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Balance and Gait in Older Adults With Systemic Hypertension*

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It has been suggested that age-associated abnormalities in blood pressure (BP) homeostasis may precipitate decreases through transient underperfusion of the brain and that hypertension may exacerbate impaired BP regulation and thus increase the risk of falling.[1] According to this hypothesis, a transient reduction in BP causes falls. Alternatively, hypertension may increase fall risk by affecting the control of gait and balance. Interestingly, increased cardiovascular mortality has been observed in older adults with gait disorders of unknown origin.[2] To better understand the effects of hypertension on locomotor function and fall risk, we tested the hypothesis that the gait and balance of older adults with hypertension are altered compared with age-matched controls.

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Twenty-four, relatively healthy older adults who were mobile and walked independently were studied. Subjects were included if they were living in a community, were aged 65 to 90 years, were able to follow instructions, and reported no disturbances in their walking abilities. Exclusion criteria included: history of stroke, Parkinson's disease, parkinsonism, or any neurologic disease, use of anti-parkinsonian or antispastic medications, orthostatic hypotension, cerebellar dysfunction, significant visual or vestibular disturbances, or significant orthopedic disturbances. Subjects with dementia, a history of psychiatric disease, or subjects who were taking antipsychotic medications were also excluded. In addition, we excluded patients with a history of head trauma or clinically documented cerebrovascular events. All subjects were recruited as "healthy controls" to provide a reference group in an ongoing study of neurologic disease in older adults. For the purposes of the present study, these "healthy controls" were stratified into 2 groups. Subjects were classified as "hypertensives" if they were under a doctor's order to take a prescription medication to control their hypertension (i.e., they reported a history of hypertension and a prescription for BP medications). Other subjects were defined as "normotensives." Informed written consent was obtained.

To characterize the study population, we obtained a detailed medical history, reviewed all medications, and performed a full, structured neurologic examination including the motor portion (part III) of the Unified Parkinson's Disease Rating Scale (UPDRS).[3] The Charlson Comorbidity Index was determined.[4] Mental health was assessed using the Mini Mental State Exam[5] and the long form of the Geriatric Depression Scale.[6] Isometric muscle strength was assessed at the quadriceps, averaging left and right legs, as previously described.[7] The ability to perform activities of daily

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*Time series used to determine stride and swing time dynamics (e.g., coefficient of variation and fractal indexes) are available for downloading and additional study via an NIH sponsored website: www.physionet.org.

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TABLE 1 Subject Characteristics

	Normotensive (n = 12)	Hypertensive (n = 12)	p Values
Age (yrs)	77.5 ± 6.8	78.0 ± 4.2	0.707
Women/men	7/5	8/4	0.673
Height (cm)	162 ± 10	166 ± 9	0.435
Weight (kg)	64 ± 9	69 ± 8	0.311
UPDRS motor score (part III: 0–108)	4.0 ± 3.1	4.5 ± 2.2	0.416
Charlson Comorbidity Index (0 = no comorbidities)	0.4 ± 0.9	0.8 ± 1.2	0.351
No. of medications*	1.3 ± 1.1	1.9 ± 1.9	0.352
Mini Mental Status Exam (0–30)	29 ± 2	29 ± 1	0.666
Geriatric Depression Scale (0–30)	5 ± 3	6 ± 4	0.661
Barthel ADL index (0–20)	20 ± 0	20 ± 0	1.00
Quadriceps strength (n)	216 ± 62	218 ± 46	0.773
Supine systolic BP (mm Hg)	143 ± 14	152 ± 13	0.093
Supine diastolic BP (mm Hg)	82 ± 5	82 ± 8	0.862
Supine heart rate (beats/min)	69 ± 10	66 ± 8	0.544
Standing systolic BP (mm Hg)	136 ± 21	147 ± 10	0.148
Standing diastolic BP (mm Hg)	86 ± 19	86 ± 8	0.311
Standing heart rate (beats/min)	75 ± 9	70 ± 7	0.260

*Number of prescription medications not including medications for treatment of hypertension. Subjects with hypertension were taking 1.6 ± 0.5 hypertension medications ($p < 0.0001$ compared with normotensives).

TABLE 2 Balance and Gait Measures

	Normotensive (n = 12)	Hypertensive (n = 12)	p Values
Pull test (a measure of postural control: 0–4)*	0.2 ± 0.4	0.7 ± 0.5	0.015
Timed Up and Go test (s)†	7.5 ± 1.5	8.3 ± 0.9	0.028
Gait speed (m/s)	1.27 ± 0.21	1.28 ± 0.11	0.908
Mean stride time (s)	1.04 ± 0.06	1.05 ± 0.07	1.00
Stride time CV (%)	2.5 ± 1.1	2.4 ± 0.7	0.686
% Swing time (%)	33.6 ± 3.2	31.2 ± 4.4	0.166
Swing time CV (%)	4.9 ± 3.5	9.7 ± 7.2	0.028
Fractal scaling index of gait	0.97 ± 0.20	0.77 ± 0.24	0.050
Tinetti balance scale (possible range: 0–16)	15.8 ± 0.5	15.4 ± 0.5	0.105
Tinetti gait scale (possible range: 0–12)	11.9 ± 0.3	12.0 ± 0.0	0.317

*Two normotensives and 8 hypertensives had scores of 1.0 = normal and 1 = retropulsion, but they recovered unaided.

†A modified version of the test was used. For the pull test, Timed Up and Go, and coefficient of variation measures, lower scores are better. For the other measures, the converse is true.

CV = coefficient of variation

living (ADL) was evaluated using the Barthel ADL index.[8] BP and heart rate were determined in the supine position after 5 minutes of quiet rest and after 2 minutes of standing.

The following, previously validated tests were used to evaluate balance and gait. (1) The pull test, part of the UPDRS, quantified the response to a backward pull on the shoulders. (2) Tinneti's performance-oriented assessment of mobility was used as basic, general measures of balance and gait.[9] (3) Functional mobility was also assessed by timing subjects as they stood from a seated position, walked 3 minutes, turned around, and returned to the starting position as quickly as possible, a modified Timed Up and Go test.[10] (4) Mean stride time (the average of the gait cycle duration), the percent swing time, and the coefficient of variation of these parameters were quantified over a 2-minute walk.[11,12] (5) A short-term fractal scaling index of gait, a measure that has been shown to be sensitive to subtle locomotor changes in maturation, aging, and neurodegenerative disease,[13–15] was also quantified (scaling range 4 to 10 strides).* Poor performance on these tests (e.g., increased gait variability and increased Up and Go times) has been associated with increased fall risk in older adults.[10–12]

Results are reported as mean ± SD. For categorical data, subjects with and without hypertension were compared using Fisher's exact test. For continuous data, the Wilcoxon rank-sum test was used to compare the 2 groups. Spearman's correlation coefficient was used to evaluate the association among measures. A p value ≤ 0.05 (2-tailed) was considered statistically significant. Statistical analysis was performed using SPSS for Windows (version 10.1, SPSS Inc., Chicago, Illinois).

Twenty-four community-living older adults met the inclusion and exclusion criteria. Subjects were equally divided into those who reported a history of hypertension and were taking medications for hypertension (n = 12) and those who were normotensive (n = 12). The 2 subject groups were similar with respect to age, gender, height, weight, cognitive function, mental health, motor scores, and lower extremity muscle strength (Table 1). All subjects reported no falls in the past month and only 3 subjects reported 1 fall in the past year (2 normotensives and 1 hypertensive). Both groups of subjects were functionally independent and relatively healthy. For all subjects, there was no impairment of proprioception or sensation, and UPDRS motor scores were close to 0 (no extrapyramidal impairment). For all subjects in both groups, the score on the ADL index was maximal, indicating intact ability to perform activities of daily living. Both groups of subjects had low scores on the Charlson Comorbidity Index and were taking few medications. Systolic supine and standing BP tended to be higher and heart rate tended to be lower in subjects with hypertension.

For both subject groups, balance and gait were generally good (Table 2). For example, all subjects in both groups had high scores on the performance-oriented assessment of mobility. Nonetheless, there were small, but significant group differences in certain balance and gait measures (Table 2), with normotensives consistently performing better. Stride-to-stride variability of swing time was reduced (more stable),

Up and Go times were shorter (better performance), the fractal scaling index of gait was higher (more fractal, less random), and postural control was better in normotensives.

There was a small, but significant, association between some of the balance and gait measures, which were different in the 2 groups, and measures of BP and heart rate. Increased BP was associated with worse performance according to these measures of balance and gait. For example, standing systolic BP was correlated with Up and Go times ($r = 0.48$; $p = 0.018$) and the fractal index of gait ($r = -0.45$; $p = 0.027$). Conversely, higher standing heart rates tended to be positively associated with better performance according to these measures of balance and gait (e.g., fractal index vs standing systolic BP: $r = 0.44$; $p = 0.033$).

Among subjects with hypertension, 5 were taking 1 medication for hypertension, and 7 were taking 2 medications. There were no significant differences in any of the balance and gait parameters when these subjects were stratified by number of hypertension medications. Subjects were taking diuretics ($n = 3$), β blockers ($n = 1$), angiotensin II receptor antagonists ($n = 1$), calcium channel blockers ($n = 7$), and angiotensin-converting enzyme inhibitors ($n = 6$). Among subjects with hypertension, Up and Go times were significantly longer ($p < 0.026$) in those taking angiotensin-converting enzyme inhibitors than in those who were not. No other medication-related differences in balance or gait were observed.

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The present findings expand our knowledge about the reciprocal relation between cardiovascular health and physical function. Here we observe that increased BP may negatively impact balance and gait, important markers and mediators of physical function and fall risk. Although some investigators have suggested that transient BP changes predispose to falls, our findings indicate that the effects of hypertension on balance and gait are chronic and continuous. In a group of relatively healthy older adults, we found that performance on balance and gait tests are significantly reduced in older adults with hypertension.

For all study participants, gait and balance were generally intact. For example, gait speed, which was similar in both groups of study subjects, was relatively high in this age group. Gait speed in a group of similarly aged healthy adults free of musculoskeletal, neurologic, or cardiac disease was reported as 0.82 ± 0.02 m/s (see Table 2).[16] Scores on Tinetti's Balance and Gait scales, a test widely used to assess fall risk, were also very high. The findings of altered gait and balance reflect relatively subtle changes in locomotor function among these older adults with "treated" hypertension. It would be informative to study gait and balance in untreated hypertensives (could isolate medication effects), and to determine if the subtle alterations observed in the present study become more severe over time, interfering with functional abilities and exacerbating fall risk.

Compliance with proper usage of BP medications is a well-known problem that is further compounded among older adults. In the present study, we did not control for proper use of BP medications, and it is difficult to know if persons who were taking their medications as prescribed did better than others. If the level of measured BP reflects compliance, than associations between BP and gait would indicate that balance and gait were most affected in those who were least compliant. Either way, these associations suggest that the greater the level of systolic BP, the greater the degree of balance and gait impairment. The association of systolic BP with balance and gait and the lack of an association with diastolic BP are consistent with other studies that have demonstrated the greater importance of systolic function in older adults.

In summary, the present findings suggest the presence of alterations in the balance and gait performance of relatively healthy, older adults with systemic hypertension compared with age-matched controls. Apparently, increased BP not only leads to cardiovascular disease, but also impacts balance, gait, and fall risk, which are important mediators of the quality of life and independence of older adults.

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