple test is a comprehensive evaluation of the subject's balance, gait speed, and functional ability. Since Okumiya and co-workers (*25*) reported its usefulness in predicting a decline in ADL in the Japanese community-dwelling elderly, the test has been widely accepted for this purpose in many fields. The Geriatric Depression Scale 15 (GDS 15) was also used to evaluate the mood of the subjects (depressive state) (*26*). Total serum cholesterol and serum high-density lipoprotein (HDL) cholesterol were analyzed in 1992.

During the period between 1992 and 2001, a total of 125 subjects (66 men, 59 women) died. In addition, the information regarding the events of stroke, myocardial infarction, congestive heart failure, and bone/joint diseases as causes of disability were collected by checking the responses provided on the annual questionnaire and the subjects' medical records.

Written informed consent was obtained from each subject at the time of the annual questionnaire. Our study was approved by the Research Ethics Committee of Kochi Medical School, Kochi University, Japan.

Statistical Analysis

All of the values were expressed as mean±SD. Mean values among the groups were compared using ANOVA. A χ^2 test was used to compare the 4 groups with respect to total mortality and incidence of stroke, as well as other CVDs. A logistic multivariate analysis was used to identify the factors that predicted a loss of functional independence or the survival and maintenance of functional independence 9 years after the initial assessment, using Stat View 5.0 for Windows (SAS Institute Inc., Cary, USA).

Table 2. Total/CVD Death and Non-Fatal Stroke

	NC (n=159)	NM (n=30)	HS (n=207)	HM (n=65)
Total death (%)*	36 (22.6)	3 (10.0)	62 (30.0)	24 (36.9)
Non-fatal stroke(%)	16 (10.1)	1 (3.3)	12 (5.8)	4 (6.2)
CVD death (%)	17 (10.7)	1 (3.3)	24 (11.6)	11 (16.9)
CVD events (%)	33 (20.8)	2 (6.7)	36 (17.4)	15 (23.1)

NC, normotensive/controlled; NM, normotensive/morning-dominant; HS, hypertensive/sustained; HM, hypertensive/morning-dominant; CVD, cardiovascular disease, including stroke. *ANOVA $p<0.1$.

Results

The distribution of mSBP and dSBP are shown in Fig. 1. The subjects were classified into the following 4 groups:

Hypertensive/morning-dominant (HM: mSBP≥135 mmHg, dSBP≥15 mmHg; n=65), hypertensive/sustained (HS: mSBP≥135 mmHg, dSBP<15 mmHg; n=207), normotensive/morning-dominant (NM: mSBP<135 mmHg, dSBP≥15 mmHg; n=30), and normotensive controlled (NC: mSBP<135 mmHg, dSBP<15 mmHg; n=159). The NC group, which was expected to be the lowest risk group because both the mSBP and the dSBP were lower than others, was used for reference.

A total of 461 elderly subjects, who were 75 years of age or older in 1992, were followed for 9 years until 2001 (Fig. 2). During that interval, 125 (27%) subjects died; 53 of these subjects had died of stroke and other CVDs. A total of 336 of the subjects were alive 9 years later (2001). One hundred-eighteen subjects had undergone a loss of their functional independence (HM, 17 [41%]; HS, 65 [45%]; NM, 7 [26%]; NC, 29 [24%]).

The basic characteristics of the 4 groups in 1992 are shown in Table 1. The subjects in the NC group were younger than those in the other 3 groups. The percentage of subjects who were taking antihypertensive agents was also the lowest in the NC group. There were no significant differences in terms of sex, PR, total serum cholesterol, HDL cholesterol, the scores of ADL, MMSE, the Up and Go test, or history of CVD among the 4 groups. There were also no differences in the scores on the GDS 15, history of bone/joint diseases, current and past cigarette smoking, and current intake of alcohol (data not shown).

Table 2 shows the total number of deaths, the number and percentage of deaths caused by stroke and other CVDs, and the incidence of non-fatal stroke during the 9-year follow-up period in the 4 groups. Although there was a difference in the total number of deaths among the 4 groups before adjustment for age, the significance of this difference disappeared after adjustment for age. There were no significant differences in the percentage of deaths from stroke or other CVDs. Although 33 subjects suffered from symptomatic strokes, no significant differences were seen in the incidence of strokes among the 4 groups.

The risk factors for loss of functional independence are shown in Table 3. Although a non-fatal event of stroke was one of the most important risk factors for loss of functional independence, HM and HS were also important risk factors, even after adjustment for age, sex, antihypertensive therapy, scores on the Up and Go test in 1992, and the ADL scores in 1992. The adjusted odds ratio (OR) of the HM group (12.2) was significantly higher than that of the HS group (3.78). Therefore, values of mSBP≥135 mmHg and dSBP≥15 mmHg were independent risk factors for a loss of functional independence (Fig. 3).

The factors associated with successful aging that contributed to the survival and maintenance of functional independence, even among the most elderly (age of 84 or older), are shown in Table 4. Although the non-fatal event of stroke was a significantly negative determinant, the HM and HS also remained as significant independent negative determinants of successful aging, after adjustment for age, sex, antihypertensive therapy, scores on the Up and Go test in 1992, and ADL scores in 1992.

As regards the elderly people aged 75 years or older living in the community, values of mSBP≥135 mmHg and dSBP≥15 mmHg were independent determinants of a loss of functional independence or successful aging, even when non-fatal stroke and these home SBP variables were simultaneously incorporated into a logistic multivariate analysis model.

In addition, since many of our subjects with morning hypertension had high home SBP, we added dSBP (≥15 mmHg) to the same model of multivariate logistic analysis, in order to elucidate whether dSBP was an independent determinant of a loss of functional independence or alive and independence. dSBP remained a significant determinant of a loss of independence (adjusted OR: 3.84, 95% confidence interval [CI]: 1.003–14.73), or alive and independence (adjusted OR: 0.46, 95% CI: 0.183–0.973), in our hypertensive subjects.

Discussion

Our prospective longitudinal study evaluating the maintenance of independence in the elderly aged 75 years or older demonstrated that a mean home SBP of ≥135 mmHg was a significantly important risk factor for a loss of functional independence. In addition, morning hypertension was an

Table 3. Independent Risk Factors for Loss of Independence in 336 Survivors

Factors	Adjusted odds ratio	95% CI	*p*
Stroke	17.4	3.67–82.8	0.0003
HM	12.2	3.00–50.0	0.0005
HS	3.78	1.45–9.83	0.0064
Age	1.17	1.05–1.30	0.0036

Data were adjusted for sex, antihypertensive therapy, Up and Go score, and activities of daily living (ADL) score in 1992. CI, confidence interval; HM, hypertensive/morning-dominant; HS, hypertensive/sustained.

Table 4. Independent Negative Factors for Survival and Maintenance of Independence (*n*=461)

Factors	Adjusted odds ratio	95% CI	*p*
Stroke	0.058	0.012–0.273	0.0003
HM	0.082	0.020–0.334	0.0005
HS	0.271	0.104–0.704	0.0073
Age	0.855	0.768–0.951	0.0038

Data were adjusted for sex, antihypertensive therapy, Up and Go score, and activities of daily living (ADL) score in 1992. CI, confidence interval; HM, hypertensive/morning-dominant; HS, hypertensive/sustained.

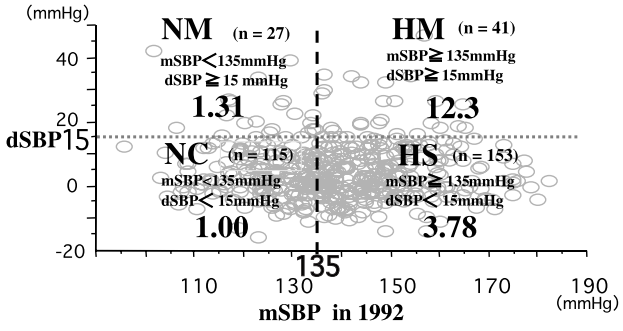

Fig. 3. *Adjusted odds ratios for loss of independence among the 4 groups. The abbreviations are the same as those introduced in Fig. 1.*

important independent predictor for the functional prognosis of our elderly subjects. The significance of dSBP should be further evaluated.

There were no differences in mortality and incidence of non-fatal stroke among the 4 groups. However, when a loss of functional independence was selected as the endpoint, significant differences were found among these groups. Home BP monitoring in the morning and in the evening was useful in predicting functional prognosis in elderly subjects aged 75 years or older.

Recent large clinical trials have clarified the importance of BP control, even among the elderly (*7–9*). However, the optimum home BP value for the elderly has not been established, and further prospective studies on the elderly will be necessary to define an adequate home BP value (*27*).

In the present study, there was no significant difference in the incidence of CVD death, stroke, and other CVD events among the 4 groups. Although the reason for this result is uncertain, further studies with a larger number of subjects may resolve this ambiguity.

Since a relationship between elevation of BP in the morning and stroke and other CVD events (*14–17*) has been reported, the importance of morning BP has been emphasized in studies of home BP monitoring (*28*, *29*). However, in most of these studies the mortality and morbidity of stroke and other CVDs, as well as organ damage, were selected as the endpoints. Functional independence, which is important for the elderly as well as for the social economy, is not mentioned in these previous studies. Thus, in our present study, we added a loss of functional independence and successful aging as two new endpoints for geriatric study. Furthermore, we evaluated morning–evening home BP differences in terms of the usefulness of this information for the prognosis of the elderly aged 75 years or older.

Skoog *et al*. (*30*) reported the relationship between the presence of hypertension at the age of 70 and the development of dementia 10 to 15 years later. In subsequent large studies including SCOPE (*10*), the association between impaired cognitive function and BP values has been evaluated, although sufficient data on the relationship between BP control and cognitive function have yet to be accumulated. In our previous study (*31*), a J-curve phenomenon was demonstrated with respect to the profile of the association between BP values and cognitive function 3 years later in an elderly sample. Those findings indicate that BP exerted an effect on cognitive function, not only in the group with high BP, but also in the group with low BP. In our previous study, casual BP was measured twice with the subject in the supine position at the time of physical examination. Here, to avoid the inclusion of various other factors affecting BP measurements, we used 20 home BP measurements in order to calculate the mean value. This method of measurement appeared to have eliminated some of the potential problems with BP monitoring.

Because the follow-up period was so long (9 years), it was difficult to reexamine cognitive function in all of the subjects examined in 2001; some subjects were too old for us to obtain reliable data from them (*i.e.*, among those at least aged 84 years of age and older). Due to our small sample size in the MMSE evaluation ($n=64$, 19%), we did not observe any significant differences between the group with high home BP values (≥135 mmHg) and the group with normal home BP values (<135 mmHg). There were also no significant differences in dSBP (≥15 mmHg). Evaluation of the cognitive functions (MMSE) of the most elderly subjects included in the sample was difficult; thus, an appropriate, reliable method

will still need to be developed for the evaluation of this group in future studies.

A variety of factors, including stroke events and other CVDs, as well as the progression of bone/joint diseases and dementia, contributes to disability among the elderly (*32*). The present study demonstrated for the first time that those elderly persons with a mean home SBP≥135 mmHg were susceptible to a loss of functional independence, even if they did not experience an event of symptomatic stroke. However, the present study did not reveal any direct mechanism to generate this relationship between hypertension reflected by the home BP monitoring value and a loss of independence. The relationships between hypertension or morning BP elevation and pathological conditions such as asymptomatic small infarctions and white matter lesions have previously been reported (*33*–*36*). It is thus possible that these lesions are related to BP elevation and may be involved in the impairment of functional abilities required for daily life. To clarify the association between home BP values, asymptomatic brain lesions, and disability among the very elderly, further study is warranted.

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