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Intraindividual Reproducibility of Postprandial and Orthostatic Blood Pressure Changes in Older Nursing-Home Patients: Relationship with Chronic Use of Cardiovascular Medications

René W.M.M. Jansen, MD, PhD,*†§ Margaret M. Kelley-Gagnon, RN,* and Lewis A. Lipsitz, MD*‡

OBJECTIVES: Although postprandial and orthostatic hypotension are commonly observed in nursing home residents, their reproducibility, relationship to each other, and association with chronic use of cardiovascular medications are poorly understood.

DESIGN: We examined blood pressure (BP) and heart rate (HR) before and after postural change, and before and after a 419-kcal meal in 22 nursing home residents (mean age 89 ± 5 [SD] years), each on two occasions, to determine reproducibility of changes. These studies were repeated in 17 residents, with and without previous administration of cardiovascular medications, in random order.

SETTING: Hebrew Rehabilitation Center for the Aged, an academic long-term care facility.

RESULTS: Systolic BP declined an average (± SE) of 16 ± 4 mm Hg and 12 ± 4 mm Hg during the first and second meal studies, respectively. Mean intra-class correlation of post-prandial systolic BP values during the two studies was 0.88 (95% CI 0.85–0.97). Systolic BP increased significantly during the first posture test to a maximum of 8 ± 6 mm Hg at 6 minutes. There was no significant difference over time in postural systolic BP between the two tests. Repeated postural studies showed a mean intra-class correlation of 0.72 (95% CI 0.62–0.92) for changes in systolic BP. Cardiovascular medications had no additional effect on mean postprandial or orthostatic BP and HR changes. During the first studies, 10 subjects had postprandial hypotension, and three subjects had orthostatic hypotension, but only two of 22 subjects had both.

CONCLUSIONS: Patterns of systolic BP response to meals or postural change are reproducible. BP responses to meals and postural change seem to be unaffected by potentially hypotensive medications in chronic users. Postprandial hypotension is distinct from orthostatic hypotension, occurring more commonly than orthostatic hypotension and frequently together in the same patients. J Am Geriatr Soc 44:383–389, 1996.

Postprandial and orthostatic hypotension are common disorders of blood pressure (BP) regulation in older persons, especially in nursing home residents.¹⁻⁶ Investigations of older people living in a nursing homes have shown that nearly all residents experience a decline in systolic BP of 10 to 20 mm Hg.³ Twenty-four to 36 percent of these patients have a fall in systolic BP of more than 20 mm Hg within 75 minutes of eating a meal.³⁻⁵ Both postprandial and orthostatic hypotension are associated with the development of falls and syncope.²⁻⁴⁻⁷ Some studies report that older persons who suffer from postprandial hypotension frequently also have orthostatic hypotension.⁴⁻⁸ Attempts to determine the etiology of these conditions in the clinical setting are often confounded by their potential relationship to each other and likely association with medications. For example, a decline in BP in an older person after a meal may be attributable to postprandial hypotension, orthostatic hypotension in response to prolonged sitting or standing up following the meal, or cardiovascular medications taken before the meal. Furthermore, the effect of an intervention to correct postprandial hypotension, such as medication adjustments, may be misinterpreted, depending on the day-to-day variability of BP response.

The purpose of this investigation is threefold: (1) To determine the reproducibility of postprandial and orthostatic hypotension; (2) to examine the relationship of these conditions to each other; and (3) to determine the effect of chronic use of cardiovascular medications on postural- and meal-related BP responses in older nursing home residents.

METHODS

Twenty-five older nursing home residents (7 males and 18 females) were recruited from the Hebrew Rehabilitation Center for the Aged, an academic long-term care facility. Ages ranged from 79 to 97, with a mean of 89 ± 5 (SD) years.
Extensive clinical information about medications, diseases, and electrocardiographic abnormalities was obtained for all subjects by a careful review of their medical records. Subjects were excluded from the study if they were unable or unwilling to follow the study protocol. The subjects had to be in sinus rhythm at the time of the study. They also had to be able to stand from the supine position within 30 seconds and remain standing for 10 minutes. Other exclusion criteria were the presence of a pacemaker and of insulin-dependent diabetes mellitus. Three subjects dropped out: two were unable to complete the protocol, and one became ill.

Disease history of the subjects is summarized in Table 1. Twenty-two subjects took part in the postural and meal reproducibility study. Seventeen subjects were using chronic cardiovascular medications and participated in the medication study. The cardiovascular medications are listed in Table 2. The study was approved by the Institutional Review Board of the Hebrew Rehabilitation Center for Aged. All subjects provided written informed consent.

Postprandial hypotension was defined as a decline in systolic BP of 20 mm Hg or more within the 90-minute-study period. Orthostatic hypotension was defined as a decline in systolic BP of 20 mm Hg or more during the first and/or third minute after assuming the upright position.

Test-retest reproducibility of postural and postprandial BP and heart rate (HR) changes was assessed in 22 subjects who underwent the same protocol on two occasions, at least 3 days and less than 2 weeks apart. The studies began at 7:00 am in the patient's own familiar room after an overnight fast from midnight the night before. Precautions were taken to keep the surroundings quiet during the study. If subjects were taking chronic medications, those routinely given two to four times daily were withheld for 24 hours before the study, and those given once daily were withheld for 24 hours before the study. BP and HR recordings were measured at intervals throughout the study by a Dinamap automated oscillometric device (Critikon, Tampa, FL). The mean arterial pressure used in this study represents the mean arterial pressure as it was measured by the Dinamap device.

After a supine rest for 30 minutes the subjects stood for 10 minutes. During the supine rest, BP and HR were measured at 5-minute intervals and three BP and HR measurements at -10, -5, and 0 minutes before the upright position were averaged and considered the baseline value. Then, BP and HR were measured at 1, 3, 6, 9, and 10 minutes after assuming the standing position.

After the subjects were allowed to use the bathroom, they resumed the supine position for 20 minutes. Subjects then sat for 10 minutes to ingest a liquid 419-kcal meal (Carnation Instant Breakfast in lactose-free whole milk) containing 78.3 g carbohydrate, 2.8 g fat, and 20.6 g protein. The amount of carbohydrates in this meal was similar to that shown previously to produce hypotension in older people. The meal was served at a temperature of 22°C to avoid potential temperature effects on BP and was ingested within 10 minutes.

After the meal, subjects resumed the supine position for the duration of the study. BP and HR were recorded at 5-minute intervals while subjects were supine. Three BP and HR measurements at -10, -5, and 0 minutes before the meal were averaged and considered the baseline value. This value and the means of the three values around the 15-, 30-, 45-, 60-, 75-, and 90-minute time points were used in the analyses.

To examine the effects of chronic cardiovascular medication use on postural and postprandial BP and HR changes, 17 patients using one or more of these drugs were selected from the group of 25 subjects. The same protocol was followed on two occasions; however, on one occasion 30 minutes before the start of the study, their usual medications were administered with 100 mL of water. Medications or no drugs were given in a random order. No change in chronic medication use was made during the study.

Data Analysis

Two-way repeated measures analysis of variance was used to examine the effects of time and test (and their interaction) on changes in systolic BP, diastolic BP, mean arterial pressure, and HR during posture and meal studies. When an overall time effect was found, the standing and postmeal measures were each compared individually with baseline using paired Student's t test when appropriate; otherwise, Wilcoxon's signed-rank test was used. A P value of .05 was used as the criterion for determining statistical significance. Intraclass correlation coefficients were calculated by one-way analysis of variance to express reproducibility of orthostatic

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**Table 1. Summary of Disease History of 22 Subjects**

<table>
<thead>
<tr>
<th>Disease</th>
<th>No. of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary Artery Disease</td>
<td>15</td>
</tr>
<tr>
<td>Hypertension</td>
<td>13</td>
</tr>
<tr>
<td>Compensated Congestive Heart Failure</td>
<td>9</td>
</tr>
<tr>
<td>Myocardial Infarction more than 6 months earlier</td>
<td>4</td>
</tr>
<tr>
<td>Stroke more than 6 months earlier</td>
<td>4</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td></td>
</tr>
<tr>
<td>Sick Sinus Syndrome</td>
<td>1</td>
</tr>
<tr>
<td>Bundle Branch Block</td>
<td>3</td>
</tr>
<tr>
<td>Paroxysmal atrial fibrillation</td>
<td>3</td>
</tr>
<tr>
<td>Valvular Heart Disease</td>
<td></td>
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<tr>
<td>Mitral regurgitation</td>
<td>5</td>
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<tr>
<td>Mitral stenosis</td>
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</tr>
<tr>
<td>Aortic regurgitation</td>
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<tr>
<td>Aortic stenosis</td>
<td>1</td>
</tr>
<tr>
<td>Parkinson's disease</td>
<td>1</td>
</tr>
<tr>
<td>Non-insulin-dependent Diabetes mellitus</td>
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</tr>
<tr>
<td>Syncope</td>
<td>4</td>
</tr>
<tr>
<td>Dizziness</td>
<td>5</td>
</tr>
</tbody>
</table>

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**Table 2. Cardiovascular Medication use of 17 Subjects**

<table>
<thead>
<tr>
<th>Medication</th>
<th>No. of Subjects</th>
</tr>
</thead>
<tbody>
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<td>Diuretics</td>
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<tr>
<td>Angiotensin-converting enzyme inhibitors</td>
<td>6</td>
</tr>
<tr>
<td>β-Adrenergic receptor blockers</td>
<td>1</td>
</tr>
<tr>
<td>Calcium channel blockers</td>
<td>13</td>
</tr>
<tr>
<td>Nitrates</td>
<td></td>
</tr>
<tr>
<td>Oral</td>
<td>6</td>
</tr>
<tr>
<td>Transdermal</td>
<td>3</td>
</tr>
<tr>
<td>Reserpine</td>
<td>2</td>
</tr>
<tr>
<td>Digoxin</td>
<td>5</td>
</tr>
</tbody>
</table>
RESULTS

Reproducibility Study

Meal-Related Changes

The residents' mean supine systolic BP and HR responses to the meal for the first and the second test are shown in Figure 1. Mean systolic BP declined significantly after the meal, by 16 ± 4 mm Hg (P < .001) at 45 minutes during the first test and by 12 ± 4 mm Hg (P < .001) at the same time during the second test. There was a significant test difference between the two studies (P < .01); however, over time, there was no difference in the pattern of BP response between the two studies (P = .42 for test x time interaction). In both tests, mean diastolic BP declined by 8 ± 2 mm Hg (P < .001) at 45 minutes after the meal. There was only a marginal difference in diastolic BP between the two studies (P = .06), and both studies showed the same response over time (P = .98 for test x time interaction). Mean arterial pressure declined at 45 minutes after each meal, by 12 ± 3 mm Hg (P < .001) and 10 ± 2 mm Hg (P < .001), respectively. Over time, there was no difference between the tests (P = .86 for test x time interaction). HR increased to a similar extent during both sessions, by 6 ± 1 bpm (P < .001) at 90 minutes during the first test and by 8 ± 1 bpm (P < .001) during the second test. The HR response between both tests was not significantly different (P = .09 for test x time interaction).

Although the maximal mean systolic BP decline was at 45 minutes after the meal, the individual changes were variable. Individual changes in systolic BP following the meal ranged from -63 to +19 mm Hg. Eight subjects had their maximal decline during the first test at 30 minutes, six subjects at 45 minutes, two subjects at 60 minutes, four subjects at 75 minutes, and two subjects at 90 minutes after meal ingestion. The mean intra-class correlations for the test-retest reproducibility of postprandial BP changes were 0.88 (95% confidence intervals (CI) 0.85–0.97) for systolic BP and 0.88 (95% CI, 0.79–0.96) for HR. Diastolic BP and mean arterial pressure had slightly lower values of 0.78 (95% CI, 0.73–0.94) and 0.81 (95% CI, 0.78–0.96), respectively, because of greater variance at 30 minutes after the meal.

Posture-Related Changes

Mean systolic BP and HR responses to standing are shown in Figure 1. Mean systolic BP increased significantly
during the first test by a maximum of $8 \pm 6$ mm Hg at 6 minutes. During the second test there was initially a small decline in systolic BP of $-7 \pm 5$ mm Hg ($P = .14$ compared with baseline) at the first minute, followed by a rise to $8 \pm 4$ mm Hg above baseline at 6 minutes. There was no significant difference over time between the two tests. Mean diastolic BP and mean arterial pressure increased to a similar extent during both tests. Mean HR increased $10 \pm 2$ bpm ($P < .001$) by 1 minute of upright posture during both tests. There was a significant difference between the first and second test measurements of systolic BP, mean arterial pressure, and HR, with mean values during the second test consistently lower than during the first ($P < .001$). However, there were no test x time interactions for any of these variables. The mean intraclass correlation coefficients were 0.72 for systolic BP changes (95% CI, 0.62–0.92), 0.50 for diastolic BP changes (95% CI 0.32–0.82), 0.56 for mean arterial pressure changes (95% CI, 0.41–0.85), and 0.69 for HR changes (95% CI, 0.46–0.87).

Relationship Between Postprandial and Orthostatic Hypotension

Ten of the 22 patients had postprandial hypotension during the first test. The second test detected only one new subject with postprandial hypotension. Seven of these 10 subjects with postprandial hypotension also had a decline in systolic BP of 20 mm Hg or more during the second test. Three of the 22 patients had orthostatic hypotension on the first test. Six patients had orthostatic hypotension during the second test, and only two of them had orthostatic hypotension on both tests. Only two of 22 patients had both postprandial and orthostatic hypotension. Orthostatic hypotension occurred significantly less frequently than postprandial hypotension ($P < .05$).

No subject experienced any symptoms during the meal studies. Seven subjects had symptoms that included light-headedness, dizziness, and feeling weak or shaky when standing. However, these symptoms were associated with BP changes in only two persons.

Cardiovascular Medications

Seventeen subjects were chronically using a mean of 2.7 medications with potentially hypotensive effects (Table 2). Administration of these cardiovascular medications 30 minutes before the meal study did not affect the subsequent BP response (Figure 2). Baseline BP before ingestion of the meal was $167/69 \pm 7/3$ mm Hg when no medication was given, compared with $154/65 \pm 10/4$ mm Hg after administration of the medications.

![Figure 2. Mean systolic blood pressure (SBP) and heart rate (HR) before and after meal ingestion (left graphs) and after postural change (right graphs) for the 17 older patients with (dots) and without (square) prior administration of their cardiovascular medications. Each value represents mean ± SEM.](image-url)
of medication. There was a trend toward lower BP after medication administration, but this difference was not statistically significant. Baseline HR was 61 ± 2 bpm during both studies. HR response was significantly higher (P < .001) when no medication was administered before the meal (Figure 2). As shown in Table 2, one patient was using a ß-blocker (atenolol), and 13 patients were using calcium channel blockers. Without medication, HR increased a maximum of 8 ± 2 bpm (P < .001); with medication, HR increased only 4 ± 1 bpm (P < .01) after the meal.

Mean systolic BP responses to standing were significantly different between studies with and without cardiovascular medication (P < .05), but there was no significant orthostatic hypotension in either case (Figure 2). When medication was given before standing, systolic BP remained unchanged. Without medication, however, there was an initial decline in systolic BP of 8 ± 5 mmHg (P = .13 when compared with baseline) at 1 minute, followed by a rise of 10 ± 5 mmHg above baseline at 3 minutes of standing (P < .05, compared with baseline). Both diastolic BP and mean arterial pressure increased significantly after standing, with no difference between the two studies. HR increase was significantly greater after standing when medication were administered than when no medications were administered (P < .001).

When defined arbitrarily as a 20-mm Hg or greater decline in systolic BP, eight of the 17 patients had postprandial hypotension and three patients had orthostatic hypotension when cardiovascular medication was given before the study. When no medication was given, the same three patients had orthostatic hypotension, and six patients (five of the original and one new) had postprandial hypotension.

DISCUSSION

The main findings of this study are threefold: First, on average, BP and HR responses to meal ingestion are similar on repeated studies, but absolute BP values are usually lower during a second study. This is consistent with many previous studies that show lower BP with acclimation to the study protocol and may also reflect the phenomenon of regression to the mean. The diagnosis of postprandial hypotension can generally be made on a single test, but orthostatic hypotension requires repeated testing to detect this condition. Second, postprandial BP reduction is distinct from orthostatic hypotension, occurring more commonly than orthostatic hypotension, and infrequently together in the same patients. Third, chronic use of one or a combination of cardiovascular medications, administered before postural change or ingestion of a meal, does not seem to worsen orthostatic or postprandial hypotension.

To our knowledge, this is the first study to evaluate the reproducibility of meal-induced BP changes. The reproducibility of postprandial systolic BP and HR changes were excellent. Postprandial diastolic BP and mean arterial pressure changes showed good reproducibility. The interindividual responses of BP and HR to meal ingestion were highly variable. Although postprandial BP reduction usually reaches its nadir between 30 and 60 minutes, a significant number of patients will have a decline in postprandial BP as early as 15 minutes or as late as 90 minutes after the meal. The clinical implication of this variability is that postprandial BP should be followed for at least 90 minutes after the start of the meal.

The reproducibility of systolic BP and HR measurements during the 10-minute standing period was acceptable with intraclass correlations of 0.57 to 0.81. Diastolic BP and mean arterial pressure responses to standing were not as reproducible for the 10-minute period. However, during the first and third minute of standing, intraclass correlation coefficients ranged between 0.60 and 0.75. In clinical practice, these are the most practical and usually most diagnostically useful times to record postural vital signs.

A wide day-to-day variability in postural BP has been reported previously in older nursing home residents. The variability in orthostatic hypotension in that study was correlated strongly with baseline systolic BP. When subjects had a baseline systolic BP below 160 mm Hg, they tended to have postural increases in BP. The findings of the present study, in which mean systolic BP before postural change was below 160 mm Hg, are consistent with this previous study. It is notable that some of the subjects had an immediate decline in BP on standing, whereas others had gradual declines that were evident at 3 minutes or later. Taking only one BP measurement after standing may miss significant hypotension occurring before or after the measurement is obtained. Therefore, one should rely on repeated measures over time for the diagnosis of orthostatic hypotension rather than a single value only.

Because the first test of BP responses to a meal identified 10 of 11 subjects with postprandial hypotension on one or both tests, an important clinical implication of this study might be that a single test of BP responses to a meal detects almost all people with postprandial hypotension. A single test of BP response to postural change detects only three out of seven patients. In the evaluation of a patient with falls, syncope, dizziness, or cerebral ischemic symptoms, attention should be paid to the possible relationship of these symptoms to a meal or posture change. When the initial work-up does not implicate meals or posture change, these tests should be repeated at least once more.

This study shows a significantly higher number of patients with postprandial hypotension than with orthostatic hypotension. In addition, both abnormalities of BP regulation infrequently occur together in the same patient. We recently reported that 50% of older patients with unexplained syncope had postprandial hypotension, but none of them had orthostatic hypotension. Masuo et al. found in middle-aged hypertensive patients that only patients with orthostatic hypotension were prone to develop postprandial hypotension. It has been suggested that the pathophysiological characteristics of postprandial and orthostatic hypotension are similar. However, the data of the present study suggest that the pathophysiological mechanisms of postprandial and orthostatic hypotension are different in older people. Of note is that in patients with autonomic failure, orthostatic hypotension and postprandial hypotension frequently occur together. This does not necessarily occur with aging.

Older patients, and nursing home residents in particular, often have multiple comorbid conditions and take multiple medications that may have important implications in BP regulation. Indeed, a high number of subjects in this study had coronary artery disease, congestive heart failure, and hypertension. Hypertension has been associated with orthostatic and postprandial hypotension in older people. There are conflicting data about whether antihypertensive treatment exacerbates hypotension, particularly after meals. In one study it was found that older nursing home residents taking angiotensin-converting enzyme inhib-
itors, calcium channel blockers, digoxin, diuretics, and nitrites had significantly greater postprandial systolic BP reductions than residents not taking these drugs. As the number of these drugs increased, a greater decline in postprandial systolic BP was found. In contrast, another study of older hypertensive patients using diuretics, β-blockers, or a combination of diuretics and β-blockers with or without vasodilators showed postprandial BP reduction similar to that of hypertensive older people not using antihypertensive medications. In addition, other studies have shown that treatment with calcium channel blockers and diuretics ameliorates meal or glucose-induced BP reduction in older hypertensive patients and older patients with coronary heart disease.

The goal of this study was not to evaluate the individual medications in relation to postprandial and orthostatic hypotension. Rather, we addressed the issue of whether different types of potentially hypotensive medications used by the patient before standing or eating a meal would exacerbate the hypotensive effects of these activities. We can only conclude from this study that a small group of nursing-home residents using different types of medications with cardiovascular effects did not demonstrate an exacerbation of their BP decline following standing or eating a meal. Although some of the patients of the current study had postprandial hypotension with declines in systolic BP as great as 65 mm Hg, they were asymptomatic. It is currently unknown whether BP-lowering medications given before or with a meal might aggravate BP declines in patients with symptomatic postprandial hypotension.

Orthostatic hypotension has been reported to occur in 13 to 14% of older patients receiving cardiovascular medications, which is significantly higher than the prevalence of 3 to 6% observed in healthy older subjects on no medications. We did not observe an exacerbation of orthostatic hypotension in response to cardiovascular medications in older nursing home residents. In contrast, when cardiovascular medications were given, systolic BP remained stable during the postprandial systolic BP was found. In contrast, another study of older hypertensive patients using diuretics, β-blockers, or a combination of diuretics and β-blockers with or without vasodilators showed postprandial BP reduction similar to that of hypertensive older people not using antihypertensive medications. In addition, other studies have shown that treatment with calcium channel blockers and diuretics ameliorates meal or glucose-induced BP reduction in older hypertensive patients and older patients with coronary heart disease.

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Orthostatic hypotension has been reported to occur in 13 to 14% of older patients receiving cardiovascular medications, which is significantly higher than the prevalence of 3 to 6% observed in healthy older subjects on no medications. We did not observe an exacerbation of orthostatic hypotension in response to cardiovascular medications in older nursing home residents. In contrast, when cardiovascular medications were given, systolic BP remained stable during the 10-minute period of standing, whereas when no medication was administered, there was an initial decline followed by an increase in systolic BP. This difference may be explained by a smaller but nonsignificant difference in baseline BP as much as it has been demonstrated that higher supine BPs are associated with greater postprandial declines after standing.

There are a few limitations to the present study. Although the sample size of this study was relatively small, we found uniform intraindividual variability of meal-induced BP and HR responses. The patients in this study were using different types of medications and multiple combinations of cardiovascular medications. Therefore, it is not possible to distinguish the effects of different types of medication. In addition, these different groups of medications may have different half-lives, and some of them may have achieved high plasma levels that persisted during the no-drug test. Despite this possibility, these medications did not appear to produce clinically significant BP reduction.

Postprandial BP is usually assessed in the sitting position. Although this position is more physiologic, postural changes in BP might contribute to the postprandial decrease in BP. We were interested in distinguishing variability of postprandial changes from postural BP changes and, therefore, chose to study postprandial BP changes in our subjects in the supine position.

Despite these limitations, our data provide new information about the reproducibility of postprandial and orthostatic hypotension in older nursing home residents. Even when cardiovascular medications were held for 12 hours, we found no major difference in BP and HR response to meals and posture change. Finally, we found that postprandial hypotension is distinct from orthostatic hypotension and seems to occur in older adults more frequently than does orthostatic hypotension. These findings will help guide the clinical evaluation of these hypotensive syndromes as well as future research.

ACKNOWLEDGMENT

The authors thank the residents and staff of the Hebrew Rehabilitation Center for Aged for their help with this study.

REFERENCES


