Hypertension, Orthostatic Hypotension, and the Risk of Falls in a Community-Dwelling Elderly Population: The Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston Study

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OBJECTIVES: To investigate the relationships between uncontrolled and controlled hypertension, orthostatic hypotension (OH), and falls in participants of the Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston Study (N = 722, mean age 78.1).

DESIGN: Prospective population-based study.

SETTING: Community.

PARTICIPANTS: Seven hundred twenty-two adults aged 70 and older living within a 5-mile radius of the study headquarters at Hebrew Rehabilitation Center in Boston.

MEASUREMENTS: Blood pressure (BP) was measured at baseline in the supine position and after 1 and 3 minutes of standing. Systolic OH (SOH) and diastolic OH at 1 and 3 minutes were defined as a 20-mmHg decline in systolic BP and a 10-mmHg decline in diastolic BP upon standing. Hypertension was defined as BP of 140/90 mmHg or greater or receiving antihypertensive medications (controlled if BP < 140/90 mmHg and uncontrolled if ≥140/90 mmHg). Falls data were prospectively collected using monthly calendars. Fallers were defined as those with at least two falls within 1 year of follow-up.

RESULTS: OH was highest in participants with uncontrolled hypertension; SOH at 1 minute was 19% in participants with uncontrolled hypertension, 5% in those with controlled hypertension, and 2% in those without hypertension ($P \leq .001$)). Participants with SOH at 1 minute and uncontrolled hypertension were at greater risk of falls (hazard ratio = 2.5, 95% confidence interval = 1.3–5.0) than those with uncontrolled hypertension without OH. OH by itself was not associated with falls.

CONCLUSION: Older adults with uncontrolled hypertension and SOH at 1 minute are at greater risk for falling within 1 year. Hypertension control, with or without OH, is not associated with greater risk of falls in older community-dwelling adults. **J Am Geriatr Soc 59:383–389, 2011.**

Key words: hypertension; orthostatic hypotension; falls; elderly

Falls are a leading cause of disability in the older population.[1,2] Orthostatic hypotension (OH) is commonly thought to increase the risk of falls, especially in nursing home residents.[3] Previous data exist regarding the timing of changes in blood pressure (BP) while standing in nursing home residents.[4] In older community-dwelling adults, this association is not clear.[5–8] The relationship between hypertension, which itself increases the risk of OH,[9] and falls is also not clear. There is a conventional belief that lowering and controlling BP with antihypertensive medications may exacerbate OH and increase falling in older adults, but existing data do not support this perspective. For example, analysis of the National Health and Nutrition Examination Survey study has shown that the prevalence of OH in people with controlled hypertension is lower than in those with uncontrolled hypertension.[10] Moreover, the association between hypertension, controlled or uncontrolled, and falls has not been investigated previously.

Another reason for the conflicting data in the literature about the relationship between OH and falls is the lack of a data-driven definition of OH as it relates to falls. Several studies have suggested that a decrease in 20 mmHg or more in systolic BP (SBP) or a decrease of 10 mmHg or more in diastolic BP (DBP) after standing for 3 minutes (after rising

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DOI: 10.1111/j.1532-5415.2011.03317.x

0002-8614/11/$15.00

from a supine position) is associated with falls.[5,6] Other studies have shown no relationship between OH and falls using the same definition.[11–13] Because the decline in BP upon standing may occur before 3 minutes, an earlier measurement may more accurately indicate the association between OH and falls, but this association has not been investigated before. To address this gap in knowledge, various definitions of OH (systolic (SOH) or diastolic OH after 1 and 3 minutes of standing) were compared for their association with the risk of falls.

It was hypothesized that the risk of falls would be highest in people with uncontrolled hypertension and in those with OH. Therefore, the objective of this study was to assess the association between hypertension, OH using multiple definitions, and their combination and the risk of recurrent falls in a community-dwelling elderly population.

METHODS

Study Design

The Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston (MOBILIZE Boston Study) is a prospective, population-based study designed to examine novel risk factors for falls in older adults.[14] The Hebrew Rehabilitation Center institutional review board approved the study, and all participants provided written informed consent.

Participant Identification

Adults aged 70 and older living within a 5-mile radius of the study headquarters at Hebrew Rehabilitation Center in Boston were identified using simple random sampling from town lists.[15] Potential participants were notified of the study by mail and then approached at home by recruitment staff. The study design and recruitment procedures have been previously described.[14,15]

Inclusion and Exclusion Criteria

The inclusion criteria were aged 70 and older, ability to understand and communicate in English, ability to walk 20 feet without personal assistance (walking aids permitted), sufficient vision to read written material, and the expectation that the person would be living in the area for at least 3 years.[14] Participants with follow-up of less than 6 months were excluded from the analysis. Older adults with terminal illness, severe vision or hearing deficits, or cognitive impairment (Mini-Mental State Examination score <18) were excluded.

Once recruited, participants underwent a two-part baseline assessment including a 3-hour in-home interview followed within 4 weeks by a 3-hour in-clinic examination. The in-home interview included medical history, fall and syncope history, cognition, medications, and sociodemographic information. The in-clinic appointment included tests for mobility performance, balance, muscle strength, and postural BP.

BP Measurement Procedure

Staff were trained in appropriate BP measurement techniques and potential sources of error (e.g., expectation bias, terminal digit preference, auscultatory gap, pseudohypertension, and cardiac arrhythmias). Standardized techniques including trained staff in BP measurement, participant resting for 5 minutes, correct cuff size use, and checking for auscultatory gaps were used to reduce measurement errors. Two supine SBP and DBP measurements were obtained, separated by 2 minutes, after the participant had been recumbent for at least 5 minutes, using a standard sphygmomanometer. The means of the two supine SBP and DBP readings were used in the analysis. SBP and DBP measurements were repeated 1 and 3 minutes after standing, with the cuff kept at heart level. Measurements were obtained at least 2 hours after breakfast or lunch.

Participants were classified into one of three groups: nonhypertensive if BP was less than 140/90 mmHg and there was no history of hypertension or receipt of antihypertensive medications; controlled hypertensive if BP was less than 140/90 mmHg and there was a history of hypertension or receiving antihypertensives; and uncontrolled hypertensive if BP was 140/90 mmHg or greater. In addition to the standard OH definition of a decline of at least 20 mmHg in SBP or at least 10 mmHg in DBP after 3 minutes of standing,[16] SOH was defined at 1 or 3 minutes if SBP dropped 20 mmHg or more 1 or 3 minutes after standing from a supine position, respectively, and diastolic OH at 1 or 3 minutes if DBP dropped 10 mmHg or more 1 or 3 minutes after standing from supine position, respectively.

Falls Ascertainment

During the home visit, participants were instructed to complete the monthly falls calendar on a postage-paid folding postcard and return it to the study center at the end of each month. Based on the approach described previously,[17] participants were instructed to mark an "F" for each day that a fall occurred and an "N" for each day that no fall occurred. Data were collected prospectively on all participants over the year after the baseline assessment. A fall event was defined as unintentionally coming to rest on the ground or other lower level not as a result of a major intrinsic event (e.g., myocardial infarction or stroke) or an overwhelming external hazard (e.g., hit by a vehicle).[18] A committee of geriatricians and investigators adjudicated all falls. Fallers were defined as participants who sustained at least two adjudicated falls over the year from baseline. Two falls were used rather than just one because multiple falls are more likely to be associated with underlying pathology, whereas a single fall may be a random event.

Data Analysis

The follow-up time was truncated at 1 year, so the range of follow-up time was 183 to 365 days. Fallers were censored at the time of the second fall. Nonfallers were censored 1 year after baseline or at the time of their death or loss to follow-up.

The characteristics of the hypertension groups (nonhypertensives, controlled hypertensives, and uncontrolled hypertensives) and of those with and without OH were compared using chi-square for bivariate variables, Fisher exact tests for categorical variables, and Wilcoxon rank sum for continuous variables.

Participants with OH were compared with those without OH and those with normotension and controlled and uncontrolled hypertension in their risk of falls. Stratified

analysis was also performed according to hypertension status (controlled and uncontrolled) to examine whether the combination of OH and controlled or uncontrolled hypertension may be associated with fall risk. Kaplan-Meier curves and multivariate Cox proportional hazard modeling were used to assess the risk of falls in participants with OH stratified according to hypertension status (controlled and uncontrolled). Models and Kaplan-Meier curves were adjusted for potential confounders of the relationship between OH and falls, including age, sex, race, education, stroke, diabetes mellitus, receiving hypertension medication, Mini-Mental State Examination, hematocrit, and benzodiazepines.

The assumption of proportional hazards was tested for each individual variable in the multivariate Cox models.[19] No variable violated the proportional hazards assumption. An alpha level of 0.05 was used to determine statistical significance. SAS version 9 (SAS Institute, Inc., Cary, NC) was used for all analyses.

RESULTS

Of the 765 participants enrolled in the MOBILIZE Boston Study, 722 had at least 6 months of follow-up. The median follow-up time was 352 days (range 183–365 days) for participants without hypertension, was 330 days (range 207–365 days) for those with controlled hypertension, and 365 days (range 203–365 days) for those with uncontrolled hypertension. Of the 722 participants, 153 (21%) did not have hypertension, 383 (53%) had controlled hypertension, and 186 (26%) had uncontrolled hypertension. Table 1 provides characteristics of the three groups. The number of participants with OH differed according to the criterion used: 42 (6%) based on the standard definition of a drop in SBP or DBP, 59 (8%) based on systolic drop at 1 minute and 26 (4%) at 3 minutes, and 29 (4%) based on diastolic drop at 1 minute and 20 (3%) at 3 minutes. Table 2 provides the baseline characteristics and demographic data of participants with and without SOH at 1 minute.

Prevalence of SOH at 1 minute was significantly higher in the group with uncontrolled hypertension (19%) than in the other two groups (2% in those without hypertension and 5% in those with controlled hypertension, $P \leq .001$; Table 1).

There was no difference in number of fallers between the hypertension groups (Table 1) or between those with and without OH according to any definition (Table 2). There was no association between OH and falls using the standard criteria in any of the hypertension groups (uncontrolled, $P = .40$; controlled, $P = .38$). There were too few participants with falls and OH in the group without hypertension to be able to conduct further analysis in this group.

In the stratified analysis, participants with SOH at 1 minute and uncontrolled hypertension had a greater risk of falls. Of participants with uncontrolled hypertension, 39% reported more than one fall within the 1-year follow-up if they had SOH at 1 minute, versus 17% in participants without OH. Of participants with controlled hypertension, 20% reported falling more than once within the 1 year follow-up if they had systolic OH at 1 minute, versus 22% in participants without OH.

After adjusting for covariates, participants with uncontrolled hypertension and SOH at 1 minute had a significantly greater risk of falls than those with uncontrolled hypertension without OH (Table 3). The hazard ratio (HR) for recurrent falls in participants with uncontrolled hypertension with OH was 2.5 (95% confidence interval (CI) = 1.3–5.0). In contrast, OH was not associated with recurrent fall risk in those with controlled hypertension (HR = 0.6, 95% CI = 0.25–1.86). Although the HR was similar (2.4) in those with controlled hypertension and OH at 3 minutes and those with uncontrolled hypertension and OH at 1 minute, the CI (0.6–10.9) was wide, and the effect on falls was not statistically significant because of the small number of people (5/383) with this finding .

Kaplan-Meier curves for the risk of falls are shown in participants with and without SOH at 1 minute in those with controlled (Figure 1) and uncontrolled (Figure 2) hypertension.

DISCUSSION

This study demonstrates the risk of falls is nearly 2.5 times higer in people with combined SOH at 1 minute and uncontrolled hypertension as those with controlled hypertension without SOH. In addition, SOH at 1 minute is most prevalent in people with uncontrolled hypertension. In contrast to prior studies, these data suggest that a systolic drop of 20 mmHg after 1 minute, if combined with uncontrolled hypertension, creates a greater risk of falling than SOH at 3 minutes of standing, which is the standard criterion.

In a prospective study of an older community-dwelling population, lower standing SBP even within the normotensive range was found to be an independent risk factor for falls.[20] Another study found that OH was a risk factor for recurrent falls in the nursing home population,[3] although a third study found that OH was not useful for determining risk for falls during the subsequent year.[21] Therefore, clinicians often wonder whether older adults should be screened for OH.[22] Part of the reason for these conflicting results is that none of the prior studies have taken into account that OH is highly associated with hypertension. Therefore, not considering hypertension status (controlled vs uncontrolled) may lead to overlooking the true relationship between OH and falls. The current study indicates that patients with uncontrolled hypertension and a drop in SBP upon standing are at greater risk of falls than in those with controlled hypertension with or without SOH, which suggests that OH should be a part of evaluating older adults with hypertension, especially if their BP is poorly controlled.

The physiological mechanisms for the association between combined high BP, OH, and falls are not clear. Aging and hypertension are associated with a decrease in baroreflex-mediated cardio-acceleration and vasoconstriction, impaired renal salt and water conservation, and slow cardiac filling, which greatly increase the risk of OH in older adults.[23] Acute orthostatic drops in BP in people with hypertension may lead to transient cerebral ischemia from diminished blood flow to the brain, which may exacerbate a chronic decrease in cerebral blood flow and subsequently lead to falls.[24]

In this study, SOH at 1 minute was associated with a greater risk of recurrent falls in participants with uncontrolled hypertension than in those with controlled

Table 1. Baseline Characteristics According to Hypertension Status in the Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston Study

Characteristics	No Hypertension (n = 153)	Controlled Hypertension (n = 383)	Uncontrolled Hypertension (n = 186)	*P*-Value
Age, mean ± SD	77 ± 5	78 ± 5	79 ± 6	<.001
Nonwhite, n (%)	18 (12)	89 (23)	54 (29)	<.001
Female, n (%)	106 (69)	225 (59)	131 (70)	.01
>High school education, n (%)	117 (76)	264 (69)	11 (54)	<.001
Receiving antihypertensive medication, n (%)	NA	361 (94)	142 (76)	<.001
≥2 falls, n (%)	39 (25)	82 (21)	40 (21)	.57
Body mass index, kg/m^2, mean ± SD	26 ± 4	28 ± 5	28 ± 5	<.001
Stroke, n (%)	5 (3)	43 (11)	20 (11)	.01
Diabetes mellitus, n (%)	9 (6)	58 (16)	34 (19)	<.01
History of previous falls, n (%)	64 (42)	149 (39)	58 (31)	.09
Angiotensin-converting enzyme inhibitors, n (%)	0	126 (33)	69 (37)	<.001
Angiotensin receptor blockers, n (%)	0	126 (33)	69 (37)	<.001
Benzodiazepines, n (%)	14 (9)	36 (9)	18 (9.7)	.99
Hematocrit, mean ± SD	40.7 ± 3.7	39.8 ± 4.1	39.1 ± 3.9	<.01
Mini-Mental State Examination score, mean ± SD	27.8 ± 2.1	27.1 ± 2.7	26.4 ± 2.9	<.001
Supine diastolic BP, mean ± SD	70 ± 8	67 ± 8	76 ± 9	<.001
Supine systolic BP, mean ± SD	122 ± 11	122 ± 11	154 ± 15	<.001
Systolic BP drop ≥20 mmHg, n (%)				
After 1 minute	3 (2)	20 (5)	36 (19)	<.001
After 3 minutes	1 (1)	5 (1)	20 (11)	<.001
Diastolic BP drop ≥10 mmHg, n (%)				
After 1 minute	5 (3)	11 (3)	13 (7)	.07
After 3 minutes	3 (2)	4 (1)	13 (7)	<.001
Pulse, mean ± SD				
Supine	68 ± 8	66 ± 9	65 ± 8	.006
Standing after 1 minute, mean ± SD	72 ± 10	69 ± 10	68 ± 9	.001
Standing after 3 minutes, mean ± SD	72 ± 9	68 ± 9	68 ± 9	<.001

SD = standard deviation; BP = blood pressure.

hypertension with or without SOH. These participants had a wider pulse pressure than the other groups, suggesting they had greater vascular stiffness. Older adults with ventricular vascular stiffening may be at greater risk of OH because of greater dependency on preload to maintain adequate cardiac output.[25] Therefore, greater reductions in preload after 1 minute than after 3 minutes of standing could have greater physiological consequences in people with uncontrolled hypertension. Previous studies have shown that controlling hypertension to less than 140/90 mmHg is associated with lower cardiovascular mortality and morbidity in older adults.[26] Nevertheless, many physicians are reluctant to reduce BP to these levels or lower in elderly patients for fear of precipitating OH and falls or syncope. One study found that reducing BP by treating hypertension in older adults decreased the prevalence of OH.[27] Moreover, it has been shown that the treatment of hypertension in older adults, using an angiotensin-converting enzyme inhibitor–based regimen, improves cerebral blood flow.[28] The current study suggests that people with controlled hypertension, even if treated, are not at greater risk of falls even if they have OH, supporting the idea that controlling hypertension in older adults may not be associated with greater falling risk. This study is the first to investigate concurrently the role of hypertension and OH and demonstrate that older adults with uncontrolled hypertension and OH are at greater risk for recurrent falls.

Although guidelines[16] suggest that OH should be defined as a systolic decline of 20 mmHg or greater or diastolic decline of 10 mmHg or greater after 3 minutes of standing, the data from the current study suggest that a systolic decline of 20 mmHg or greater after 1 minute of standing is more sensitive in signaling greater risk of falls in older adults with uncontrolled hypertension.

Although it was found that OH in individuals with controlled hypertension is not associated with falls, lowering BP in special instances, such as in people with autonomic failure or those who cannot tolerate lower BP levels, should be carefully monitored whenever treatment to lower BP is considered.

Limitations to this study include recall bias for falls. The use of fall calendars has been shown to minimize the effect of recall bias, and the staff's close contact with the participants may have lowered this bias even further.[15]

Table 2. Characteristics of Study Population According to Systolic Orthostatic Hypotension* (SOH)

Characteristics	No SOH (n = 663)	SOH (n = 59)	*P*-Value
Age, mean ± SD	78 ± 5	78 ± 6	.98
Nonwhite, n (%)	148 (22)	13 (22)	.95
Female, n (%)	423 (64)	39 (66.1)	.74
>High school education, n (%)	447 (67.5)	35 (59.3)	.2
Receiving antihypertensive medication, n (%)	456 (69)	47 (80)	.08
≥2 falls, n (%)	182 (28)	21 (36)	.18
Body mass index, kg/m^2 mean ± SD	28 ± 5	27 ± 5	.64
Stroke, n (%)	182 (28)	21 (36)	.24
Diabetes mellitus, n (%)	93 (15)	8 (14)	.41
Angiotensin-converting enzyme inhibitors, n (%)	175 (26.7)	20 (34.5)	.20
Angiotensin receptor blockers, n (%)	175 (26.7)	20 (34.5)	.20
Benzodiazepine, n (%)	58 (8.8)	10 (17.2)	.04
Diuretic, n (%)	243 (37	23 (39.7)	.69
Alpha blocker, n (%)	48 (7.3)	8 (13.8)	.08
Beta-blocker, n (%)	265 (40.4)	29 (50)	.15
Analgesic, n (%)	500 (76.2)	44 (75.9)	.95
Hematocrit, mean ± SD	39.8 ± 4.0	39.6 ± 3.3	.71
Mini-Mental State Examination score, mean ± SD	27.1 ± 2.7	27.1 ± 2.6	.96
Supine diastolic BP, mean ± SD	129.1 ± 18	144.8 ± 21	<.001
Supine systolic BP, mean ± SD	70 ± 87	72 ± 8	.20
Normotension, n (%)	150 (23)	3 (5)	<.001
Controlled hypertension	363 (54)	20 (34)	<.001
Uncontrolled hypertension	150 (23)	36 (61)	<.001

* Systolic blood pressure ≥20 mmHg at 1 minute.
SD = standard deviation.

Another limitation is that standing BP was not measured beyond 3 minutes. OH prevalence decreased from the 1- to the 3-minute measurement, suggesting that a small number of individuals might have OH at beyond 3 minutes. BP was measured only at baseline during the study. It is possible that additional people with OH may have been missed because the prevalence of OH may vary throughout the day or those who developed OH beyond the baseline assessment. The findings are also limited to older community-dwelling adults, the majority of whom were Caucasian, and the data should be interpreted in context of the study design. BP medications may have been used for indications other than

Table 3. Cox Proportional Hazards Model for the Association Between Orthostatic Hypotension After Standing for 1 or 3 Minutes and Being a Faller in Subjects with Controlled and Uncontrolled Hypertension

	Hazard Ratio* (95% Confidence Interval)	
Predictor	Controlled Hypertension	Uncontrolled Hypertension
Drop in SBP ≥20 mmHg after 1 minute standing	0.68 (0.25–1.86)	2.54 (1.27–5.09)
Drop in SBP ≥20 mmHg after 3 minute standing	2.55 (0.60–10.9)	1.26 (0.47–3.3)
Drop in DBP ≥10 mmHg after 1 minute standing	0.25 (0.04–1.84)	0.36 (0.04–3.0)
Drop in DBP ≥10 mmHg after 3 minute standing	1.22 (0.16–9.17)	0.71 (0.17–2.9)

*Models were adjusted for age, sex, race, education, stroke, diabetes, receiving hypertension medication, Mini Mental State Examination score, hematocrit, and benzodiazepines.
SBP = systolic blood pressure; DBP = diastolic blood pressure.

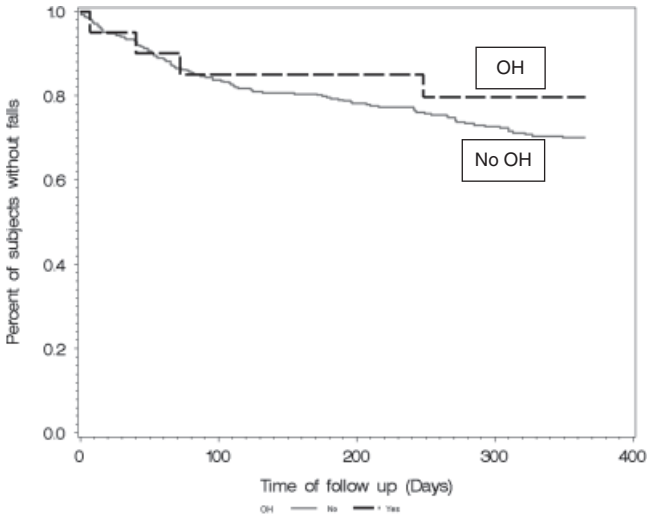

Figure 1. Kaplan-Meier curve (adjusted for potential confounders) for falls rates (≥2) in participants with and without orthostatic hypotension (OH) in the group with controlled hypertension (no difference between OH and no OH, $P = .43$).

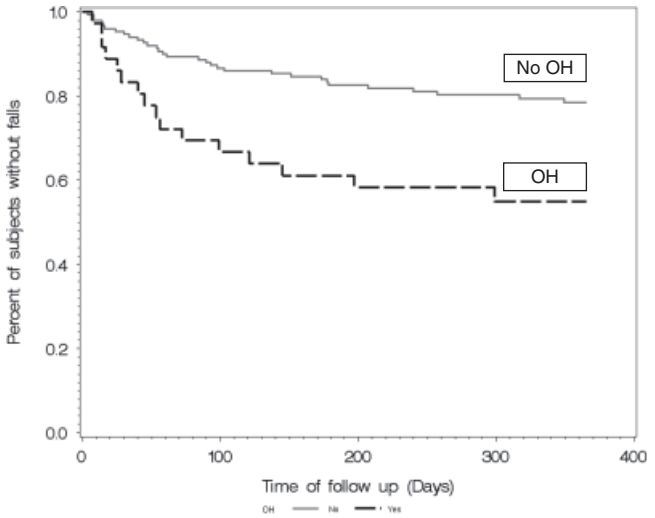

Figure 2. Kaplan-Meier curve (adjusted for potential confounders) for falls rates (≥2) in participants with and without orthostatic hypotension (OH) within the group with controlled hypertension (difference between OH and no OH is significant, $P < .001$).

BP control; this information was not available for the study. Nevertheless, even if the medications were prescribed for other reasons, they would lower BP and hence may not change the overall outcome of the study. Another limitation of the study includes the lack of availability of information and analyses regarding medication changes during the follow-up period. Change in medications can theoretically be related to greater fall risk. The low prevalence of SOH in patients with no hypertension or controlled hypertension is important and confirms prior studies showing that OH is more prevalent with higher levels of BP, but this low prevalence limits power to make robust conclusions about falls risk in these groups.

Finally, it is possible there is a bias toward less-aggressive hypertension control in people at risk of falling and those with OH. This may lead to a higher percentage of fallers in people with OH and uncontrolled hypertension. No difference in falling was seen according to hypertension control status or OH.

CONCLUSIONS

The prevalence of OH is higher in older community-dwelling adults with uncontrolled hypertension than in those with controlled hypertension. The risk of recurrent falls is 2.5 times higher in older community-dwelling adults with OH 1 minute after standing and uncontrolled hypertension than in those with uncontrolled hypertension and no OH.

Implications

Orthostatic BP, especially after 1 minute of standing, may be helpful for the identification of falls risk in older adults with hypertension. Those with uncontrolled hypertension and a SBP drop of 20 mmHg or greater after 1 minute of standing should be targeted for fall prevention programs. Although lowering BP in older adults with hypertension should be performed cautiously, this study suggests that those with controlled hypertension are not at greater risk of OH or falls. These conclusions need to be confirmed in a clinical trial setting.

ACKNOWLEDGMENTS

The authors acknowledge the MOBILIZE Boston research team and the study participants for the contribution of their time, effort, and dedication.

Conflict of Interest: This work was supported by a Research Fellowship Grant from the Hartford Center of Excellence in Geriatric Medicine and the Geriatric Academic Career Award (K01HP20501-01-00) at Harvard Medical School to Anupama Gangavati. MOBILIZE Boston is supported by Grant AG004390 from the National Institute on Aging (NIA). Dr. Hajjar is supported by Grant K23AG30057 from the NIA. Dr. Lipsitz holds the Irving and Edyth S. Usen Chair in Geriatric Medicine at Hebrew SeniorLife. He was also supported by Grants AG004390, AG08812, AG025037, and AG005134 from the NIA.

Author Contributions: Anupama S. Gangavati: study concept and design; acquisition, analysis, and interpretation of the data; manuscript preparation. Ihab Hajjar and Dan K. Kiely: study concept and design, data interpretation, manuscript development. Lien Quach and Richard Jones: analysis (design and performance) and interpretation of data, manuscript development. Peggy Gagnon: data interpretation and manuscript development. Lewis A. Lipsitz: study concept and design, interpretation of data, manuscript writing.

Sponsor's Role: None.

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