

Landing Safely to Prevent Fall Injuries

Authors: Steven Phu, Kim Delbaere, Daina Sturnieks, Stephen Lord

Summary:

- Falls and fall-related injuries are a significant concern, with one third of older people falling annually and falls being the leading cause of hospitalised injuries in NSW.
- The way older people fall, including their body position, contact points and stiffness, can determine whether they do or do not sustain an injury.
- Safe landing techniques, such as martial arts-adapted tuck-and-roll techniques and landing while absorbing impact forces (e.g., bending the elbows) show promise in reducing injuries from falls.
- Preliminary evidence suggests that older people can learn safe landing techniques. However, practical applications are limited by safety concerns.
- Proven interventions such as balance and functional strength exercise should remain the priority for fall prevention. Safe landing strategies may complement these approaches for some older people, though more research is required.

Understanding the act of falling

Falls and fall-related injuries are a significant issue in older people, with one-third of older people falling each year (1). Falls are the leading cause of hospitalised-injury in Australia (2). Falling can be categorised into three phases – destabilisation, descent and impact (3). Numerous interventions have targeted destabilisation to prevent falls in older people, including exercise interventions and risk management (e.g. addressing vision impairment, foot problems, and environmental hazards) and multifactorial interventions that address multiple fall risk factors (4–6).

Reducing fall-related injuries

Complementary research has sought to reduce the risk of fall injury during descent and/or impact phases of a fall. Passive approaches, such as hip protectors and compliant flooring, aim to minimise impact forces when the body contacts the ground. Hip protectors have shown effectiveness in preventing hip fractures in residential care settings, but not in community

settings (7,8), where low adherence due to inconvenience, discomfort and stigma reduce their utility (9). Compliant flooring has shown promise in absorbing impact forces without impairing balance (10), though mixed results have been reported regarding their effectiveness in preventing fall injuries in long-term care facilities (11,12).

Active approaches, which teach people how to minimise harm from falls have also been explored. These interventions focus on reducing the impact forces experienced during a fall to lower the risk of injury (13–15). For example, falling forwards with bent arms to slow body motion can reduce wrist impact forces by 40% compared to falling with stiff arms (14). Similarly, adopting specific knee positions during a fall can reduce hip impact forces by more than 50% (13). However, these studies have predominantly involved young, healthy people, leaving uncertainty about whether similar benefits can be achieved in older people, who often have reduced muscle strength, slower reaction time, decreased flexibility and increased fear of falling.

Review of safe landing strategies

A 2017 systematic review identified 13 studies on safe landing strategies (15), including techniques such as squatting when falling backwards, bending the elbows when falling forwards and employing a rolling and forward rotation technique (Figure 1) when falling sideways. These strategies were found to be effective in reducing hip impact forces and optimising trunk positioning. However, the review highlighted significant limitations, such as few studies involving older people and the absence of unpredictable balance disturbances during assessments (16).

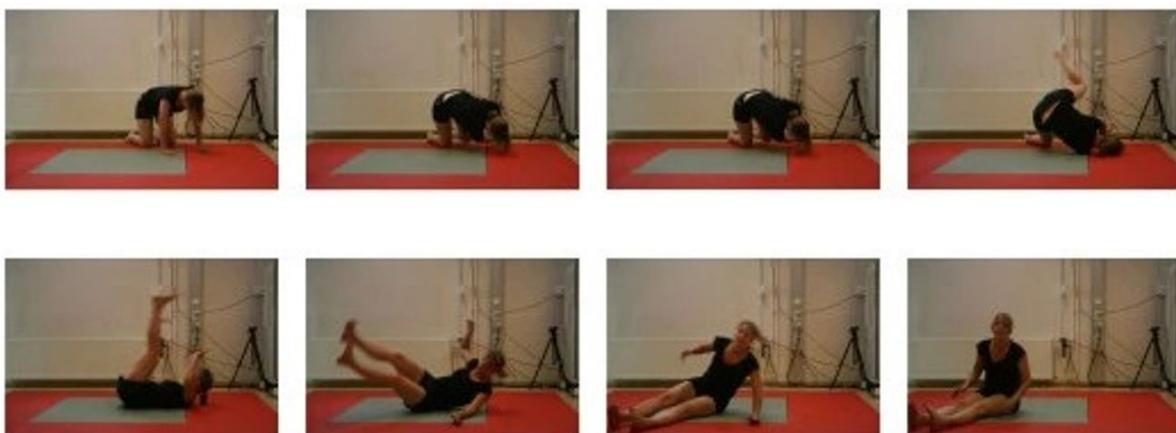


Figure 1. An example of a martial arts rolling technique taught for safe landing from a fall.
Adapted from Groen et al. (17).

Safe landing training programs for older people

Six studies have specifically investigated whether healthy, community-dwelling older people can learn safe falling techniques, often in the form of martial arts movements (Table 1). For example, Groen et al reported martial arts training reduced hip impact forces during a fall by up to 30%, regardless of whether the arms were used to break the fall (18) due to the rolling action absorbing the impact forces (18). Similarly, Moon et al evaluated the effectiveness of a single training session of the martial arts-inspired tuck-and-roll technique (19). Participants lowered their bodies with bent knees, tucked their chins and rolled upon contact with the ground, resulting in significantly reduced hip impact forces. Importantly, training on one side (e.g., right) transferred effectively to the opposite side (e.g., left), suggesting some generalisability.

Table 1. Summary of findings from interventions training safe falling strategies in older people

Author	Technique	Findings
Arkkukangas et al. (20,21)	Judo4Balance – program containing a mix of strength/power/balance training and breakfall techniques	Improved performance of practiced landing techniques (higher grading of Judo fall technique achieved)
Arkkukangas et al. (22)	FallFitness – an initial strength and functional training block, followed by paired balance training. Safe landing for backward and sideways falls was practiced in all sessions	Improved physical activity levels and backward and sideways falling techniques (higher level achieved)
Arnold et al. (23,24)	Fall arrest strategy training – lower limb strength, balance and agility combined with upper limb strength/power and reaching exercises	Improved speed of arm protective responses (faster time to reach and touch a wall opposite the participant)
Groen et al. (16,18)	Five sessions – balance and gait exercises combined the falling techniques based on martial arts in forward, backward and lateral directions	Reduced impact forces following a self-initiated fall from a kneeling position
Moon et al. (19)	Martial arts adapted tuck and roll strategy training	Reduced hip impact forces after one training session and transfer of training from right side to left side falls
Zanotto et al. (25)	Falling Safely Training study – a martial arts adapted tuck and roll strategy training	Participants reported increased confidence and self-efficacy in preventing harm from falls

Combining safe landing with exercise-based approaches to fall and injury prevention

A combined approach incorporating safe landing training, exercise (balance and functional strength) (26) and step training (27) may be beneficial for preventing both falls and fall-related injuries. Five studies have used this combined approach. In one study, five sessions combining balance and gait exercises with martial arts-inspired falling techniques (28), enabled older people to reduce their impact forces following a self-initiated fall (16). Another study combined strength, power and balance training with breakfall techniques derived from Judo (20–22) and demonstrated improvements in landing technique. The FALLing Safely Training (FAST) study used a 4-week program (two 30 min sessions per week) to progressively teach martial arts-derived tuck-and-roll strategies, starting from the floor and progressing to a standing position (25). Preliminary findings indicated increased confidence in falling safely and protecting the head during a fall (29), with main results pending publication. Finally, the Fall Arrest Strategy Training program combined balance, agility and lower limb strength exercises with forward landing training (23,24), and was found to be effective in improving reaction times (24), and upper limb strength and range of motion (23) potentially reducing the likelihood of head impact during a fall (24).

Conclusions, challenges and opportunities

There is growing evidence that body position and landing strategies during a fall can significantly reduce injury risk. Safe landing techniques, particularly those derived from martial arts, can be learned in an effective manner to reduce impact forces among older people. However, several challenges remain. Long-term studies are needed to assess the durability of these skills and their real-world effectiveness in reducing fall-related injuries. Safety concerns during training must be addressed with robust protocols, especially for frail older adults. Middle-aged individuals or healthier older people may be appropriate groups to trial these techniques, given their greater physical capabilities and lower injury risk.

Before safe landing strategies can be implemented more widely, further research is needed to establish long-term effectiveness, refine training protocols to enhance safety and determine the optimal populations and settings. Pending supporting research findings, these interventions may complement proven interventions such as balance and functional strength exercises to deliver a comprehensive approach to reducing fall-related injuries.

References

1. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. *Age Ageing*. 2006 Sep 1;35(suppl_2):ii37–41.
2. Injury in Australia: Falls [Internet]. Australian Institute of Health and Welfare; 2023 Jul [cited 2024 Jan 30]. (Injury in Australia). Available from: <https://www.aihw.gov.au/reports/injury/falls>
3. Hsieh KL, Sosnoff JJ. A Motor Learning Approach to Reducing Fall-Related Injuries. *J Mot Behav*. 2021;53(5):663–7.
4. Gillespie LD, Robertson MC, Gillespie WJ, Sherrington C, Gates S, Clemson LM, et al. Interventions for preventing falls in older people living in the community. *Cochrane Database Syst Rev*. 2012 Sep 12;2012(9):CD007146.
5. Clemson L, Stark S, Pighills AC, Fairhall NJ, Lamb SE, Ali J, et al. Environmental interventions for preventing falls in older people living in the community - Clemson, L - 2023 | Cochrane Library. [cited 2024 Nov 29]; Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD013258.pub2/full>
6. Hopewell S, Adedire O, Copsey BJ, Boniface GJ, Sherrington C, Clemson L, et al. Multifactorial and multiple component interventions for preventing falls in older people living in the community - Hopewell, S - 2018 | Cochrane Library. [cited 2024 Nov 29]; Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD012221.pub2/full>
7. Da Q, Xiao Y, Wu F, Chen Y, Li L. Does hip protector prevent falls and hip fractures? An umbrella review of meta-analyses. *BMC Geriatr*. 2024 Jun 12;24(1):514.
8. Gillespie WJ, Gillespie LD, Parker MJ. Hip protectors for preventing hip fractures in older people - Gillespie, WJ - 2010 | Cochrane Library. [cited 2024 Nov 29]; Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD001255.pub4/full>
9. Parker MJ, Gillespie WJ, Gillespie LD. Effectiveness of hip protectors for preventing hip fractures in elderly people: systematic review. *BMJ*. 2006 Mar 11;332(7541):571–4.
10. Laing AC, Robinovitch SN. Low stiffness floors can attenuate fall-related femoral impact forces by up to 50% without substantially impairing balance in older women. *Accid Anal Prev*. 2009 May 1;41(3):642–50.
11. Mackey DC, Lachance CC, Wang PT, Feldman F, Laing AC, Leung PM, et al. The Flooring for Injury Prevention (FLIP) Study of compliant flooring for the prevention of fall-related injuries in long-term care: A randomized trial. *PLOS Med*. 2019 Jun 24;16(6):e1002843.
12. Knoefel F, Patrick L, Taylor J, Goubran R. Dual-Stiffness Flooring: Can It Reduce Fracture Rates Associated With Falls? *J Am Med Dir Assoc*. 2013 Apr 1;14(4):303–5.
13. Lim KT, Choi WJ. Effect of fall characteristics on the severity of hip impact during a fall on the ground from standing height. *Osteoporos Int J Establ Result Coop Eur Found Osteoporos Natl Osteoporos Found USA*. 2020 Sep;31(9):1713–9.

14. DeGoede KM, Ashton-Miller JA. Fall arrest strategy affects peak hand impact force in a forward fall. *J Biomech.* 2002 Jun;35(6):843–8.
15. Moon Y, Sosnoff JJ. Safe Landing Strategies During a Fall: Systematic Review and Meta-Analysis. *Arch Phys Med Rehabil.* 2017 Apr;98(4):783–94.
16. Groen BE, Smulders E, de Kam D, Duysens J, Weerdesteyn V. Martial arts fall training to prevent hip fractures in the elderly. *Osteoporos Int J Establ Result Coop Eur Found Osteoporos Natl Osteoporos Found USA.* 2010 Feb;21(2):215–21.
17. Groen BE, Smulders E, Duysens J, van Lankveld W, Weerdesteyn V. Could martial arts fall training be safe for persons with osteoporosis?: a feasibility study. *BMC Res Notes.* 2010 Apr 22;3:111.
18. Groen BE, Weerdesteyn V, Duysens J. Martial arts fall techniques decrease the impact forces at the hip during sideways falling. *J Biomech.* 2007;40(2):458–62.
19. Moon Y, Bishnoi A, Sun R, Shin JC, Sosnoff JJ. Preliminary investigation of teaching older adults the tuck-and-roll strategy: Can older adults learn to fall with reduced impact severity. *J Biomech.* 2019 Jan 23;83:291–7.
20. Arkkukangas M, Bååthe KS, Hamilton J, Ekholm A, Tonkonogi M. Feasibility of a novel Judo4Balance - fall preventive exercise programme targeting community-dwelling older adults. *J Frailty Sarcopenia Falls.* 2020 Sep;5(3):47–52.
21. Arkkukangas M, Strömqvist Bååthe K, Ekholm A, Tonkonogi M. High Challenge Exercise and Learning Safe Landing Strategies among Community-Dwelling Older Adults: A Randomized Controlled Trial. *Int J Environ Res Public Health.* 2022 Jun 16;19(12):7370.
22. Arkkukangas M, Bååthe KS, Hamilton J, Hassan A, Tonkonogi M. FallFitness exercise program provided using the train-the-trainer approach for community-dwelling older adults: a randomized controlled trial. *BMC Geriatr.* 2024 Nov 30;24(1):983.
23. Arnold CM, Walker-Johnston J, Lanovaz JL, Lattimer LJ. Does Fall Arrest Strategy Training Added to a Fall Prevention Programme Improve Balance, Strength, and Agility in Older Women? A Pilot Study. *Physiother Can.* 2017;69(4):323–32.
24. Arnold CM, Lanovaz J, Farthing JP, Legg H, Weimer M, Kim S. Fall arrest strategy training improves upper body response time compared to standard fall prevention exercise in older women: A randomized trial. *Clin Rehabil.* 2022 Jul;36(7):940–51.
25. Zanotto T, Chen L, Fang J, Bhattacharya SB, Alexander NB, Sosnoff JJ. Minimizing fall-related injuries in at-risk older adults: The falling safely training (FAST) study protocol. *Contemp Clin Trials Commun.* 2023 Jun;33:101133.
26. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community - Sherrington, C - 2019 | *Cochrane Library.* [cited 2024 Dec 12]; Available from: <https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD012424.pub2/full>
27. Okubo Y, Schoene D, Lord SR. Step training improves reaction time, gait and balance and reduces falls in older people: a systematic review and meta-analysis. *Br J Sports Med.* 2017 Apr;51(7):586–93.

28. Weerdesteyn V, Rijken H, Geurts ACH, Smits-Engelsman BCM, Mulder T, Duysens J. A Five-Week Exercise Program Can Reduce Falls and Improve Obstacle Avoidance in the Elderly. *Gerontology*. 2006 Apr 27;52(3):131–41.
29. Zanotto A, Zanotto T, Alexander NB, Sosnoff JJ. Views and experiences of older people taking part in a safe-falling training program: Lessons learned from the Falling Safely Training (FAST) trial. *BMC Geriatr*. 2024 Oct 11;24(1):818.