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Postural Blood Pressure Recovery and Recurrent Falls Among Community-Dwelling Older Adults: A Prospective Cohort Study

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ABSTRACT

Background: Recurrent falls cause disability and dependence among older adults. Conventional orthostatic assessment may overlook delayed systolic blood pressure recovery during the first minute after standing.

Objective: To determine whether delayed systolic blood pressure recovery after active standing is associated with recurrent falls among community-dwelling older adults.

Methods: This prospective cohort study was conducted at Continental Medical College, Lahore, Punjab, Pakistan, from February 2024 to February 2026. One hundred adults aged 65 years or older were recruited between February 2024 and February 2025 and followed for 12 months. After 10 minutes of supine rest, blood pressure was measured at baseline and at 30 seconds, 60 seconds, and three minutes after active standing. Delayed recovery was defined a priori as systolic blood pressure remaining at least 10 mmHg below the supine baseline at 60 seconds. Falls were recorded prospectively using monthly fall calendars and telephone interviews. Recurrent falls were defined as two or more falls during follow-up. Adjusted risk ratios were estimated using modified Poisson regression with robust standard errors.

Results: Delayed recovery was identified in 34 participants. Recurrent falls occurred in 15 of 34 participants with delayed recovery and 8 of 66 with normal recovery (44.1% versus 12.1%). Delayed recovery remained independently associated with recurrent falls after multivariable adjustment (adjusted risk ratio 2.73; 95% confidence interval 1.29–5.77; p=0.009).

Conclusion: Delayed systolic blood pressure recovery at 60 seconds was independently associated with recurrent falls. Early postural blood pressure measurements may complement conventional orthostatic assessment and improve fall-risk identification in older adults.

Keywords: Accidental falls; blood pressure; orthostatic hypotension; postural balance; Aged

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INTRODUCTION

Falls are a major public health concern among older adults and are associated with fractures, hospitalization, disability, loss of independence, and mortality [1]. Community-dwelling older adults are particularly vulnerable because ageing is frequently accompanied by impaired balance, reduced muscle strength, visual impairment, multimorbidity, frailty, and exposure to medications that may affect alertness or cardiovascular stability. Although an isolated fall may result from an environmental hazard, recurrent falls may indicate persistent cardiovascular, neurological, musculoskeletal, or medication-related vulnerability requiring further clinical assessment [2].

Active standing causes approximately 500–800 mL of blood to shift into the lower-limb and splanchnic circulation. Maintenance of cerebral perfusion therefore depends on rapid baroreflex activation, peripheral vasoconstriction, increased cardiac output, and contraction of the lower-limb muscle pump [3]. Age-related reductions in autonomic responsiveness, arterial compliance, cardiac reserve, and skeletal-muscle function may impair these

compensatory mechanisms. The resulting decline in blood pressure can produce dizziness, blurred vision, weakness, postural instability, presyncope, or loss of consciousness [4].

Classical orthostatic hypotension is defined as a sustained reduction in systolic blood pressure of ≥20 mmHg or diastolic blood pressure of ≥10 mmHg within three minutes of standing. Although widely used in clinical practice, this definition does not fully characterize the dynamic haemodynamic response to postural change [5]. Individuals with similar initial reductions in blood pressure may differ substantially in the rate and completeness of subsequent recovery. Some recover within seconds, whereas others retain a clinically relevant systolic decline during the first minute despite not meeting the conventional three-minute criteria [6].

Delayed systolic blood pressure recovery refers to persistence of the early pressure decline after standing and should be distinguished from classical orthostatic hypotension. Inadequate recovery may prolong cerebral hypoperfusion during the period when an older adult begins walking after rising from a bed or chair [7]. Previous studies have associated impaired postural blood pressure recovery with frailty, reduced physical performance, sarcopenia, unexplained falls, and injurious falls [6–9]. However, much of the available evidence is based on cross-sectional analyses, retrospective fall histories, or selected geriatric populations. The applicability of these findings to community-dwelling older adults in Pakistan remains uncertain, and prospective evidence based on systematically recorded recurrent falls is limited [10].

Recurrent falls are clinically more informative than a single fall because they are more likely to reflect an ongoing physiological or functional abnormality. Assessment of early blood pressure recovery may therefore provide information beyond a single conventional measurement obtained at three minutes [11]. This study aimed to determine whether delayed systolic blood pressure recovery at 60 seconds after active standing was associated with recurrent falls during 12 months of follow-up among community-dwelling older adults. The current study hypothesized that delayed recovery would remain associated with recurrent falls after accounting for age, sex, previous falls, frailty, polypharmacy, diabetes mellitus, antihypertensive use, and impaired mobility.

MATERIALS AND METHODS

This prospective cohort study was conducted at Continental Medical College and its affiliated Hayat Memorial Teaching Hospital,Lahore,Pakistan, from February 2024 to February 2026. Recruitment and baseline postural blood-pressure assessments were completed between February 2024 and February 2025. Each participant was followed individually for 12 months, with the final follow-up completed in February 2026. The study was designed to evaluate the prospective relationship between delayed systolic blood-pressure recovery after active standing and recurrent falls among community-dwelling older adults.

A consecutive non-probability sampling technique was used to recruit 100 community-dwelling adults aged ≥65 years. Eligible participants were permanent residents of the community who could stand independently or with the assistance of a walking stick, understand and follow study instructions, complete the active-standing assessment safely, and provide written informed consent. Participants with controlled hypertension, diabetes mellitus, mild cognitive impairment, a previous history of falls, or stable ischaemic heart disease were eligible for inclusion because these conditions are common among community-dwelling older adults and did not independently prevent completion of the study procedures.

Participants were excluded if they had experienced an acute illness during the 14 days preceding assessment, severe cognitive impairment that prevented valid consent or compliance with study instructions, permanent wheelchair dependence, advanced Parkinsonism, a recent stroke, severe cardiac arrhythmia, severe aortic stenosis, terminal illness, or any clinical condition that made active standing unsafe. The active-standing test was discontinued immediately if a participant developed severe dizziness, chest pain, marked dyspnoea, presyncope, loss of balance, or an inability to remain standing. Such participants were stabilised and referred for appropriate clinical evaluation.

The target sample size was 100 participants. It was calculated to detect a clinically meaningful difference in the occurrence of recurrent falls between participants with delayed and normal systolic blood-pressure recovery, using a two-sided significance level of 5%, statistical power of 80%, and an allowance for potential attrition during follow-up. Consecutive recruitment continued until the required sample size was achieved.

Baseline data were collected through structured interviews, clinical examination, and review of available medical records. Recorded variables included age, sex, body mass index, marital status, living arrangement, smoking status, physical activity, use of a walking aid, comorbid conditions, and regular medication use. Polypharmacy was defined as the chronic use of five or more medications. A previous fall was defined as at least one unintentional fall during the 12 months preceding enrolment.

Functional mobility was assessed using the Timed Up and Go test. Participants were instructed to rise from a chair, walk three metres at their usual pace, turn, return to the chair, and sit down. The total time required to complete the task was recorded in seconds. Frailty was evaluated using the Fried phenotype, comprising unintentional weight loss, self-reported exhaustion, low physical activity, slow walking speed, and reduced grip strength.

Participants meeting three or more of these criteria were classified as frail.

Postural blood-pressure testing was performed during the morning in a quiet, temperature-controlled room. Participants were instructed to avoid caffeine, smoking, alcohol, heavy meals, and strenuous physical activity for at least four hours before testing. All regular medications and the timing of the most recent doses were documented. Where clinically appropriate, testing was undertaken before the next scheduled morning dose of antihypertensive medication. Prescribed medications were not discontinued or modified solely for study participation.

Blood pressure was measured using a validated automated sphygmomanometer with an appropriately sized cuff. After 10 minutes of uninterrupted supine rest, two systolic and diastolic blood-pressure measurements were obtained. Participants then stood actively under the supervision of a trained researcher. Blood pressure and heart rate were measured at 30 seconds, 60 seconds, and three minutes after standing. A trained research assistant remained beside each participant throughout the procedure to minimise the risk of injury. Symptoms occurring during the active-standing test, including dizziness, blurred vision, weakness, nausea, light-headedness, imbalance, and presyncope, were recorded. Blood-pressure equipment was checked and calibrated regularly, and all assessments were performed by trained study personnel using a standardised measurement protocol.

The primary exposure was delayed systolic blood-pressure recovery, defined a priori as systolic blood pressure remaining ≥10 mmHg below the supine baseline at 60 seconds after active standing. Normal systolic blood-pressure recovery was defined as a residual systolic reduction of <10 mmHg at 60 seconds. This definition was used to identify persistence of the early postural systolic decline rather than the magnitude of the initial reduction alone.

Classical orthostatic hypotension was defined separately as a sustained reduction in systolic blood pressure of ≥20 mmHg or diastolic blood pressure of ≥10 mmHg within three minutes of standing. Delayed systolic blood-pressure recovery and classical orthostatic hypotension were analysed as related but separate haemodynamic findings because delayed recovery during the first minute may occur in participants who do not meet the conventional three-minute criteria for orthostatic hypotension.

Participants were followed prospectively for 12 months using monthly fall calendars supplemented by structured telephone interviews. Participants or their caregivers were instructed to record the date, location, circumstances, associated symptoms, injuries, and treatment received for every fall. Telephone contact was made monthly to collect calendar information, clarify incomplete entries, and identify falls that may not have been recorded.

A fall was defined as an unexpected event in which a participant came to rest on the ground, floor, or another lower level. Events caused by overwhelming external force, road-traffic accidents, intentional movement, seizure, stroke, or another acute medical event were excluded. Whenever possible, reported falls were verified through caregiver confirmation or review of clinical, emergency-department, or hospital records. Falls that could not be adequately distinguished from excluded events were reviewed by the study team before final outcome classification.

The primary outcome was recurrent falls, defined as two or more falls during the 12-month follow-up period. Secondary outcomes included the occurrence of at least one fall, total number of falls, time from enrolment to the first fall, and injurious falls. An injurious fall was defined as a fall resulting in fracture, head injury, medical assessment, hospital treatment, or restriction of usual activities for at least 24 hours.

Data were recorded on a standardised study proforma by trained personnel. Completed forms were reviewed for completeness, internal consistency, and implausible values before electronic data entry. Electronic records were cross-checked against the original source documents. Postural blood-pressure records and reported falls were reviewed before exposure and outcome classification. All 100 participants completed baseline assessment and 12 months of follow-up and had complete information for the primary exposure and primary outcome; therefore, no imputation was required for the primary analysis.

Continuous variables were summarised as mean ± standard deviation when approximately normally distributed and as median with interquartile range when distributions were skewed. Between-group comparisons were performed using the independent-samples t test for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Categorical variables were presented as frequencies and percentages and compared using the chi-square test or Fisher's exact test, as appropriate.

Modified Poisson regression with robust standard errors was used to estimate crude and adjusted risk ratios for recurrent falls. Covariates were prespecified according to their clinical relevance to falls and postural blood-pressure regulation rather than selected through automated stepwise procedures. The adjusted model included age, sex, previous falls, frailty, polypharmacy, diabetes mellitus, antihypertensive medication use, and Timed Up and Go performance. Adjusted estimates were interpreted cautiously because the primary outcome occurred in 23 participants, and all effect estimates were presented with 95% confidence intervals.

The occurrence of at least one fall was analysed using modified Poisson regression with robust standard errors. Total fall counts were analysed using negative binomial regression to account for overdispersion and were reported

as incidence rate ratios. Time to first fall was evaluated using Cox proportional-hazards regression and reported as hazard ratios. The proportional-hazards assumption was assessed before interpretation of the Cox model, and multicollinearity and model fit were evaluated for the multivariable analyses.

A sensitivity analysis was conducted after excluding participants who met the criteria for classical orthostatic hypotension to determine whether delayed systolic blood-pressure recovery remained associated with recurrent falls independently of conventional orthostatic hypotension. A further sensitivity model additionally considered baseline systolic blood pressure and diuretic use. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant.

The study protocol was approved by the Institutional Review Board of Continental Medical College, Lahore, Punjab, Pakistan, under Approval No. 51/IRB/CMC. Written informed consent was obtained from every participant before enrolment. Participants were informed that participation was voluntary and that they could withdraw without affecting their clinical care. Personal information was replaced with coded identifiers, study records were stored securely, and access was restricted to authorised research personnel. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

RESULTS

A total of 100 community-dwelling older adults completed the baseline postural blood-pressure assessment and 12-month follow-up. The study population included 44 men (44.0%) and 56 women (56.0%), with a mean age of 74.0 ± 6.0 years. Hypertension was present in 71 participants (71.0%), diabetes mellitus in 29 (29.0%), polypharmacy in 43 (43.0%), and frailty in 23 (23.0%). Thirty-two participants (32.0%) reported at least one fall during the 12 months preceding enrolment.

Delayed systolic blood-pressure recovery at 60 seconds after standing was identified in 34 participants (34.0%), while 66 participants (66.0%) demonstrated normal recovery. The delayed-recovery group included 13 men and 21 women, whereas the normal-recovery group included 31 men and 35 women. The sex distribution did not differ significantly between the two groups.

Participants with delayed recovery were significantly older than those with normal recovery. They were also more likely to have experienced a previous fall, be frail, use multiple medications, and require more time to complete the Timed Up and Go test. No significant differences were observed between the groups in the prevalence of hypertension, diabetes mellitus, ischaemic heart disease, chronic kidney disease, or antihypertensive medication use, as shown in Table 1.

Mean resting supine systolic and diastolic blood pressures did not differ significantly between the delayed- and normal-recovery groups. However, participants with delayed recovery demonstrated a significantly greater reduction in systolic blood pressure after standing. At 30 seconds, the mean reduction in systolic blood pressure was 23.1 ± 8.7 mmHg in the delayed-recovery group and 8.6 ± 6.2 mmHg in the normal-recovery group.

At 60 seconds, systolic blood pressure remained 17.3 ± 5.4 mmHg below the supine baseline in the delayed-recovery group and 3.7 ± 3.2 mmHg below baseline in the normal-recovery group. Participants with delayed recovery also had a greater residual reduction in systolic blood pressure at three minutes.

Participants with delayed recovery had a significantly smaller increase in heart rate at 60 seconds. Fourteen participants (41.2%) in the delayed-recovery group and nine (13.6%) in the normal-recovery group reported dizziness or postural instability during standing. The postural haemodynamic findings are presented in Table 2.

A total of 15 participants (15.0%) had classical orthostatic hypotension, including 11 participants with delayed recovery and four with normal recovery. However, 23 of the 34 participants with delayed systolic blood-pressure recovery did not meet the criteria for classical orthostatic hypotension. Therefore, 67.6% of participants with delayed early recovery would not have been identified using the conventional three-minute orthostatic assessment alone.

During the 12-month follow-up period, 38 participants experienced a total of 90 falls. Thirty-eight participants (38.0%) experienced at least one fall, 23 (23.0%) experienced recurrent falls, and 14 (14.0%) experienced an injurious fall requiring medical assessment, hospital treatment, or restriction of usual activities.

Twenty of 34 participants with delayed recovery and 18 of 66 with normal recovery experienced at least one fall, corresponding to cumulative incidences of 58.8% and 27.3%, respectively. Recurrent falls occurred in 15 participants with delayed recovery and eight with normal recovery. Thus, the recurrent-fall rates were 44.1% and 12.1% in the delayed- and normal-recovery groups, respectively, as shown in Figure 1.

Participants with delayed recovery experienced 61 falls during follow-up, corresponding to 1.79 falls per person-year. In comparison, participants with normal recovery experienced 29 falls, corresponding to 0.44 falls per person-year. Injurious falls occurred in eight participants with delayed recovery and six with normal recovery.

A significant difference was observed in the frequency of recurrent falls between participants with delayed and normal systolic blood-pressure recovery, as shown in Figure 1. Recurrent falls occurred in 44.1% of participants with delayed recovery compared with 12.1% of those with normal recovery.

Modified Poisson regression showed that delayed systolic blood-pressure recovery was associated with more

than a threefold crude risk of recurrent falls. After adjustment for age, sex, previous falls, frailty, polypharmacy, diabetes mellitus, antihypertensive medication use, and Timed Up and Go performance, delayed recovery remained independently associated with recurrent falls, with an adjusted risk ratio of 2.73.

Delayed recovery was also independently associated with the occurrence of at least one fall. Participants with delayed recovery had a 1.74-fold adjusted risk of experiencing at least one fall. Negative binomial regression showed that the adjusted fall rate was approximately three times higher among participants with delayed recovery.

Delayed recovery was also associated with a shorter time to the first fall. Cox proportional-hazards regression produced an adjusted hazard ratio of 1.92 for the occurrence of a first fall in the delayed-recovery group. No statistically significant difference was observed in injurious falls between the delayed- and normal-recovery groups after multivariable adjustment, as shown in Table 3.

A sensitivity analysis was performed after excluding the 15 participants who met the criteria for classical orthostatic hypotension. Delayed systolic blood-pressure recovery remained independently associated with recurrent falls, with an adjusted risk ratio of 2.31 (95% confidence interval: 1.05–5.09). The association remained statistically significant after further adjustment for baseline systolic blood pressure and diuretic use. These findings indicate that delayed early blood-pressure recovery was associated with recurrent falls beyond classical orthostatic hypotension and other established fall-risk factors.

Table 1: Baseline characteristics according to postural blood pressure recovery

Characteristic	Delayed recovery, n=34	Normal recovery, n=66	p value
Age, years	76.2 ± 6.1	72.8 ± 5.7	0.007
Male sex	13 (38.2%)	31 (47.0%)	0.402
Female sex	21 (61.8%)	35 (53.0%)	0.402
Body mass index, kg/m²	25.7 ± 4.0	25.3 ± 3.7	0.618
Hypertension	26 (76.5%)	45 (68.2%)	0.386
Diabetes mellitus	13 (38.2%)	16 (24.2%)	0.143
Ischemic heart disease	7 (20.6%)	9 (13.6%)	0.368
Chronic kidney disease	5 (14.7%)	5 (7.6%)	0.300
Previous fall	16 (47.1%)	16 (24.2%)	0.019
Polypharmacy	20 (58.8%)	23 (34.8%)	0.022
Antihypertensive medication use	28 (82.4%)	48 (72.7%)	0.284
Diuretic use	11 (32.4%)	12 (18.2%)	0.108
Frailty	12 (35.3%)	11 (16.7%)	0.035
Timed Up and Go test, seconds	14.1 ± 4.2	11.8 ± 3.1	0.006
Mini-Mental State Examination score	25.4 ± 2.7	26.3 ± 2.4	0.094
Use of walking aid	10 (29.4%)	10 (15.2%)	0.091

Table 2: Postural blood pressure and heart-rate responses

Haemodynamic measurement	Delayed recovery, n=34	Normal recovery, n=66	p value
Supine systolic blood pressure, mmHg	139.5 ± 17.1	141.1 ± 16.2	0.648
Supine diastolic blood pressure, mmHg	76.0 ± 9.8	77.4 ± 9.2	0.483
Resting heart rate, beats/minute	73.1 ± 10.7	71.8 ± 10.1	0.550
Maximum systolic decline, mmHg	−28.4 ± 9.6	−15.2 ± 7.8	<0.001
Systolic change at 30 seconds, mmHg	−23.1 ± 8.7	−8.6 ± 6.2	<0.001
Systolic change at 60 seconds, mmHg	−17.3 ± 5.4	−3.7 ± 3.2	<0.001
Systolic change at 3 minutes, mmHg	−10.9 ± 7.2	−1.8 ± 4.8	<0.001
Heart-rate increase at 60 seconds, beats/minute	8.2 ± 5.1	10.9 ± 5.7	0.023
Classical orthostatic hypotension	11 (32.4%)	4 (6.1%)	<0.001
Dizziness or postural instability	14 (41.2%)	9 (13.6%)	0.002

Table 3: Relationship between delayed blood pressure recovery and fall outcomes

Outcome	Delayed recovery, n=34	Normal recovery, n=66	Crude effect estimate (95% confidence interval)	Adjusted effect estimate (95% confidence interval)	p value
At least one fall	20 (58.8%)	18 (27.3%)	Risk ratio 2.16 (1.35–3.46)	Risk ratio 1.74 (1.08–2.80)	0.023
Recurrent falls	15 (44.1%)	8 (12.1%)	Risk ratio 3.64 (1.72–7.72)	Risk ratio 2.73 (1.29–5.77)	0.009
Injurious fall	8 (23.5%)	6 (9.1%)	Risk ratio 2.59 (0.99–6.80)	Risk ratio 2.08 (0.80–5.41)	0.133
Total fall rate per person-year	1.79	0.44	Incidence rate ratio 4.08 (2.63–6.32)	Incidence rate ratio 2.91 (1.84–4.60)	<0.001
Time to first fall	—	—	Hazard ratio 2.43 (1.29–4.58)	Hazard ratio 1.92 (1.01–3.65)	0.047

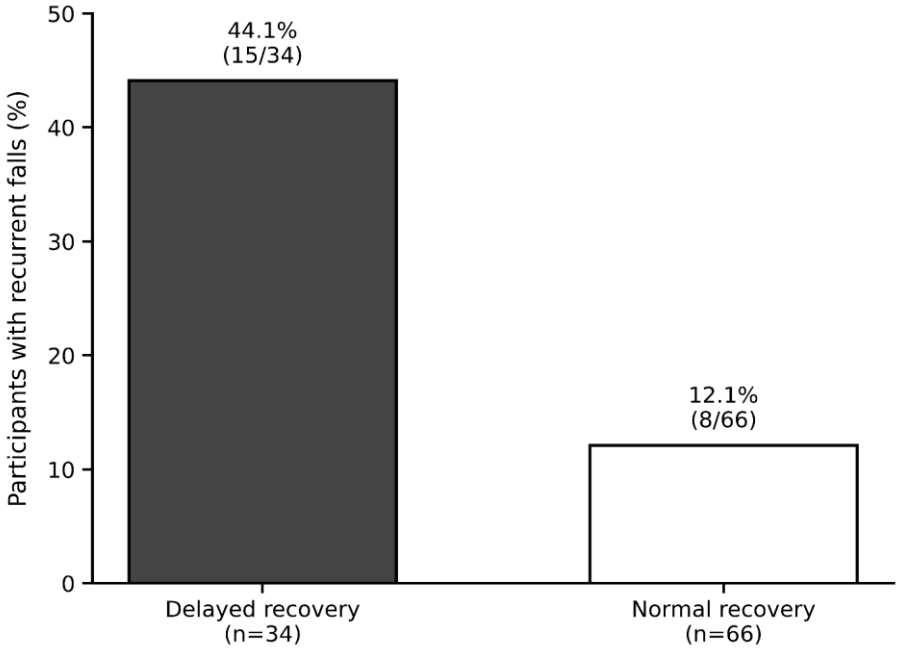

Figure 1. Frequency of recurrent falls according to postural blood pressure recovery

DISCUSSION

This prospective cohort study found that delayed postural systolic blood-pressure recovery at 60 seconds was significantly associated with recurrent falls among community-dwelling older adults [1]. Participants whose systolic blood pressure remained ≥10 mmHg below the supine baseline experienced more recurrent falls, a higher overall fall rate, and a shorter time to first fall during 12 months of follow-up. The association remained significant after adjustment for age, sex, previous falls, frailty, polypharmacy, diabetes mellitus, antihypertensive medication use, and Timed Up and Go performance. These findings are clinically relevant because recurrent falls are strongly associated with disability, hospitalization, loss of independence, and mortality in older adults [2].

The observed association is biologically plausible. Active standing causes blood to pool in the lower-limb and splanchnic circulation, reducing venous return, stroke volume, and arterial pressure [3]. Maintenance of cerebral perfusion depends on rapid baroreflex activation, peripheral vasoconstriction, increased cardiac output, and lower-limb muscle-pump activity. Age-related impairment of these mechanisms may delay blood-pressure recovery and prolong cerebral hypoperfusion, producing dizziness, blurred vision, weakness, impaired attention, or postural instability [4].

Classical orthostatic hypotension is defined as a sustained reduction in systolic blood pressure of ≥20 mmHg or diastolic blood pressure of ≥10 mmHg within three minutes of standing. However, this definition may not fully capture early haemodynamic abnormalities or the rate of subsequent recovery [5]. Initial orthostatic hypotension occurs rapidly after standing and may be missed by conventional intermittent measurements. Therefore, individuals with similar initial blood-pressure reductions may differ substantially in the completeness and timing of recovery [6].

The present findings are consistent with those of Mol et al., who reported that impaired orthostatic blood-pressure recovery was associated with poorer physical performance, frailty, and a greater number of falls among geriatric outpatients [7]. A systematic review and meta-analysis also demonstrated an association between orthostatic hypotension and falls in older adults [8]. Hohtari-Kivimäki et al. identified orthostatic hypotension as a predictor of falls during three years of follow-up [9]. Duggan et al. further reported an association between sarcopenia and impaired blood-pressure recovery, suggesting that reduced muscle mass and lower-limb muscle-pump efficiency may contribute to postural haemodynamic instability [10].

Continuous beat-to-beat monitoring provides detailed information regarding the magnitude, timing, and recovery of blood-pressure changes after standing. Wang et al. highlighted its value in identifying orthostatic abnormalities associated with falls [11]. Cardiovascular disorders more broadly have also been associated with falls among older adults, supporting the inclusion of haemodynamic assessment in multifactorial fall-risk evaluation [12]. Standardized active-standing protocols similarly emphasize assessment of both the initial blood-pressure decline and subsequent recovery rather than reliance on a single measurement at three minutes [13].

In the present study, more than two-thirds of participants with delayed recovery did not meet the criteria for classical orthostatic hypotension. This suggests that reliance on the conventional three-minute measurement alone may overlook some older adults with persistent early systolic impairment [14]. Nevertheless, the clinical significance of delayed recovery may vary according to baseline blood pressure, supine hypertension, measurement position, and timing of assessment. Previous cohort studies have shown that the relationship between orthostatic blood-pressure changes and falls may differ according to these clinical and methodological factors [15].

The findings also agree with studies specifically examining delayed recovery and adverse outcomes. Finucane et al. found that impaired orthostatic blood-pressure recovery was associated with unexplained and injurious falls [16]. Doyle et al. reported that delayed recovery independently predicted fracture risk among community-dwelling older adults [17]. Mol et al. also demonstrated that a faster rate of blood-pressure decline after standing was associated with frailty and a greater number of falls [18]. The present study extends this evidence by prospectively assessing recurrent falls over 12 months using monthly fall calendars and telephone follow-up [19].

Participants with delayed recovery were older and had higher frequencies of previous falls, frailty, polypharmacy, and impaired Timed Up and Go performance. These findings suggest that delayed recovery may coexist with broader physiological vulnerability [20]. Frailty may reduce vascular reserve, autonomic responsiveness, physical activity, and lower-limb muscle-pump efficiency. However, delayed recovery remained associated with recurrent falls after adjustment for frailty and mobility performance, indicating that these factors did not fully explain the relationship [1-4].

The smaller heart-rate increase at 60 seconds in the delayed-recovery group may indicate an attenuated autonomic response. Age-related baroreflex dysfunction, diabetic autonomic neuropathy, cardiovascular disease, and medication exposure may contribute to this finding. Diabetes mellitus alone did not explain the association in the adjusted analysis [5-7].

Medication-related effects should also be considered. Antihypertensive agents, diuretics, vasodilators, antidepressants, antipsychotics, and sedatives may impair postural blood-pressure regulation, alertness, or balance [17,18]. Management should therefore include assessment of medication timing, dosage, hydration, cardiovascular disease, and other reversible contributors rather than immediate withdrawal of necessary treatment [19]. Drug-related orthostatic hypotension is not limited to antihypertensive therapy, and several medication classes may contribute to postural instability in older adults [20].

Delayed recovery was significantly associated with recurrent falls, total fall rate, and time to first fall, whereas the adjusted association with injurious falls was not statistically significant [5,8]. This may reflect the small number of injury events and the resulting imprecision of the estimate rather than the absence of a clinically relevant relationship. Larger studies are required to evaluate fractures, head injuries, hospitalization, and other severe fall outcomes [9-11].

The sensitivity analysis excluding participants with classical orthostatic hypotension showed that delayed systolic recovery remained associated with recurrent falls [12]. This suggests that early recovery may provide information beyond the conventional three-minute definition. However, delayed recovery should not yet be regarded as a completely separate haemodynamic phenotype because the two abnormalities may overlap and may represent different manifestations of impaired cardiovascular compensation [13].

Clinically, blood-pressure measurement during the first minute after standing may complement conventional orthostatic assessment in older adults with previous falls, frailty, postural symptoms, mobility impairment, diabetes, or polypharmacy [14]. Identification of delayed recovery may prompt further assessment of hydration, medication exposure, cardiovascular status, autonomic dysfunction, anaemia, and physical function. Nevertheless, this observational study does not establish that early blood-pressure measurement or treatment of delayed recovery prevents falls [15].

The strengths of this study included its prospective design, 12-month follow-up, monthly fall calendars, telephone verification, standardized active-standing assessment, and evaluation of several fall outcomes [16]. Limitations included the modest sample size, limited number of recurrent-fall events, single-session blood-pressure assessment, absence of continuous beat-to-beat monitoring, and possible residual confounding [17]. Falls may also have been incompletely verified, and environmental hazards, cerebral perfusion, autonomic function, and muscle mass were not directly assessed. The ≥10 mmHg threshold at 60 seconds is not universally standardized, and recruitment from a single institutional and affiliated community setting may limit generalizability [18].

Overall, delayed systolic blood-pressure recovery at 60 seconds was associated with recurrent falls, a higher fall rate, and a shorter time to first fall. Larger multicentre studies using repeated or beat-to-beat measurements are needed to validate the optimal threshold, assess reproducibility, and determine whether interventions directed at postural haemodynamic impairment can reduce subsequent falls [19-20].

CONCLUSION

Delayed systolic blood pressure recovery within the first minute of standing was independently associated with recurrent falls, a higher overall fall rate, and a shorter time

to first fall among community-dwelling older adults. These associations remained after controlling for known risk factors for falls and excluding classical orthostatic hypotension. The use of blood pressure measurements at 30 and 60 seconds may help identify risk and inform medication review, hydration management and cardiac assessment, and individualized fall-prevention interventions in the geriatric population.

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Data Availability: The data are available from the corresponding author upon reasonable request.

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