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# Gait instability in community-dwelling older fallers: How visual search behaviors reveal hidden fall risk

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ABSTRACT

*Introduction*: Falls during walking contribute significantly to injuries in older adults, with gait instability being a key risk factor. While visual search behaviors are essential for safe navigation, their relationship to instability remains unclear. This study compared visual search behaviors during walking between community-dwelling older adults with and without a fall history and examined their association with gait instability. *Methods:* Seventy-four older adults (mean age: 70.7 ± 3.9 years; 37 fallers, 37 non-fallers) walked at a self-selected pace along an 8-m level-ground walkway for five trials. Gait stability was assessed by variability of spatial and temporal gait parameters, where greater variability reflects reduced stability. Visual search behaviors were assessed by the percentage of total fixations and the percentage of total fixation duration directed towards the ground (floor area of the walkway), the destination (end-point of the walkway), and random areas (non-task-relevant areas). *Results:* No significant differences in visual search behaviors were observed between groups. In fallers, greater variability of stride time was associated with greater percentages of the number of fixations on the ground ($\rho = 0.348$, $p = 0.043$), while greater variability of step width was associated with fewer percentages of the number of fixations ($\rho = -0.464$, $p = 0.006$) and fixation duration on the destination ($\rho = -0.452$, $p = 0.007$). These associations were not apparent in non-fallers. *Conclusions:* Despite similar visual search behaviors between older fallers and non-fallers, fallers exhibited unique associations between reduced visual scanning towards the destination and lateral instability (i.e., increased variability of step width) during walking—an effective predictor of falls. This suggests maladaptive visuomotor behaviors and compromised gait stability may be interrelated, collectively increasing fall injury risk in older fallers. *Practical Applications:* The observed associations suggest that visuomotor training could be explored in fall prevention programs to improve gait safety in older fallers. Future studies should investigate causality and evaluate efficacy in hazard-rich environments.

## 1. Introduction

Falls are most prevalent among older adults while walking, typically resulting from tripping, slipping, or missteps (Robinovitch et al., 2013). Maintaining a safe and steady gait is essential for older adults to remain independent and reduce fall-related injuries in the community (Hamacher et al., 2011). Vision plays a central role in supporting and coordinating effective locomotion (Patla, 1998). In particular, Patla (1997) proposed that visual input is crucial for proactive gait adjustments to maintain stability in dynamic environments, implement avoidance strategies, and plan routes to destinations that may not be immediately visible. As a result, visual-spatial information enables the anticipatory adjustment of gait patterns, ensuring safe navigation through both natural and hazardous environments (Matthis et al., 2018; Matthis & Fajen, 2014).

Previous research has discussed various visual strategies employed by older walkers navigating complex walking environments. For instance, older adults at low risk of falling tend to use exploratory and proactive visual strategies. They frequently fixate on, and shift their gaze between, upcoming environmental challenges (Young et al., 2012). In contrast, older adults at high risk of falling tend to consciously monitor their movements and focus their gaze on the immediate walking

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path—possibly attempting to minimize the immediate risk of tripping—while displaying limited visual planning/previewing of upcoming hazards or stepping targets (Young et al., 2012). Critically, this limited visual search strategy has been associated with compromised stepping accuracy, which could escalate injury risk in unpredictable settings (Ellmers, Cocks, & Young, 2020). These results indicate that restricted visual planning/previewing among older adults at high risk of falling may hinder their ability to anticipate and respond to potential environmental hazards while navigating complex walking environments.

A common factor that might result in excessive attention towards the ground or a heightened tendency of conscious movement control in older adults is a history of falls (Masters & Maxwell, 2008). Previous research has shown that older individuals with a history of falls are more likely to consciously monitor and control their body movements than those without any fall history (Wong et al., 2008). From a psychomotor perspective, this group may exhibit greater internal awareness around their feet or lower limb movements due to anxiety from previous falls, which encourages them to over-reflect on the mechanics of their movements instead of detecting potential environmental hazards (Masters & Maxwell, 2008). Although previous work has shown that older fallers prioritize planning future stepping actions over executing ongoing steps when negotiating multiple obstacles (Chapman & Hollands, 2007), it remains unclear whether their heightened tendency for conscious movement control potentially manifests as increased visual attention towards the ground areas during simple walking when compared to those with a history of falls (non-fallers). While one might argue that the association may resemble the comparison between those at high and low risk of falling, the mechanisms underpinning such associations may be different due to previous experiences of falls. Therefore, this study first aims to examine these differences and enhance our understanding of how visuomotor control, as reflected in visual search behaviors during simple walking, may be associated with fall history among older adults. Understanding the association between visual search behaviors and fall history can help inform the development of more tailored gait rehabilitation strategies for fall prevention in older adults, such as incorporating visuomotor training to address suboptimal visual search behaviors identified in those with a history of falls.

Prioritizing visual information associated with conscious movement control over environmental awareness may also reduce safety by disrupting automated motor processes responsible for regulating highly coordinated actions, such as walking (Masters & Maxwell, 2008; Wulf, 2013). Earlier work has provided evidence of gait instability when older adults were instructed to consciously monitor and control their body movements while walking (Mak et al., 2020). Yet, there is limited research on how these constrained visuomotor behaviors correlate with gait instability in older adults, particularly within a cohort at high risk of falling (Deandrea et al., 2013). Such information could enhance our understanding of the extent to which specific visual search behaviors are linked to better (or poorer) gait stability. By addressing this significant research gap, researchers could develop more effective fall injury prevention strategies in geriatric rehabilitation to improve gait stability and reduce fall incidence, ultimately strengthening community safety for the older population.

Before investigating complex adaptations, it is essential to first understand how older individuals utilize vision for fundamental stability control and path anticipation in a low-demand context. Current research indicates that visual information acquired even under normal conditions (i.e., before any perturbation or obstacle negotiation) is essential for assessing an individual's capacity to react to unexpected environmental changes, thereby preventing injuries from falls (Zettel et al., 2007). Thus, this study's first objective was to examine the differences in visual search behaviors between older fallers and non-fallers in normal walking conditions. We hypothesized that older fallers would focus more on the ground area compared to older non-fallers. The second objective was to examine the association between visual search behaviors and gait stability in both groups. We hypothesized that a more constrained pattern of visual search—characterized by increased focus on the ground area and/or reduced focus on the destination—would be associated with reduced gait stability.

## 2. Materials and methods

### 2.1. Participants

Seventy-four community-dwelling older adults (mean age = 70.7 ± 3.9) were recruited through convenience sampling from local community centers. Based on an effect size of 0.86 from a previous study (Young et al., 2012), a sample size of 60 participants was deemed sufficient to achieve 90% power. The sample size was conservatively increased by approximately 20%, resulting in a total of 74 participants. All participants were aged 65 years or older and were able to walk indoors independently (without the use of walking aids). Those with untreated major neurological, vestibular or musculoskeletal disorders (e.g., Parkinson's disease or stroke), significant visual impairment (i.e., static visual acuity worse than 20/40 vision) or who scored 23/30 or less on the Chinese version of the Mini-Mental State Examination (MMSE-C) (Chiu et al., 1994) were excluded. Participants who had experienced a fall resulting in unintentional landing on the ground within the past three years were categorized as fallers (n = 37), while those without any previous fall incidents were categorized as non-fallers (n = 37). The study was approved by the host university's institutional review board. Written informed consent was obtained before any experimental procedures.

### 2.2. Procedures

The participants' demographic information was first collected, and their clinical baseline characteristics of functional mobility and falls efficacy were evaluated using established and reliable assessment tools. Functional mobility was assessed using the Timed Up & Go (TUG) test (Shumway-Cook et al., 2000). Participants were instructed to stand up from a chair and walk three meters before turning around and walking back to the chair to sit down. Falls efficacy was evaluated using the Chinese version of the Falls-Efficacy Scale International (FES-I (Ch)) (Kwan et al., 2013)—a 16-item scale that assesses participants' level of concern about falling while performing various daily tasks. Following the clinical assessments (i.e., TUG and FES-I(Ch)), participants first completed one practice walking trial on an 8-metre straight, level-ground walkway. Subsequently, all participants were invited to participate in five consecutive experimental walking trials. They were required to walk at their comfortable, natural pace to the end of the walkway.

### 2.3. Outcome measures

#### 2.3.1. Gait stability

The current study utilized a three-dimensional motion capture system (Vicon; Oxford Metrics Ltd., Oxford, UK) to measure gait kinematics. Sixteen ball-shaped reflective markers were placed at specific bony landmarks of the participants according to the Plug-in Gait lower body model used in the Vicon system and tracked by multiple infrared cameras at a sampling rate of 100 Hz (Mak et al., 2020). The marker position data were filtered using a low-pass, third-order Butterworth filter operating at 20 Hz. Heel contact and toe-off were identified based on the local vertical minimum of the heel and toe markers, respectively. A stride was defined as heel-to-heel contact between the same feet. Spatial and temporal gait parameters (i.e., stride length, step width, and stride time) were computed using MATLAB (R2015b; MathWorks Inc., USA). The mean and standard deviation (SD) of the parameters were averaged across the five trials. The SD of the related gait parameters were used to represent variability measures reflecting gait stability (Hamacher et al., 2011; Lövdén et al., 2008).

### 2.3.2. Visual search behaviors

All participants were equipped with a wireless eye tracker (Dikablis Eye Tracking Glasses; Ergoneers GmbH, Egling, Germany) with a tracking frequency of 60 Hz to record visual search behaviors. Visual fixation was defined as a gaze focused on a single location for at least 100 ms (Patla & Vickers, 1997). These fixations were then categorized into three areas of interest (AOIs): "ground area" (the floor of the walking area), "destination" (any area on the wall at the end of the walkway) and "random" (areas not included in the previous AOIs, such as equipment and cameras). Subsequently, these AOIs were used to determine the number of fixations and the duration of each fixation. The number of fixations and fixation duration for each AOI were averaged across the five trials. The number of fixations for each AOI was expressed as a percentage of the total number of fixations in a single trial, while fixation duration for each AOI was expressed as a percentage of the total duration of that trial.

### 2.4. Statistical analysis

The statistical analysis was performed using SPSS Statistics version 28.0 (IBM Corp, Armonk, NY, USA). The significance level was set at $p < 0.05$. Prior to primary analyses, we assessed the reliability of visual search parameters across trials using intraclass correlation coefficients (ICC). All measures demonstrated good to excellent reliability (ICC = 0.86) (Cicchetti, 1994; Koo & Li, 2016), supporting the use of trial-averaged values for subsequent analyses. For our first objective, the baseline characteristics (e.g., age, gender, cognitive functioning, functional mobility, and falls efficacy) and visual search behaviors were compared between fallers and non-fallers using separate independent t-tests (for continuous variables) and chi-square tests (for categorical variables). Analyses of Covariance (ANCOVAs) were also performed to compare visual search behaviors between groups while controlling for age, functional mobility, and falls efficacy. Mann–Whitney U-tests were used when data were non-normally distributed. Subsequently, for our second objective, the association between visual search behaviors and gait stability was examined in both fallers and non-fallers separately using partial correlation analysis, controlling for age, functional mobility and falls efficacy. Spearman's correlations were conducted when data were non-normally distributed. To examine whether the strength of these associations differed between groups, Fisher's r-to-z transformation was applied to the partial correlation coefficients, followed by a Z-test for independent correlations.

## 3. Results

### 3.1. Between-group comparisons

The individual baseline characteristics of fallers and non-fallers are presented in Table 1. The mean age was 70.7 ± 3.9 years. There were significant differences in gender and functional mobility between fallers and non-fallers ($p = 0.01$ and $0.02$, respectively). There were no significant differences in age, cognitive functioning, and falls efficacy between fallers and non-fallers (all $p > 0.05$).

The comparisons of visual search behaviors between fallers and non-fallers are presented in Table 2. There were no significant differences in all visual search variables between fallers and non-fallers, both before and after controlling for age, functional mobility, and falls efficacy (all $p > 0.05$).

### 3.2. Correlation analyses

This section only includes the significant correlations. A list of r-values for all analyzed correlations were presented in Supplementary Tables 1 and 2. All correlations have been adjusted for age, functional mobility, and falls efficacy.

Regarding fallers, greater variability of stride time was associated with greater percentages of the number of fixations on the ground area ($\rho = 0.348$, $p = 0.043$). Greater variability of step width was associated with fewer percentage of the number of fixations on the destination ($\rho = -0.464$, $p = 0.006$) and fewer percentage of fixation duration on the destination ($\rho = -0.452$, $p = 0.007$).

Regarding non-fallers, no significant associations were observed between any variability of gait parameters and visual search behaviors (all $p > 0.05$).

To assess whether these associations differed significantly between fallers and non-fallers, Fisher's r-to-z transformation was applied. For the association between variability of stride time and percentages of the number of fixations on the ground area, the correlation strength in fallers was significantly greater than in non-fallers ($\rho = -0.121$; $Z = 2.00$, $p = 0.046$). The associations between variability of step width and percentage of the number of fixations on the destination and percentage of fixation duration on the destination were marginally and significantly stronger in fallers compared to non-fallers, respectively ($\rho = -0.033$; $Z = -1.94$, $p = 0.052$; $\rho = 0.072$; $Z = -2.31$, $p = 0.021$) (Fig. 1).

## 4. Discussion

This study first examined whether differences existed in visual search behaviors of older fallers and non-fallers during natural level-ground walking. Our findings revealed no significant differences in visual search behaviors between the two groups. While this observation does not align with our initial hypothesis, it is not entirely unexpected, as previous research has suggested that preferential visual attention to nearby walking areas (at the expense of previewing environmental constraints) is more commonly exhibited in older adults who are anxious—potentially induced by fear of falling or environmental challenges (Ellmers, Cocks, Kal, et al., 2020). These behaviors likely serve as a compensatory mechanism to minimize the immediate injury risk of missteps by prioritizing a visual strategy that allows conscious

**Table 1**
Descriptive statistics of participants.

| | Fallers (N = 37) | Non-fallers (N = 37) | p-value |
|---|---|---|---|
| | Mean (SD) | Mean (SD) | |
| Age | 70.32 (3.66) | 71.03 (4.11) | 0.52 |
| Gender, female, n (%) | 30 (81.08) | 19 (51.35%) | 0.01* |
| Fall within 1 year, n (%) | 19 (51.35%) | – | – |
| Injurious falls, n (%) | 23 (62.16%) | – | – |
| MMSE-C | 29.32 (0.82) | 29.16 (0.83) | 0.36 |
| Timed up and go test | 10.67 (2.29) | 11.95 (2.39) | 0.02* |
| FES-I(Ch) | 37.62 (12.58) | 42.41 (12.03) | 0.07 |

*Note*. Abbreviations: SD, standard deviation; MMSE-C, Cantonese version of the Mini-Mental State Examination (maximum total score 30); FES-I(Ch), Chinese version Fall Efficacy Scale International (maximum total score 64). * denotes significant difference.

**Table 2**
Comparisons of visual search behaviors between older fallers and non-fallers.

| | Non-fallers (N = 37) | | Fallers (N = 37) | | P value |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Number of fixation – Ground area (%) | 18.82 | 17.80 | 20.46 | 20.95 | 0.92 |
| Number of fixation – Destination (%) | 68.75 | 18.87 | 64.57 | 20.54 | 0.44 |
| Number of fixation – Random (%) | 12.43 | 12.67 | 14.43 | 14.72 | 0.83 |
| Fixation duration – Ground area (%) | 12.22 | 14.60 | 14.43 | 21.25 | 0.94 |
| Fixation duration – Destination (%) | 80.55 | 16.62 | 77.10 | 22.09 | 0.75 |
| Fixation duration – Random (%) | 6.63 | 10.11 | 7.80 | 10.49 | 0.93 |

*Note.* Abbreviations: SD, standard deviation.

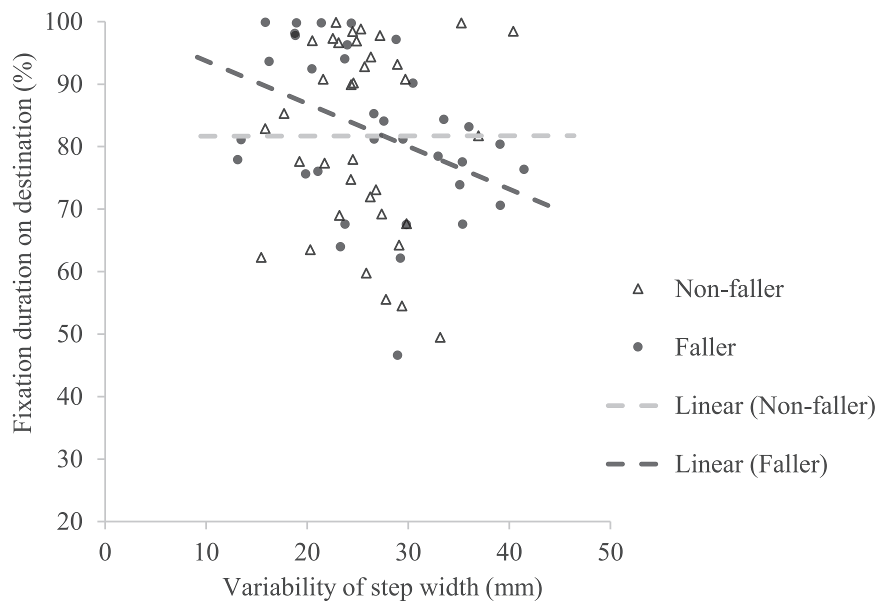


**Fig. 1.** Scatter plot showing the percentage of fixation duration on destination against the variability of step width in fallers (dark color) and non-fallers (light color).

monitoring and control of every individual step (Ellmers & Young, 2019). Given that both groups of older individuals in our cohort have similar level of falls efficacy (but different functional mobility), our observation suggests that shared psychological factors—such as anxiety linked to fear of falling—may drive similar visual search behaviors in older adults, overriding differences in physical functioning or fall experience.

Our second objective was to examine the extent to which visual search behaviors correlated with gait stability in both groups of older adults. Our findings revealed significant associations between altered visual search behaviors and gait instability in older fallers but not in non-fallers. Specifically, in fallers, more fixations on the ground area has been associated with greater variability of stride time. Conversely, fewer fixations and less time spent previewing the destination or future pathway has been associated with an increase in variability of step width – both indicative of worsened gait stability. Existing evidence has identified a link between higher step width variability and the risk of falls in older adults; studies have collectively shown that step width variability can predict falls (Brach et al., 2005, 2007; Hausdorff et al., 2001; Maki, 1997) and distinguish between older adults who fell and those who did not after slipping (Yang & Pai, 2014). Higher step width variability is likely contributed by imprecise active adjustments of lateral foot placement in older adults (Dean et al., 2007), which could, in turn, increase fall-related injury risk by compromising lateral stability during walking (Roos & Dingwell, 2010).

The current finding demonstrates evidence of how suboptimal visual search strategies are linked with gait instability, which could implicate elevated injury risk in older fallers, in addition to the known risk factor of fall history. While this observation was uniquely found in older fallers, the association appeared to be unrelated to their overall functional mobility and psychological state. We postulate that there may be additional underlying mechanisms that, whether in conjunction with or separate from visual attention, determine how older fallers control their gait stability. For example, previous research qualitatively studied the impact of falls in older adults and found that older fallers were more likely to reflect on the causes of their falls, often attributing them to their advanced age and inherent factors like physical conditions (Faes et al., 2010). This ruminations—exclusive to older fallers—could heighten their awareness of their own limitations, irrespective of their actual physical ability or any fear factor related to falling. We propose that reflecting on previous falls could result in the formation of new movement cues (e.g., 'raise my feet higher, take smaller steps') intended to prevent the perceived physical causes of earlier falls. However, fallers with a higher propensity to adopt these new movement-relevant cues were more likely to induce conscious awareness of their movement mechanics (Masters & Maxwell, 2008) in conjunction with a more constrained visual search behavior of gazing towards areas closer to their feet. This hypervigilance, characterized by over-reliance on conscious movement processing, could disrupt automatic processes of rhythmic gait control (Masters & Maxwell, 2008), thus contributing to the inconsistency of walking patterns and compromising gait safety (Barak et al., 2006; Dubost et al., 2006) – even in a normal walking environment.

Gait stability appears to be independent of visual search behaviors in older adults without a history of falls during natural walking. Previous research has reported that visual search behaviors linked with greater attention towards internal movements did not directly compromise gait safety in highly functional older adults (Ellmers, Cocks, Kal, et al., 2020). The lack of association between altered visual search behaviors and gait stability in our cohort of non-fallers—who exhibited relatively high functional capacity—may reflect compensatory behavioral adaptations (e.g., cautious gait strategies) or a reliance on non-visual cues. These adaptations may enable them to maintain their walking performance in terms of gait variability, regardless of their visual search behaviors. This interpretation is consistent with work by Pothier et al. (2015), who demonstrated that healthy older adults with high functional ability preserved walking performance comparable to young adults under dual-task conditions involving simple walking and a low-demand visual tracking task. These findings suggest that walking performance might not necessarily decline when highly functional older adults engage in visual activities (regardless of task relevance) with relatively low cognitive demands. However, one might expect walking performance of the primary task to deteriorate when the primary task (i.e., walking) becomes more challenging or when cognitive load increases (Pothier et al., 2015).

Although the current findings describe the association between visual search behaviors and gait stability, such analyses cannot provide evidence of a causal relationship. Future research should, therefore, look to experimentally manipulate visual patterns in older adults with and without a history of falls. Another limitation is that we did not investigate how older adults adapt in more complex walking conditions (e.g., navigating through obstacles). However, we do not consider this to be a major weakness as we provide evidence of a significant association even under a simple, natural walking task; one would logically expect the effect to be more substantial under more challenging conditions. Moreover, our use of a 3-year fall history window is consistent with previous studies employing extended recall periods (Choi et al., 2023), but it may capture different risk profiles than standard 12-month frameworks. Further research could evaluate how varying recall periods affect visuomotor risk profiles in older adults. Additionally, our broad AOI classification of "ground area" did not distinguish between fixations directed to near versus far areas on the floor, nor did it include head movement data, which may have limited our ability to detect specific patterns of visual search; future studies should employ more detailed spatial gaze analysis and/or incorporate head movement measures.

## 5. Practical applications

While our cross-sectional design precludes causal inferences, the observed fall-specific association between altered visual search behaviors and lateral stability suggests exploratory value in targeting visuomotor strategies to enhance safety in older fallers. A recent systematic review has suggested that rehabilitative training aimed at reducing the variability of step width while walking could effectively lower the risk of falling in older adults (Skiadopoulos et al., 2020). In line with this, our findings show that in fallers, increased fixation and time spent previewing the future pathway are associated with reduced variability of step width—a known predictor of fall risk (Brach et al., 2005, 2007; Hausdorff et al., 2001; Maki, 1997). These results justify exploring whether rehabilitative strategies targeting visual exploration (e.g., guided hazard scanning, pathway previewing) could enhance gait safety. Proactive visual exploration (e.g., scanning for tripping hazards, uneven surfaces) may theoretically enhance gait adaptability during complex locomotor tasks requiring quick, precise, and reactive stepping actions (Ellmers, Cocks, & Young, 2020), while neglect of such strategies could heighten injury risk in dynamic environments (e.g., crowded spaces or sudden obstacles in the community). Recent evidence has shown that training older individuals to direct their gaze more towards their destination, rather than the ground, can improve gait stability during adaptive walking (Mak et al., 2025). Given that current fall prevention guidelines advocate gait training for injury reduction (Moncada, 2011), our results identify a mechanistically plausible target for enhancing these protocols. Thus, future intervention studies should test whether integrating visuomotor components (e.g., obstacle negotiation drills) into fall prevention programs could improve the ability to anticipate environmental hazards and improve practical safety outcomes.

## 6. Conclusions

Our findings reveal that lateral instability during walking in older adults with a history of falls is associated with visual strategies of limited destination previewing. Critically, this relationship was not found in those without a history of falls, and it was independent of typical factors commonly associated with gait performance. Specifically, fewer fixations and time spent previewing the destination correlated with increased variability of step width –an effective predictor of falls. While causality remains unestablished, these results highlight visuomotor components as a potential intervention target for enhancing safety in high-risk populations. Future studies should investigate whether integrating visuomotor training (e.g., guided hazard scanning, pathway previewing) into fall injury prevention programs improves practical safety outcomes in older adults.

## CRediT authorship contribution statement

**Toby C.T. Mak:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Thomson W.L. Wong:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Debbie C.L. Chan:** Visualization, Formal analysis, Data curation. **Duo W.C. Wong:** Software, Resources, Formal analysis, Data curation. **Shamay S.M. Ng:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsr.2026.01.001.

## References

Barak, Y., Wagenaar, R. C., & Holt, K. G. (2006). Gait characteristics of elderly people with a history of falls: A dynamic approach. *Physical Therapy, 86*(11), 1501–1510. https://doi.org/10.2522/ptj.20050387

Brach, J. S., Berlin, J. E., VanSwearingen, J. M., Newman, A. B., & Studenski, S. A. (2005). Too much or too little step width variability is associated with a fall history in older persons who walk at or near normal gait speed. *Journal of NeuroEngineering and Rehabilitation, 2*, 21. https://doi.org/10.1186/1743-0003-2-21

Brach, J. S., Studenski, S. A., Perera, S., VanSwearingen, J. M., & Newman, A. B. (2007). Gait variability and the risk of incident mobility disability in community-dwelling older adults. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 62*(9), 983–988.

Chapman, G. J., & Hollands, M. A. (2007). Evidence that older adult fallers prioritise the planning of future stepping actions over the accurate execution of ongoing steps during complex locomotor tasks. *Gait & Posture, 26*(1), 59–67. https://doi.org/10.1016/j.gaitpost.2006.07.010

Chiu, H. F. K., Lee, H. C., Chung, W. S., & Kwong, P. K. (1994). Reliability and validity of the Cantonese version of Mini-Mental State Examination-a preliminary study. *Hong Kong Journal of Psychiatry, 4*(2), 25.

Choi, N. G., Marti, C. N., Choi, B. Y., & Kunik, M. M. (2023). Recurrent falls over three years among older adults age 70+: Associations with physical and mental health statues, exercise, and hospital stay. *Journal of Applied Gerontology, 42*(5), 1089–1100. https://doi.org/10.1177/07334648221150884

Cicchetti, D. V. (1994). Guidelines, criteria, and rules of thumb for evaluating normed and standardized assessment instruments in psychology. *Psychological Assessment, 6*(4), 284–290. https://doi.org/10.1037/1040-3590.6.4.284

Dean, J. C., Alexander, N. B., & Kuo, A. D. (2007). The effect of lateral stabilization on walking in young and old adults. *IEEE Transactions on Bio-Medical Engineering, 54*(11), 1919–1926. https://doi.org/10.1109/TBME.2007.901031

Deandrea, S., Bravi, F., Turati, F., Lucenteforte, E., La Vecchia, C., & Negri, E. (2013). Risk factors for falls in older people in nursing homes and hospitals. A systematic review and meta-analysis. *Archives of Gerontology and Geriatrics, 56*(3), 407–415. https://doi.org/10.1016/j.archger.2012.12.006

Dubost, V., Kressig, R. W., Gonthier, R., Herrmann, F. R., Aminian, K., Najafi, B., & Beauchet, O. (2006). Relationships between dual-task related changes in stride velocity and stride time variability in healthy older adults. *Human Movement Science, 25*(3), 372–382. https://doi.org/10.1016/j.humov.2006.03.004

Ellmers, T. J., Cocks, A. J., Kal, E. C., & Young, W. R. (2020). Conscious movement processing, fall-related anxiety, and the visuomotor control of locomotion in older adults. *The Journals of Gerontology: Series B, 75*(9), 1911–1920. https://doi.org/10.1093/geronb/gbaa081

Ellmers, T. J., Cocks, A. J., & Young, W. R. (2020). Evidence of a link between fall-related anxiety and high-risk patterns of visual search in older adults during adaptive locomotion. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences, 75*(5), 961–967. https://doi.org/10.1093/gerona/glz176

Ellmers, T. J., & Young, W. R. (2019). The influence of anxiety and attentional focus on visual search during adaptive gait. *Journal of Experimental Psychology: Human Perception and Performance, 45*(6), 697–714. https://doi.org/10.1037/xhp0000615

Faes, M. C., Reelick, M. F., Joosten-Weyn Banningh, L. W., de Gier, M., Esselink, R. A., & Olde Rikkert, M. G. (2010). Qualitative study on the impact of falling in frail older persons and family caregivers: Foundations for an intervention to prevent falls. *Aging & Mental Health, 14*(7), 834–842. https://doi.org/10.1080/13607861003781825

Hamacher, D., Singh, N. B., Van Dieën, J. H., Heller, M. O., & Taylor, W. R. (2011). Kinematic measures for assessing gait stability in elderly individuals: A systematic review. *Journal of the Royal Society, Interface, 8*(65), 1682–1698. https://doi.org/10.1098/rsif.2011.0416

Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: A 1-year prospective study. *Archives of Physical Medicine and Rehabilitation, 82*(8), 1050–1056. https://doi.org/10.1053/apmr.2001.24893

Koo, T. K., & Li, M. Y. (2016). A Guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Kwan, M. M. S., Tsang, W. W. N., Close, J. C. T., & Lord, S. R. (2013). Development and validation of a Chinese version of the Falls Efficacy Scale International. *Archives of Gerontology and Geriatrics, 56*(1), 169–174. https://doi.org/10.1016/j.archger.2012.10.007

Lövdén, M., Schaefer, S., Pohlmeyer, A. E., & Lindenberger, U. (2008). Walking variability and working-memory load in aging: A dual-process account relating cognitive control to motor control performance. *The Journals of Gerontology: Series B, 63*(3), P121–P128. https://doi.org/10.1093/geronb/63.3.P121

Mak, T. C. T., Wong, T. W. L., Leung, M. C. Y., Wong, D. W. C., Chan, D. C. L., & Ng, S. S. M. (2025). External focus strategy improves visuomotor control of gait in older adults. *Psychological Research, 89*(3), 95. https://doi.org/10.1007/s00426-025-02122-3

Mak, T. C. T., Young, W. R., Chan, D. C. L., & Wong, T. W. L. (2020). Gait stability in older adults during level-ground walking: The attentional focus approach. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 75*(2), 274–281. https://doi.org/10.1093/geronb/gby115

Maki, B. E. (1997). Gait changes in older adults: Predictors of falls or indicators of fear. *Journal of the American Geriatrics Society, 45*(3), 313–320.

Masters, R., & Maxwell, J. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology, 1*(2), 160–183. https://doi.org/10.1080/17509840802287218

Matthis, J. S., & Fajen, B. R. (2014). Visual control of foot placement when walking over complex terrain. *Journal of Experimental Psychology. Human Perception and Performance, 40*(1), 106–115. https://doi.org/10.1037/a0033101

Matthis, J. S., Yates, J. L., & Hayhoe, M. M. (2018). Gaze and the Control of Foot Placement When Walking in Natural Terrain. *Current Biology, 28*(8), 1224–1233.e5. https://doi.org/10.1016/j.cub.2018.03.008

Moncada, L. V. V. (2011). Management of falls in older persons: A prescription for prevention. *American Family Physician, 84*(11), 1267–1276.

Patla, A. E. (1997). Understanding the roles of vision in the control of human locomotion. *Gait & Posture, 5*(1), 54–69. https://doi.org/10.1016/S0966-6362(96)01109-5

Patla, A. E. (1998). How is human gait controlled by vision? *Ecological Psychology, 10*(3–4), 287–302. https://doi.org/10.1207/s15326969eco103&4_7

Patla, A. E., & Vickers, J. N. (1997). Where and when do we look as we approach and step over an obstacle in the travel path? *Neuroreport, 8*(17), 3661–3665. https://doi.org/10.1097/00001756-199712010-00002

Pothier, K., Benguigui, N., Kulpa, R., & Chavoix, C. (2015). Multiple object tracking while walking: Similarities and differences between young, young-old, and old-old adults. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 70*(6), 840–849. https://doi.org/10.1093/geronb/gbu047

Robinovitch, S. N., Feldman, F., Yang, Y., Schonnop, R., Lueng, P. M., Sarraf, T., Sims-Gould, J., & Loughin, M. (2013). Video capture of the circumstances of falls in elderly people residing in long-term care: An observational study. *Lancet, 381*(9860), 47–54. https://doi.org/10.1016/S0140-6736(12)61263-X

Roos, P. E., & Dingwell, J. B. (2010). Influence of simulated neuromuscular noise on movement variability and fall risk in a 3D dynamic walking model. *Journal of Biomechanics, 43*(15), 2929–2935. https://doi.org/10.1016/j.jbiomech.2010.07.008

Shumway-Cook, A., Brauer, S., & Woollacott, M. (2000). Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. *Physical Therapy, 80*(9), 896–903.

Skiadopoulos, A., Moore, E. E., Sayles, H. R., Schmid, K. K., & Stergiou, N. (2020). Step width variability as a discriminator of age-related gait changes. *Journal of NeuroEngineering and Rehabilitation, 17*, 41. https://doi.org/10.1186/s12984-020-00671-9

Wong, T. W. L., Masters, R. S. W., Maxwell, J. P., & Abernethy, A. B. (2008). Reinvestment and falls in community-dwelling older adults. *Neurorehabilitation and Neural Repair, 22*(4), 410–414. https://doi.org/10.1177/1545968307313510

Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology, 6*(1), 77–104. https://doi.org/10.1080/1750984X.2012.723728

Yang, F., & Pai, Y. C. (2014). Can stability really predict an impending slip-related fall among older adults? *Journal of Biomechanics, 47*(16), 3876–3881. https://doi.org/10.1016/j.jbiomech.2014.10.006

Young, W. R., Wing, A. M., & Hollands, M. A. (2012). Influences of state anxiety on gaze behavior and stepping accuracy in older adults during adaptive locomotion. *The Journals of Gerontology. Series B, Psychological Sciences and Social Sciences, 67*(1), 43–51. https://doi.org/10.1093/geronb/gbr074

Zettel, J. L., Scovil, C. Y., McIlroy, W. E., & Maki, B. E. (2007). Gaze behavior governing balance recovery in an unfamiliar and complex environment. *Neuroscience Letters, 422*(3), 207–212. https://doi.org/10.1016/j.neulet.2007.06.020

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