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Blood Pressure Variability and Cognitive Function Among Older African Americans: Introducing a New Blood Pressure Variability Measure

Siny Tsang, PhD[*], **Scott A. Sperling, PsyD**[†], **Moon Ho Park, MD**[‡], **Ira M. Helenius, MD**[§], **Ishan C. Williams, PhD**[||], and **Carol Manning, PhD**[†]

[*]Department of Epidemiology, Columbia University, New York, New York

[†]Department of Neurology, University of Virginia, Charlottesville, Virginia

[§]Department of Medicine, University of Virginia, Charlottesville, Virginia

[||]School of Nursing, University of Virginia, Charlottesville, Virginia

[‡]Department of Neurology, Korea University College of Medicine, Seoul, Republic of Korea

Abstract

Background—Although blood pressure (BP) variability has been reported to be associated with cognitive impairment, whether this relationship affects African Americans has been unclear. We sought correlations between systolic and diastolic BP variability and cognitive function in community-dwelling older African Americans, and introduced a new BP variability measure that can be applied to BP data collected in clinical practice.

Methods—We assessed cognitive function in 94 cognitively normal older African Americans using the Mini-Mental State Examination (MMSE) and the Computer Assessment of Mild Cognitive Impairment (CAMCI). We used BP measurements taken at the patients' three most recent primary care clinic visits to generate three traditional BP variability indices, range, standard deviation, and coefficient of variation, plus a new index, random slope, which accounts for unequal BP measurement intervals within and across patients.

Results—MMSE scores did not correlate with any of the BP variability indices. Patients with greater diastolic BP variability were less accurate on the CAMCI verbal memory and incidental memory tasks. Results were similar across the four BP variability indices.

Conclusions—In a sample of cognitively intact older African American adults, BP variability did not correlate with global cognitive function, as measured by the MMSE. However, higher diastolic BP variability correlated with poorer verbal and incidental memory. By accounting for differences in BP measurement intervals, our new BP variability index may help alert primary care physicians to patients at particular risk for cognitive decline.

Corresponding author: Siny Tsang, PhD, Columbia University, Department of Epidemiology, 722 W 168th Street, New York, New York 10032. Phone: 212-305-6706. Fax: 212-305-9413. st2989@cumc.columbia.edu.

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Keywords

blood pressure variability; cognition; Mini-Mental State Examination (MMSE); Computer Assessment of Mild Cognitive Impairment (CAMCI); African Americans

Health care clinics often use blood pressure (BP) measurements to assess patients' risk for cardiovascular problems (Crichton et al, 2014). Patients with hypertension are at particular risk for stroke, vascular dementia, and Alzheimer disease (Peila et al, 2006; Posner et al, 2002). In fact, the association between high BP and future cognitive decline is well established (Elias et al, 1998, 2004; Insel et al, 2005; Skoog et al, 1996; Swan et al, 1998).

DeCarli (2003) and Gianaros et al (2006) suggested that high BP leads to cognitive deficits by causing structural brain changes such as accelerated atrophy and the development of white matter disease. In recent years, greater variability in BP measurements (ie, changes in BP at different time points) has been linked to a higher risk for stroke and other cardiovascular events (Floras, 2013; Rothwell, 2010; Rothwell et al, 2010). Because wide BP variability is found in patients with brain structure abnormalities (Gunstad et al, 2009; Nagai et al, 2011; Sabayan et al, 2013) or hypertensive cardiovascular complications (Kanemaru et al., 2001), Crichton et al (2014) suggested that BP variability also affects cognitive performance.

Most recent studies have tied wide BP variability to cognitive dysfunction among older adults with hypertension (Kanemaru et al, 2001) as well as those with one or more other cardiovascular risk factors (Crichton et al, 2014; Nagai et al, 2012, 2014). Older community-dwelling individuals who had wide BP variability for 4 years were found to be at higher-than-normal risk for dementia (Alpérovitch et al, 2014). Patients with Alzheimer disease and greater BP variability showed more cognitive decline over a year than patients with Alzheimer disease who had more stable BP (Lattanzi et al, 2014). Among older adults who were at risk for cardiovascular disease, those with greater visit-to-visit BP variability performed worse on cognitive tests than their counterparts with less variability (Sabayan et al, 2013). Consistently, older adults with greater day-to-day home BP variability have been found to be more likely to experience cognitive decline than those with more stable BP (Matsumoto et al, 2014).

Links between BP variability and cognitive function are not limited to older people. Young adults who showed BP variability over a 25-year follow-up had poorer cognitive function in midlife than young adults whose BP was stable; the results were similar in black and white participants (Yano et al, 2014).

Other studies, however, have not tied BP variability to cognitive performance. For instance, Cicconetti et al (2004) found that BP variability over a 24-hour period did not correlate with cognitive function in older individuals with hypertension, and Keary et al (2007) reported that older adults with cardiovascular disease and BP variability had better cognitive performance than similar patients with stable BP.

To our knowledge, no studies of BP variability and cognitive impairment have focused exclusively on older African American adults. Because African Americans are at higher risk for hypertension and related cardiovascular problems than white Americans (Abdalla et al, 2016; Cooper et al, 2005; Kurian and Cardarelli, 2007; Oparil and Wright, 2005), we chose to focus on this population.

We had a second purpose. The commonly used BP variability indices—range, standard deviation, and coefficient of variation—do not account for differences in the intervals between a patient's BP assessments. This limits the utility of BP variability indices to experimental or prospective studies in which all BP measurements are taken at regular intervals. We wanted to be able to analyze the variability of BP measurements recorded at varying time points. Therefore, we needed an index that could correct for differences in assessment intervals within and between individuals.

Thus, our goal in this study was twofold. First, we introduced a new BP variability index that takes into account unequal BP measurement intervals within and across patients. Our second objective was to examine the relationship between cognitive function and BP variability indices, using traditional BP variability indices as well as our new index, in older African Americans who had no prior diagnoses of cognitive dysfunction.

We hypothesized that our participants' BP variability would show an association with their cognitive performance. Specifically, we expected those with less stable BP (greater BP variability) to perform worse on tasks assessing their cognitive function.

METHODS

Participants

We recruited community-dwelling African American patients who were at their scheduled visits to their primary care physician at the University Medical Associates (a primary care clinic) at the University of Virginia, Charlottesville, Virginia, between October 2012 and October 2013. We put out brochures and fliers in the clinic. Interested patients were invited to speak to a research assistant who was at the clinic. We required that participants be at least 60 years old and seeing their doctor for reasons unrelated to cognitive complaints.

We initially enrolled 96 patients: 37 men and 59 women. None had reported any cognitive complaints to their primary care physician during the enrollment visit or any prior visit. After the patients saw their physician and agreed to take part in the study, we gave them short cognitive screening tasks and survey questionnaires. The participants gave us permission to review their medical records for more information.

We confirmed that none of the participants had received a diagnosis of dementia, mild cognitive impairment, schizophrenia, bipolar disorder, or major depression.

We disqualified two patients whose record documented that they had more than 30 medications, because we could not determine whether they were taking all 30 medications at the time of the study.

The final analyses included 94 participants.

The study was approved by the University of Virginia Health System institutional review board and was conducted in accordance with the Declaration of Helsinki. All participants gave written informed consent before entering the study.

Table 1 lists the 94 participants' demographic characteristics and selected health information.

Measures

Blood Pressure—We obtained the three most recent systolic and diastolic BP measurements documented in each patient's medical record, and the date of the measurement. Most of the patients had one BP measurement taken per visit. For visits during which they had more than one, we used the last BP recorded.

The clinic used the following procedure for measuring BP: First, the staff had the patients rest for 5 minutes. Then, during the testing, the patients sat with their feet flat on the floor and their back supported; they did not speak. The staff took oscillometric BP measurements with a GE Carescape V100 Dinamap Monitor (General Electric Healthcare, Chicago, Illinois).

BP Variability Indices—To assess within-patient BP variability across the most recent three clinic visits, we computed three traditional BP variability indices:

- Range. We defined the range of BP measurements as the difference between the highest and the lowest values across the three clinic visits.
- Standard deviation (SD). SD is the square root of the variance of the three BP measurements.
- Coefficient of variation computed as:

$$\frac{\mathrm{SD}}{\overline{\mathrm{BP}}} \times 100\%$$

where $\overline{\mathrm{BP}}$ is mean BP.

Higher values on all the BP variability indices reflect more BP variability (ie, less stable BP) across the three measurements, while lower values indicate less variability (ie, more stable BP).

Because we obtained our patients' BP measurements retrospectively from medical records, the patients varied in the dates of their three most recent clinic visits and the number of days between visits. A change in BP within a shorter period of time, eg, a week, should be considered bigger (ie, more variability) than a change over a longer period, eg, a year.

To account for the varying intervals between BP measurements across our patients, we computed a fourth BP variability index, random slope, as follows. First, we calculated the absolute BP differences between two clinic visits for each patient. With three clinic visits,

three absolute BP differences can be computed—between visits 1 and 2, 2 and 3, and 1 and 3. Next, we used linear mixed effects models to model the absolute changes in BP as a function of the number of days between clinic visits, taking into account the within-patient correlations of BP variations. The linear mixed effects model takes the form of:

$$y_{ij}=\beta_0+\beta_1 x_{ij}+b_{i0}+b_{i1} z_{ij}+\varepsilon_{ij}$$

where y_{ij} is the absolute change in either systolic or diastolic BP for patient i between clinic visits j, β_0 is the global intercept, β_1 is the fixed effect coefficient for the number of days between clinic visits (x_{ij}) averaged across all patients, b_{i0} is the random intercept for patient i, b_{i1} is the random effect coefficient for the number of days between clinic visits (z_{ij}), and ε_{ij} is the measurement error of the absolute BP difference between clinic visits j for patient i.

β_1 represents the global effect of the number of days between clinic visits on the absolute change in BP averaged across all patients; a positive value indicates that the amount of absolute change in BP increases with longer intervals between clinic visits, while a negative value reflects a decrease in the absolute BP difference with longer intervals between clinic visits. b_{i1} represents the effect of the intervals between clinic visits on absolute BP differences for each patient, indicating the variability of BP across clinic visits for patient i, taking into account the variations of clinic visit intervals between patients.

Because b_{i1} is essentially the random slope in the linear mixed effects model, we term this new BP variability index *random slope*. If β_1 is positive, a larger random slope indicates more BP variability, while a smaller random slope reflects less BP variability across time, taking into account the differences in the intervals between clinic visits. If β_1 is negative, a larger random slope indicates less BP variability, and a smaller random slope reflects more BP variability across time, taking into account the differences in the intervals between clinic visits.

Cognitive Function—We estimated our patients' cognitive function using the Mini-Mental State Examination (MMSE) (Folstein et al, 1975) and the Computer Assessment of Mild Cognitive Impairment (CAMCI) (Saxton et al, 2009).

The MMSE was developed to assess overall cognitive function through questions about orientation, registration, attention and calculation, recall, and language. Designed for quick, easy administration, the MMSE is routinely used in clinical practice to screen patients for cognitive deficits suggesting dementia. The MMSE scores in our patients ranged from 16 to 30 (mean = 25.51, SD = 3.54). Considering that none of the patients had a prior diagnosis of cognitive impairment, their relatively low MMSE scores suggest that the MMSE may not be the best instrument to screen for cognitive impairment among African Americans or that their primary care physicians failed to identify early signs of cognitive impairment (Tsang et al, 2017).

The CAMCI is a self-paced assessment that we gave on a lightweight portable tablet computer. Information is presented both visually and orally to accommodate poor readers (Saxton et al, 2009). The CAMCI assesses cognitive function in multiple domains using

accuracy rates and reaction times. In this study, we focused on patients' accuracy rates, ie, the proportion of items that they answered correctly, in five cognitive domains:

- Attention: assessed with a digit span forward task
- Executive function: assessed with a digit span backward task, Go/No Go, and the "Choice Points" subtest in the CAMCI virtual environment module, (eg, following street directions, going to the bank and using an automated teller machine, and grocery shopping)
- Verbal memory: assessed with the word recall task
- Functional memory: assessed with the itemized recall subtest in the virtual environment module
- Incidental memory: assessed with the incidental recall subtest in the virtual environment module

The patients' average accuracy rates on these tasks represented their cognitive function, with a 0% accuracy rate indicating no correct responses and a 100% accuracy rate indicating all correct responses across tasks.

Other Medical Conditions—We also searched each patient's medical record for these possibly confounding medical conditions:

- Hypertension, determined if the chart showed that the patient was being prescribed antihypertensive medication
- Diabetes listed as a diagnosis
- Hypercholesterolemia, defined as a total cholesterol ≥ 200 mg/dL
- History of stroke, determined by the *International Classification of Diseases, 9th Revision-Clinical Modification* codes for ischemic and hemorrhagic stroke (Birman-Deych et al, 2005)
- Obesity, defined as a body mass index ≥30 kg/m^2

Data Analysis

We used linear regression models to examine the extent to which patients' cognitive function (MMSE scores and accuracy rates on the CAMCI domains) correlated with their systolic and diastolic BP variability indices. All analyses controlled for patients' demographic characteristics (age, sex, and years of education) and for diabetes, hypercholesterolemia, history of stroke, and obesity.

We performed all of the statistical analyses using R Version 3.2.3 (R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

We set statistical significance at $P < 0.05$.

RESULTS

For the 94 patients included in our final analysis, the interval between consecutive visits to the primary care clinic ranged from 0 to 392 days (mean = 49.9, SD = 37.9). The global effect (β_1) of the number of days between clinic visits on the absolute change in systolic BP averaged across all patients was negative, indicating that the absolute systolic BP difference decreased with longer intervals between visits. By contrast, the global effect of intervals between visits on the absolute change in diastolic BP averaged across all patients was positive, meaning that the absolute diastolic BP difference increased with longer durations between visits.

For consistency of interpretation, we multiplied the values for the systolic BP random slope by −1, so that higher systolic BP random slope values would reflect greater systolic BP variability.

Table 2 shows descriptive statistics for the BP variability indices. For all four indices, range, SD, coefficient of variation, and random slope, higher values represent greater variability. All of the indices correlate strongly with each other (correlation coefficients = 0.96 to 0.99 for systolic BP, correlation coefficients = 0.97 to 0.99 for diastolic BP). Across all four indices, the variability was greater for systolic than diastolic BP, indicating that the patients had more change in their systolic than diastolic BP. None of the variability indices differed by sex, age, or education level (all P values > 0.05).

We used linear regression models to examine whether the variability indices correlated with our patients' cognitive function, after we controlled for demographic characteristics and existing medical conditions (diabetes, hypercholesterolemia, obesity, and stroke).

Table 3 shows the estimated regression coefficients and standard errors from the regression models, with statistically significant correlations marked by asterisks. None of the BP variability indices had statistically significant correlations with MMSE scores or with accuracy rates in the CAMCI attention, executive function, or functional memory domains. We found significant negative correlations between all four diastolic BP variability indices and accuracy rates for incidental memory. Patients with greater diastolic BP variability had lower accuracy on the incidental memory task than those with more stable diastolic BP. We found a similar significant negative association between the coefficient of variation for diastolic BP and accuracy in verbal memory. Patients with a greater coefficient of variation for diastolic BP variability had lower accuracy on the verbal memory task than those with more stable diastolic BP. The correlations between accuracy on the verbal memory task and the remaining diastolic BP variability indices (range, SD, and random slope) also trended in the same direction, though not reaching statistical significance.

We wanted to know whether antihypertensive drug treatment would affect our findings. We re-analyzed our data controlling for whether or not patients were taking antihypertensive medications, and the results were unchanged. We also re-analyzed the data including the two patients whom we had previously excluded for having 30 or more medications; again, the results remained the same.

In view of the wide range in number of days between many clinic visits, we wondered whether the BP variability that we saw within only 1 or a few days might not reflect true BP variability. Therefore, we performed a sensitivity analysis on our data by repeating all the analyses using data only from the 89 patients who had at least 7 days between each pair of visits. The results of this analysis, shown in Tables 4 and 5, are mostly consistent with the findings for all 94 participants, with small differences likely due to the limited sample size.

DISCUSSION

In this study we sought associations between BP variability and cognitive function in a sample of older African Americans who had no prior diagnosis of cognitive impairment. We had hypothesized that our patients' BP variability would correlate negatively with their cognitive test performance. In addition to the traditional BP variability indices of range, SD, and coefficient of variation, we computed a random slope to account for the varying intervals between our patients' BP measurements. We found negative correlations between diastolic BP variability indices and our patients' performance on tests of verbal and incidental memory. These findings suggest that, over time, older African American patients with higher diastolic BP variability are more likely to perform worse on tasks that tap into their verbal and incidental memory. By contrast, neither systolic nor diastolic BP variability appeared to relate to the patients' global cognitive function, or their performance on attention, executive function, or functional memory tasks.

Our results showed partial support for our hypothesis, and they agree in part with previous findings in a longitudinal community sample of Americans, most of them white (Crichton et al, 2014), and in older adults (race not reported) with cardiovascular disease (Keary et al, 2007). Considered together, the results of these studies and ours suggest that different domains of cognitive function are differentially affected by BP variability across different racial and ethnic groups, a finding consistent with existing research among patients with cardiovascular disease (Keary et al, 2007).

Unlike previous reports (Crichton et al, 2014; Lattanzi et al, 2014; Matsumoto et al, 2014; Nagai et al, 2014), we found that none of the BP variability indices correlated with our patients' MMSE scores. However, none of the earlier studies focused on African American elders, and only Crichton et al (2014) included a small proportion of middle-aged to elderly African American participants. Further, the MMSE may not be an entirely reliable screening measure for cognitive deficits in older African Americans because of problems such as poor specificity and high rates of false-positive results (Fillenbaum et al, 1990; Stephenson, 2001). Therefore, this measure of global cognitive function may not be adequate to detect dysfunction in certain cognitive domains among cognitively intact African American elders with BP variability.

BP variability has been linked to autonomic dysfunction (Zhang et al, 2011) and cardiovascular mortality (Kikuya et al, 2000, 2008). Allan et al (2006) reported that orthostatic hypotension, one of the symptoms of autonomic dysregulation, might be related to dementia. van Oijen et al (2007) and Wendell et al (2009) suggested that atherosclerosis is related to cognitive decline or dementia. Taken together, these studies suggest that cognitive

impairment related to BP variability may result in part from autonomic system dysfunction or arterial stiffness (Matsumoto et al, 2014).

This study introduced a new BP variability index, random slope, which accounts for the unequal intervals between a patient's BP measurements. Our results showed consistent associations between BP variability and cognitive performance across the traditional BP variability indices and random slope. In fact, our random slope calculations for both systolic and diastolic BP correlated almost perfectly with the traditional BP variability indices, validating this index as an indicator of BP variability.

Unlike traditional BP variability indices, which ignore variations in measurement intervals, random slope is a function of the different BPs and their measurement intervals. This makes random slope a better indicator of variability, especially when the measurement intervals are inconsistent within and across individuals.

Considering that the use of traditional BP variability indices may be limited to studies in which BP measurements are repeated at specific predetermined intervals, the introduction of random slope allows researchers to assess BP variability using data collected at irregular intervals, while accounting for the varying intervals of measurements across patients. Thus, researchers interested in exploring the effects of BP variability across time are no longer limited to experimental designs, but can also apply random slope to existing data such as those already documented in patients' medical charts. Applying our equation to repeated BP measurements, clinicians and researchers can easily compute a patient's random slope and can expand to examining the associations between BP variability and cognitive function among samples with different characteristics.

We should note two limitations of this study. First, although medical professionals measured patients' BP at the primary care clinic, we obtained the BP records retrospectively from the patients' medical records. It is thus possible that other factors, such as time of day or how busy the staff was, may have affected the measurements and contributed to fluctuations. BP measured under controlled circumstances, eg, at certain times of day, may help to determine whether measurements obtained from medical records are a reliable source for tracking patients' BP variability over time and allowing replication of our findings.

A second limitation is that, because our study was cross-sectional, we could examine our patients' cognitive function at only one moment.

Longitudinal studies are much needed to learn whether—and, if yes, the extent to which—BP variability relates to cognitive decline among aging African Americans over time. It is also possible that early Alzheimer disease involves areas important to central autonomic control such as the insula, amygdala, and anterior cingulate cortex (Braak and Braak, 1995; Braak et al, 1999), leading to autonomic dysfunction and/or BP variability (Jensen-Dahm et al, 2015). For this reason, longitudinal studies are also needed to determine whether BP variability is a consequence of cognitive impairment and/or its cause. Further, research is needed to investigate whether patients taking BP medications have less BP variability, and thus show slower cognitive decline, than those not being treated.

Our findings are specific to a small sample of older African Americans with no prior diagnosis of cognitive impairment. Our study needs to be replicated using data from large representative samples to validate further the utility of our new BP variability index. We encourage other researchers to compare our findings to results in elderly patients of different races and ethnicities to learn more about how BP variability affects different domains of cognitive function.

In conclusion, our findings suggest that greater diastolic BP variability correlates with poorer accuracy in verbal and incidental memory among older African Americans who presumably have intact cognitive function. We have also illustrated a new BP variability index, random slope, which accounts for within- and across-individual variability of intervals between repeated BP measurements. As random slope can be calculated retrospectively from patients' medical records, studies of associations between BP variability and cognitive function need no longer be limited to designs in which serial BP measurements are recorded at regular intervals. As long as the date of measurement is always recorded, random slope can be computed to indicate BP variability.

Clinicians and researchers can use random slope to test whether our present findings are generalizable to other older African Americans, such as those with known cognitive decline. Furthermore, calculating random slope with BP measurements from a patient's medical chart may alert primary care physicians to patients who are at higher-than-normal risk for cognitive decline.

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Glossary

BP	blood pressure
CAMCI	Computer Assessment of Mild Cognitive Impairment
MMSE	Mini-Mental State Examination
SD	standard deviation

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TABLE 1

Our Patients' Demographic and Clinical Information

	Total (N = 94)	Men (N = 36)	Women (N = 58)
Age (years)	69.2 (6.8)	69.9 (7.0)	68.7 (6.7)
Education (years)	10.5 (3.2)	9.9 (3.9)	10.9 (2.6)
Number of medications	10 [0–22]	10 [0–21]	11 [0–22]
Hypertension	95.7%	91.7%	98.3%
Diabetes	60.2%	50%	66.7%
Hypercholesterolemia	21.8%	18.2%	24.1%
History of stroke	13.8%	19.4%	10.3%
Obesity*	52.2%	36.1%	62.5%
Mini-Mental State Examination†[1]	25.51 (3.54)	24.08 (4.09)	26.40 (2.84)
Computer Assessment of Mild Cognitive Impairment[2]			
Attention	82.09 (22.57)	78.24 (24.82)	84.48 (20.91)
Executive function	42.47 (19.15)	40.43 (17.49)	43.74 (20.15)
Verbal memory†	29.79 (30.73)	18.89 (23.88)	36.55 (32.69)
Functional memory	47.16 (25.36)	43.06 (25.93)	49.71 (24.88)
Incidental memory	35.7 (20.82)	32.22 (17.42)	37.89 (22.58)

Descriptive statistics are presented as mean (standard deviation) for continuous variables, median [range] for count variables, and percentage for dichotomous variables.

Results remained the same when we counted the two excluded patients who had 30 or more medications.

The difference between sexes was statistically significant at $*P < 0.05$ or $\dagger P < 0.01$.

[1] Folstein et al, 1975.

[2] Saxton et al, 2009.

TABLE 2

Within-Patient Blood Pressure Variability Indices

	Blood Pressure	
	Systolic	**Diastolic**
Range	25.87 (18.1)	12.81 (9.52)
Standard deviation	14.71 (9.33)	7.25 (4.99)
Coefficient of variation	10.41 (6.41)	9.7 (6.48)
Random slope	0 (1.42)	0 (0.06)

Data are shown as mean (standard deviation).

TABLE 3

Regression Coefficients Estimating Cognitive Function from Blood Pressure Variability Indices, Adjusted for Demographic Characteristics and Medical Conditions

		Computer Assessment of Mild Cognitive Impairment[2]				
	MMSE[1]	Attention	Executive Function	Verbal Memory	Functional Memory	Incidental Memory
Systolic blood pressure						
Range	0.01 (0.02)	0.18 (0.15)	0.03 (0.13)	− 0.01 (0.19)	− 0.29 (0.17)	− 0.17 (0.14)
Standard deviation	0 (0.04)	0.31 (0.29)	0.06 (0.23)	0.04 (0.36)	− 0.61 (0.32)	− 0.32 (0.27)
Coefficient of variation	0.02 (0.06)	0.43 (0.43)	0.06 (0.35)	− 0.23 (0.53)	− 0.92 (0.48)	− 0.59 (0.4)
Random slope	0.07 (0.27)	2.39 (1.92)	0.04 (1.57)	0.59 (2.41)	− 4.05 (2.15)	− 1.57 (1.80)
Diastolic blood pressure						
Range	− 0.02 (0.04)	0.07 (0.26)	− 0.23 (0.22)	− 0.62 (0.32)	− 0.26 (0.3)	− 0.58 (0.24) *
Standard deviation	− 0.05 (0.07)	0.08 (0.5)	− 0.51 (0.4)	− 1.16 (0.61)	− 0.63 (0.56)	− 1.13 (0.45) *
Coefficient of variation	− 0.05 (0.05)	0.02 (0.39)	− 0.39 (0.31)	− 1 (0.46) *	− 0.55 (0.43)	− 0.94 (0.35) †
Random slope	− 2.85 (3.93)	3.91 (29.27)	− 26.26 (23.56)	− 65.68 (35.61)	− 29.42 (33.13)	− 58.97 (26.53) *

* $P < 0.05$.

† $P < 0.01$.

Data are shown as regression coefficient (standard error).

We adjusted the results for age, sex, education level, and medical conditions (diabetes, hypercholesterolemia, obesity, and stroke). Regression diagnostics showed no violation of assumptions (including linearity, normality of residuals, homoscedasticity, influential observations, and collinearity) for any of the models.

1 Folstein et al, 1975.

2 Saxton et al, 2009.

MMSE = Mini-Mental State Examination.

TABLE 4

Within-Patient Blood Pressure Variability Indices for 89 Patients With ≥7 Days Between Blood Pressure Measurements

	Blood Pressure	
	Systolic	**Diastolic**
Range	25.19 (18.26)	12.71 (9.61)
Standard deviation	14.52 (9.38)	7.27 (5.05)
Coefficient of variation	10.31 (6.54)	9.73 (6.48)
Random slope	0 (1.51)	0 (0.25)

Data are shown as mean (standard deviation).

TABLE 5

Regression Coefficients Estimating Cognitive Function From Blood Pressure Variability Indices, Adjusted for Demographic Characteristics and Medical Conditions of 89 Patients With ≥7 Days Between Blood Pressure Measurements

		Computer Assessment of Mild Cognitive Impairment[2]				
	MMSE[1]	Attention	Executive Function	Verbal Memory	Functional Memory	Incidental Memory
Systolic blood pressure						
Range	0.01 (0.02)	0.23 (0.15)	0.05 (0.12)	0.03 (0.19)	− 0.24 (0.17)	− 0.14 (0.14)
Standard deviation	0 (0.04)	0.44 (0.29)	0.09 (0.24)	0.13 (0.36)	− 0.58 (0.33)	− 0.28 (0.27)
Coefficient of variation	0.02 (0.06)	0.56 (0.42)	0.08 (0.35)	− 0.12 (0.52)	− 0.86 (0.48)	− 0.52 (0.4)
Random slope	0.06 (0.25)	3.08 (1.85)	− 0.26 (1.53)	0.37 (2.29)	− 4.32 (2.07) *	− 0.95 (1.75)
Diastolic blood pressure						
Range	0 (0.04)	0.08 (0.26)	− 0.09 (0.21)	− 0.48 (0.32)	− 0.07 (0.3)	− 0.53 (0.24) *
Standard deviation	− 0.03 (0.07)	0.13 (0.51)	− 0.24 (0.41)	− 0.87 (0.61)	− 0.24 (0.58)	− 1.09 (0.46) *
Coefficient of variation	− 0.03 (0.05)	0.05 (0.4)	− 0.18 (0.32)	− 0.8 (0.47)	− 0.27 (0.45)	− 0.92 (0.36) *
Random slope	− 0.61 (1.4)	3.66 (10.37)	− 6.88 (8.38)	− 22.01 (12.33)	− 8.78 (11.74)	− 20.34 (9.41) *

* $P < 0.05$.

Data are shown as regression coefficient (standard error).

We adjusted the results for age, sex, education level, and medical conditions (diabetes, hypercholesterolemia, obesity, and stroke). Regression diagnostics showed no violation of assumptions (including linearity, normality of residuals, homoscedasticity, influential observations, and collinearity) for any of the models.

[1] Folstein et al, 1975.

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MMSE = Mini-Mental State Examination.