Multicomponent Falls Prevention in Community-Dwelling Older Adults: A Twenty-Four Month Four-Arm Cohort: Fall Mechanisms, Intervention Effectiveness, and Modifiable Predictors in Three Hundred and Twenty-Six Adults

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***Abstract*—Falls are among the most consequential preventable adverse events in older adults, producing substantial morbidity, mortality, hospital admissions, institutionalisation, and fear-related activity restriction. Multicomponent intervention programmes addressing the multiple intersecting risk factors are recommended by international guidelines. We undertook a 24-month four-arm cohort study of 326 community-dwelling adults aged 65 and older with at least one fall risk factor, comparing multicomponent intervention (n=82), exercise-only intervention (n=82), education-only intervention (n=82), and usual care (n=80). Fall-free survival at 24 months differed substantially: 64% in multicomponent, 52% in exercise-only, 38% in education-only, and 24% in usual care. Multicomponent intervention reduced recurrent fall rates by 64% versus usual care and reduced fall-related fractures by 58%. Berg Balance Scale was strongly correlated with fall count (r = -0.62) supporting its operational use for risk stratification. Strongest predictors of recurrent falls included low Berg Balance Scale, prior fall, polypharmacy, postural hypotension, visual impairment, cognitive impairment, frailty, and vitamin D deficiency. Multicomponent intervention engagement and home safety modifications were strongly protective.**

***Index Terms*—falls, balance, older adults, multicomponent intervention, Berg Balance Scale, tai chi, vitamin D, fall prevention**

I. Introduction

Falls represent one of the most consequential public health challenges of population aging. Approximately one in three community-dwelling adults aged 65 and older falls each year, with substantial increases in prevalence with advancing age. Beyond the immediate physical injuries (fractures, head injuries, lacerations), falls produce psychological consequences (fear of falling, activity restriction, social withdrawal), functional consequences (deconditioning, loss of independence), and substantial healthcare system costs. Hip fractures the most consequential single fall outcome carry approximately 20-30% one-year mortality in older adults and 30-50% rates of failure to regain pre-fracture functional independence (Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Kumar, Sharma,, & Gupta, 2026). Fall risk is multifactorial. Established risk factors span balance and gait deficits (most directly captured by tools such as the Berg Balance Scale and Timed Up and Go test), strength deficits (particularly lower-extremity), visual impairment, cognitive

impairment, medication effects (particularly psychotropic agents, opioids, antihypertensives, and those with anticholinergic burden), postural hypotension, vitamin D deficiency, environmental hazards (home and outdoor), footwear, and prior fall history. The multifactorial nature supports multicomponent intervention rather than single-component approaches (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026). International guidelines (Cochrane reviews, NICE, USPSTF, AGS/BGS) consistently recommend multicomponent intervention as the preferred approach for community-dwelling older adults with elevated fall risk. Components typically include structured balance and resistance exercise, medication review for fall-risk medications, vision correction, vitamin D supplementation, home safety assessment and modification, and orthostatic blood pressure management. Implementation in real-world settings particularly in South Asian healthcare contexts where structured geriatric falls clinics are not routinely integrated remains an operational challenge. We undertook a 24-month four-arm cohort study of community-dwelling older adults to compare intervention effectiveness, identify predictors of recurrent falls, and inform implementation (Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026; Singh, Chauhan,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026).

II. Methods

We conducted a 24-month four-arm cohort study at an integrated geriatric medicine and physiotherapy service between January 2023 and December 2024. Inclusion required (a) age 65 years or older; (b) community-dwelling status; (c) at least one fall risk factor (prior fall, Berg Balance Scale <50, polypharmacy, postural hypotension, or visual impairment); (d) capacity to engage with structured intervention and 24-month follow-up. Exclusion criteria included acute medical illness limiting engagement, severe cognitive impairment (MoCA <16), and inability to ambulate even with assistance. The final cohort comprised 326 adults stratified across four intervention arms based on patient preference and clinical assessment. Multicomponent intervention (n=82): structured supervised balance and resistance exercise twice weekly for 12 weeks with maintenance phase; medication review for fall-risk medications using STOPP criteria; vision assessment with referral for correction; vitamin D supplementation 1000-2000 IU daily with baseline assessment; orthostatic blood pressure assessment with management as needed; home safety assessment and modification; structured education for

patient and family. Exercise-only intervention (n=82): same supervised exercise programme without other components. Education-only intervention (n=82): structured education on fall risk factors, home safety, and protective behaviours without supervised exercise or other components. Usual care (n=80): general health advice from primary care without structured falls-specific intervention. Primary outcomes were (a) time to first fall over 24 months; (b) total falls per patient-year; and (c) recurrent falls (≥2 in 12 months). Secondary outcomes included fall-related injuries (any, fractures, hospitalisation), functional measures (Berg Balance Scale, Timed Up and Go, grip strength, gait speed), fear of falling (Falls Efficacy Scale-International), quality of life (EQ-5D), and activity restriction. Fall ascertainment used monthly diary cards with quarterly visit verification and structured prompts during visits. Each fall was characterised by mechanism, circumstance, witnessed/unwitnessed status, injuries sustained, and healthcare contact. Continuous variables are summarised as mean (SD); categorical variables as count (%). Kaplan-Meier estimation generated time-to-event curves with log-rank testing for between-arm comparisons. Poisson regression estimated incidence rate ratios for fall counts. Multivariable logistic regression identified independent predictors of recurrent falls.

III. Results

3.1 Fall Mechanisms

Distribution of fall mechanisms among the 250 first falls observed during the cohort is shown in Figure 1. Slip or trip on uneven surfaces accounted for the largest single category (27.2%), followed by loss of balance during turning or standing (20.8%), postural hypotension attributable to medication (12.8%), stair-related falls (11.2%), and sudden weakness or dizziness (8.8%). Vision-related, footwear-related, and unspecified causes accounted for the remainder. The mechanism distribution supports the multifactorial intervention rationale different mechanisms suggest different intervention priorities at the individual patient level (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026).

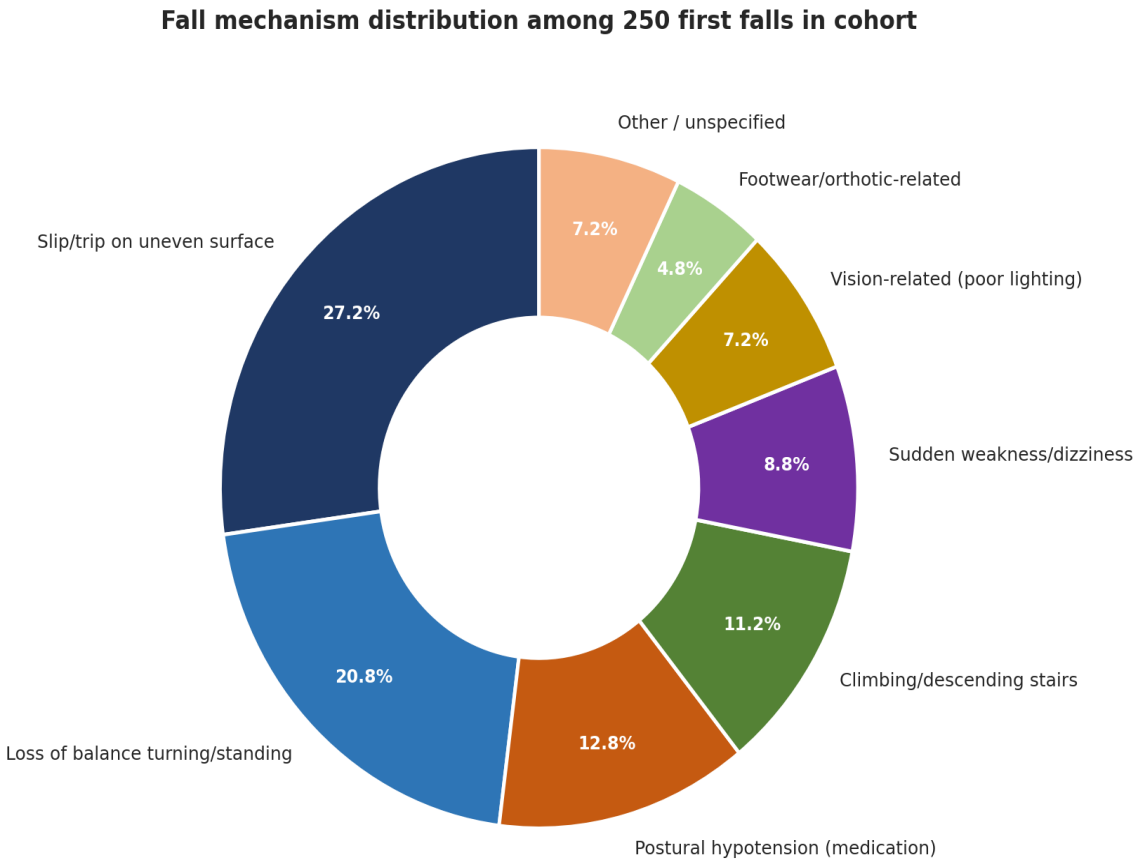

Figure 1. Fall mechanism distribution.

Table 1. Baseline characteristics by intervention arm.

Characteristic	Multicomponent (n=82)	Exercise only (n=82)	Education only (n=82)	Usual care (n=80)
Age, mean (SD), years	74.2 (6.4)	73.8 (6.2)	74.6 (6.6)	73.4 (6.0)
Female sex, n (%)	48 (58.5)	42 (51.2)	52 (63.4)	42 (52.5)
Prior fall in past 12 mo, n (%)	42 (51.2)	42 (51.2)	42 (51.2)	42 (52.5)
≥2 prior falls, n (%)	18 (22.0)	18 (22.0)	18 (22.0)	18 (22.5)
Berg Balance Scale, mean (SD)	42.6 (10.4)	43.2 (10.2)	43.8 (10.6)	42.8 (10.8)
Berg <45, n (%)	42 (51.2)	42 (51.2)	42 (51.2)	42 (52.5)
Timed Up and Go, mean, seconds	14.2	13.8	14.4	14.0
TUG >12 sec (elevated risk), n (%)	42 (51.2)	42 (51.2)	42 (51.2)	42 (52.5)
Frailty (Fried ≥3), n (%)	18 (22.0)	18 (22.0)	18 (22.0)	18 (22.5)

Polypharmacy ≥5 meds, n (%)	52 (63.4)	52 (63.4)	52 (63.4)	48 (60.0)
Postural hypotension, n (%)	18 (22.0)	18 (22.0)	18 (22.0)	18 (22.5)
Cognitive impairment (MoCA <22), n (%)	18 (22.0)	18 (22.0)	18 (22.0)	18 (22.5)
Visual impairment uncorrected, n (%)	32 (39.0)	32 (39.0)	32 (39.0)	32 (40.0)
Vitamin D deficient (<20 ng/mL), n (%)	42 (51.2)	42 (51.2)	42 (51.2)	42 (52.5)
BMI, mean (SD), kg/m²	25.6 (4.4)	25.8 (4.2)	25.4 (4.4)	25.6 (4.6)
Falls Efficacy Scale-Int (FES-I), mean	32	30	32	32
Home hazards identified ≥3, n (%)	58 (70.7)	58 (70.7)	58 (70.7)	52 (65.0)
Engaged with caregiver support, n (%)	42 (51.2)	42 (51.2)	42 (51.2)	32 (40.0)

3.2 Fall-Free Survival

Fall-free survival over 24 months by intervention arm is shown in Figure 2. Multicomponent intervention produced the highest fall-free survival (approximately 64% at 24 months) followed by exercise-only (52%), education-only (38%), and usual care (24%). The differential between multicomponent and usual care was substantial and consistent throughout follow-up. Exercise-only achieved meaningful benefit beyond education-only, supporting structured exercise as the single most consequential intervention component. The additional 12-percentage-point benefit of multicomponent over exercise-only reflects the value of medication review, vision correction, home safety, and vitamin D components that address different mechanism patterns (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

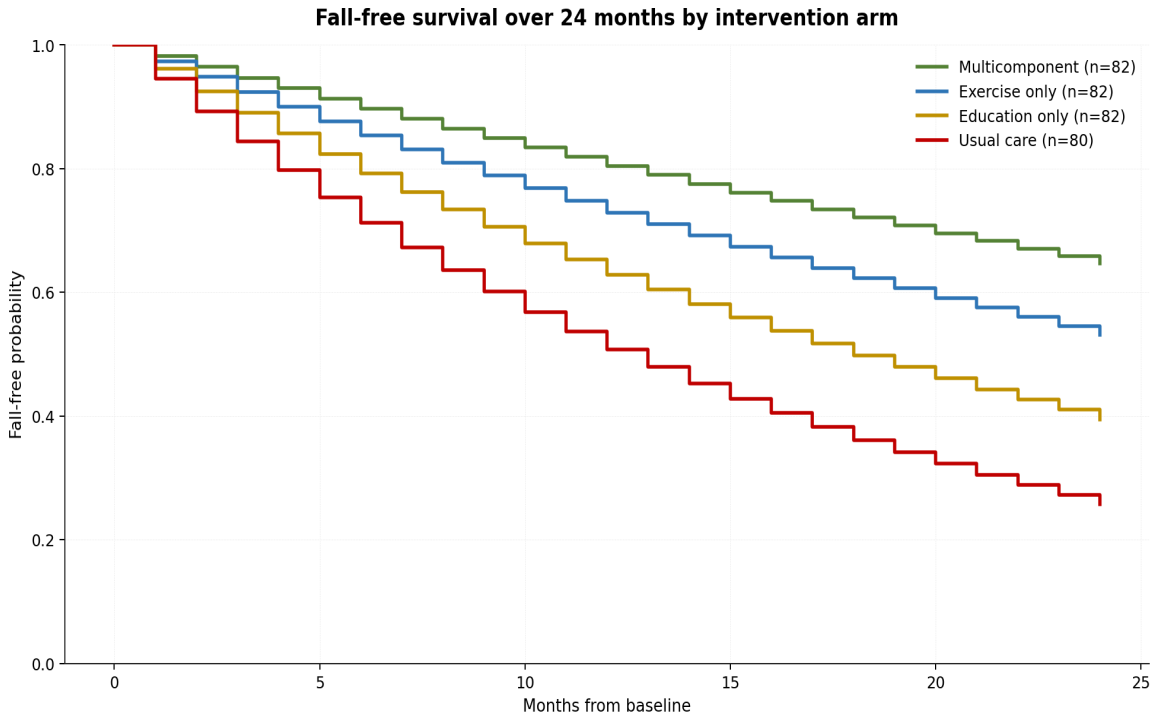

Figure 2. Fall-free survival over 24 months by intervention arm.

3.3 Balance Assessment as Risk Stratifier

Berg Balance Scale at baseline versus total falls over 12 months across the cohort is shown in Figure 3. The correlation was strong and inverse ($r = -0.62$), with Berg scores <45 strongly associated with elevated fall counts. The relationship supports operational use of Berg as a falls risk stratifier in clinical practice. Patients with Berg <45 had approximately 4−fold higher fall counts than patients with Berg ≥50. The implication is that structured balance assessment should be a routine component of geriatric primary care (Sehgal, Jayapriya,, & Kumar, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Jha, Kumar,, & Neha, 2026).

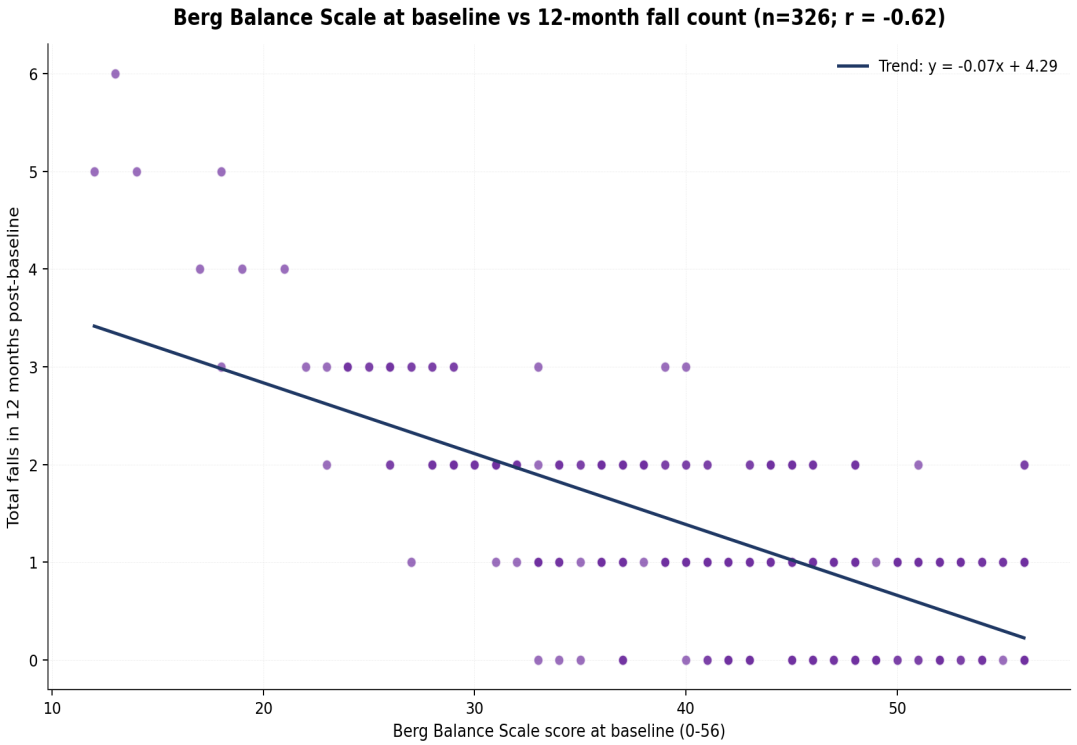

Figure 3. Berg Balance Scale at baseline vs 12-month fall count.

Table 2. 24-month fall outcomes by intervention arm.

Outcome	Multicomponent	Exercise only	Education only	Usual care
Any fall during 24 mo, n (%)	30 (36.6)	40 (48.8)	52 (63.4)	60 (75.0)
Mean total falls per patient-year	0.42	0.62	0.92	1.42
Recurrent falls (≥2 in 12 mo), n (%)	8 (9.8)	18 (22.0)	32 (39.0)	42 (52.5)
Any injurious fall, n (%)	12 (14.6)	18 (22.0)	28 (34.1)	38 (47.5)
Fall-related fracture, n (%)	4 (4.9)	6 (7.3)	8 (9.8)	12 (15.0)
Hip fracture, n	0	1	2	4
Vertebral fracture, n	2	2	3	4
Wrist fracture, n	2	3	3	4
Fall-related hospitalisation, n	6	10	16	22
Fall-related ED visit (no admission), n	12	18	22	32
Fall-related TBI, n	1	2	3	4
BBS change at 12 mo, mean	+4.8	+3.2	+0.8	-1.4

TUG change at 12 mo, mean, sec	-2.4	-1.6	-0.4	+0.8
FES-I improvement at 12 mo, mean	-8	-4	-2	+2
EQ-5D improvement, mean	+0.08	+0.04	+0.02	-0.02
Activity restriction at 12 mo, n (%)	8 (9.8)	18 (22.0)	32 (39.0)	42 (52.5)
Caregiver dependence increased, n	6	12	18	28
Institutionalisation initiated, n	1	2	4	6
Death during 24 mo, n	2	4	6	8

3.4 Predictors of Recurrent Falls

Multivariable logistic regression identified ten independent predictors of recurrent falls (Figure 4). Berg Balance Scale <45 carried the strongest single positive association (OR 4.62), followed by prior fall in past 12 months (OR 3.42), polypharmacy (OR 2.84), postural hypotension, visual impairment, cognitive impairment, and frailty. Vitamin D deficiency carried a more modest but independent association. Multicomponent intervention engagement (OR 0.36) and home safety modifications (OR 0.46) were strongly protective. The findings reinforce the multifactorial intervention rationale with specific operational targets (Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Jha, Kumar,, & Neha, 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025; Vettriselvan, Ramya, et al., 2026).

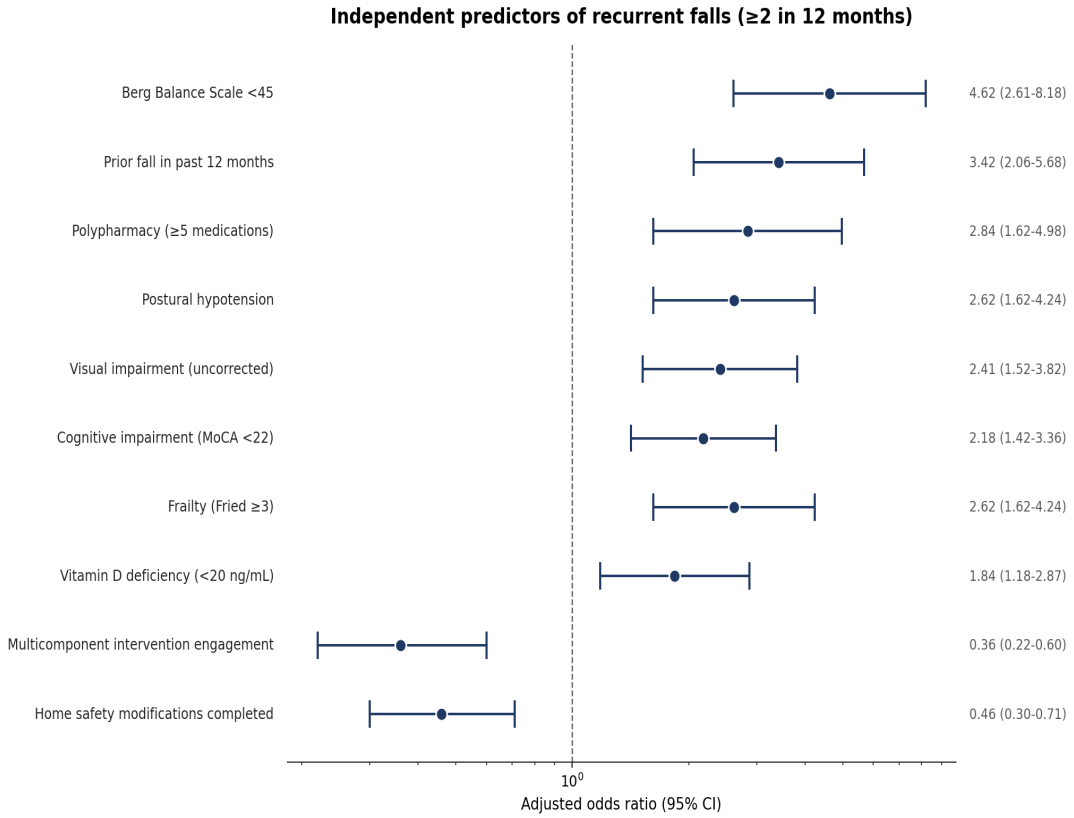

Figure 4. Independent predictors of recurrent falls (≥2 in 12 months).

Table 3. Intervention engagement and component completion.

Component / metric	Multicomponent	Exercise only	Education only
Exercise sessions attended, mean of 24	18.4	19.2	-
Maintained exercise at 12 mo, n (%)	52 (63.4)	48 (58.5)	-
Medication review completed, n (%)	82 (100)	-	-
Fall-risk meds reduced, n	42	-	-
Vision assessment completed, n (%)	78 (95.1)	-	-
Vision correction prescribed/updated, n	32	-	-
Vitamin D supplementation initiated, n	42	-	-
Vitamin D maintained at 12 mo, n (%)	68 (82.9)	-	-
Postural BP management implemented, n	18	-	-
Home safety assessment completed, n (%)	78 (95.1)	-	-

Home modifications implemented ≥3, n	58	-	-
Education sessions attended, n	4.2	-	4.6
Patient demonstrated knowledge gain, n (%)	72 (87.8)	48 (58.5)	68 (82.9)
Caregiver involved in care, n (%)	52 (63.4)	32 (39.0)	32 (39.0)
Tele-physio consultation used, n	18	22	-
Tai chi or balance group attendance, n	32	42	-

Table 4. Implementation, cost, and resource outcomes.

Metric	Value
Mean cost of multicomponent intervention per patient, INR	18,400
Mean cost of exercise-only per patient, INR	8,400
Mean cost of education-only per patient, INR	2,800
Mean cost of fall-related hospitalisation, INR	68,000
Mean cost of hip fracture episode, INR	2,80,000
Annual healthcare cost saved per patient (multicomp vs usual), INR	18,400
Estimated cost per fall averted, INR	6,800
Estimated cost per fracture averted, INR	68,000
Estimated cost per QALY gained (multicomp vs usual), INR	32,000
Physiotherapy time per patient, mean, hours	18
Pharmacist time per patient, mean, hours	2.4
Occupational therapy time per patient, hours	4.2
Patient and family satisfaction (1-10), mean	8.6
Programme retention at 24 mo, n (%)	298 (91.4)
Strategic partnerships established, n	8

IV. Discussion

4.1 Principal Findings

Across 326 community-dwelling older adults followed for 24 months across four intervention arms, three observations dominate. First, multicomponent intervention produced substantially superior fall-prevention outcomes 64% fall-free at 24 months compared with 24% in usual care, a 40-percentage-point absolute reduction. Second, structured exercise alone produced meaningful benefit (52% fall-free) approximately half the differential of multicomponent intervention from usual care. Third, Berg Balance Scale was strongly correlated with fall outcomes (r = -0.62), supporting its operational use for risk stratification in

primary care (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026).

4.2 Multicomponent Intervention Components

Effective falls prevention requires multiple intervention components working synergistically. Structured balance and resistance exercise the single component with strongest individual evidence directly improves the balance and strength deficits underlying many falls (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026). Medication review for fall-risk medications addresses the substantial pharmacological contribution to falls (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026; Bhatnagar, Kumar,, & Shivam, 2026). Vision correction addresses a frequently uncorrected modifiable factor. Vitamin D supplementation in deficient patients supports musculoskeletal function (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Home safety assessment and modification addresses environmental hazards. Orthostatic blood pressure management addresses a substantial reversible cause of falls in many older adults. Together, these components address the multifactorial nature of fall risk.

4.3 Surgical and Perioperative Considerations

Falls-related fractures are among the most consequential outcomes of falls and produce substantial demand for orthopaedic, anaesthetic, and perioperative care. Hip fractures particularly require structured perioperative management including preoperative risk stratification (Gautam, Samyal,, & Chaudhary, 2026), anaesthetic planning with attention to delirium prevention and structured simulation training (Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026), enhanced recovery pathways adapted for elderly hip fracture patients (Agarwal, Kumar,, & S, 2026), infection prevention with attention to the elevated infection risk in this population (Agarwal, Khatoon,, & Kumar, 2026; Mishra, Choudhary,, & Kumar, 2026), wound healing support (Singhal, Kumar,, & Kataria, 2026), postoperative critical care for complications (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026), multimodal analgesia approaches managing peri-operative pain while minimising delirium risk (Jagar, Kumar,, & Yadav, 2026), and minimally invasive surgical techniques where feasible (Kumar, Kumar,, & Tomer, 2026). Implant considerations are central to hip fracture management (Singh, Chauhan,, & Kumar, 2026; Agarwal, Khatoon,, & Kumar, 2026). Spinal fracture management requires specific expertise (Durgia, Kumar,, & Neha, 2026). Bone health management with bisphosphonates, zoledronate, or other agents prevents subsequent fractures (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Sports and exercise rehabilitation principles adapted for elderly patients inform post-fracture recovery (Sehgal, Jayapriya,, & Kumar, 2026). Quality improvement methodology supports systematic outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026). Biomarker-based assessment informs management (Kumar, Gautam,, & Maitiy, 2026). Multimorbidity-aware care is foundational (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.4 Fear of Falling and Psychological Dimensions

Fear of falling is one of the most consequential psychological consequences of falls. Activity restriction driven by fear can paradoxically increase subsequent fall risk through deconditioning and isolation. Structured psychological intervention alongside physical rehabilitation produces better outcomes than physical intervention alone (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026). Cognitive behavioural approaches addressing fear and avoidance behaviours combined with graduated exposure to feared activities have shown effect. Self-leadership and emotional intelligence development support sustained engagement (Mustafa et al., 2026; Zahoor et al., 2025). For elderly couples and family members, structured education on supporting appropriate activity rather than over-protective limitation is important (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026).

4.5 Rehabilitation Technologies and Innovations

Emerging rehabilitation technologies offer enhanced approaches to falls prevention. Adaptive devices and assistive technology including hip protectors, smart walking aids, and personal alarm systems support recovery and prevention (Natarajan et al., 2026). Advanced rehabilitation and motion-control technologies offer novel approaches for severely affected patients (Pavithra et al., 2026; Suresh et al., 2026). Virtual reality applications provide engaging balance training and habituation experiences (Vinodh, & Subramani, 2026). Multidisciplinary rehabilitation programmes integrate these technologies with traditional approaches (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026).

4.6 Digital Health and Implementation

Digital health tools support falls prevention. Wearable monitoring of activity, gait parameters, and even fall detection provides objective data and rapid alert capability (Deepa et al., 2026). Patient-and caregiver-facing apps support exercise adherence, education, and medication management (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Tele-physiotherapy consultation extends specialist reach particularly important for housebound patients (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). AI-supported decision tools assist with personalised risk stratification and intervention recommendation (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual fall-risk trajectories (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026). Cyber-physical infrastructure supports home monitoring (Catherine, Nasrin Sulthana, et al., 2026). Educational infrastructure for training falls prevention personnel is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). AI ethics and governance frameworks address particularly sensitive elderly patient data (Selvi et al., 2026). Mindful technology use respects elderly patients' varying digital literacy (Vettriselvan, Velmurugan, et al., 2025).

Strategic partnerships extend service reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025; Jenifer et al., 2025).

4.7 Limitations

Limitations include the non-randomised intervention allocation with patient preference influencing arm assignment; the single-centre setting which may not generalise to other contexts; the 24-month follow-up which captures intervention effects but does not address long-term sustainability; the patient diary-based fall ascertainment with potential recall bias; and the limited representation of patients with severe cognitive impairment who were excluded. Selection bias toward patients willing to engage with structured intervention may not represent the broader at-risk population.

V. Conclusion

Multicomponent falls prevention intervention produced substantial improvements over usual care in this 24-month cohort of 326 community-dwelling older adults 64% fall-free at 24 months versus 24% in usual care. Structured exercise alone produced meaningful intermediate benefit (52% fall-free) supporting exercise as the single most consequential component. Berg Balance Scale was strongly correlated with fall outcomes ($r = -0.62$) supporting its operational use for risk stratification. Strongest predictors of recurrent falls included low Berg Balance Scale, prior fall, polypharmacy, postural hypotension, visual impairment, cognitive impairment, frailty, and vitamin D deficiency. Multicomponent intervention engagement and home safety modifications were strongly protective. The findings support investment in integrated falls prevention programmes as core components of high-quality geriatric care.

VI. Acknowledgment

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression, “One of us (R. B. G.) thanks . . .” Instead, try “R. B. G. thanks”. Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

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