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Original Research Report

Gait Stability in Older Adults During Level-Ground Walking: The Attentional Focus Approach

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Abstract

Objectives: The objective of this study was to investigate the effect of attentional focus instructions on gait stability during level-ground walking among older adults.
Methods: We recruited 140 community-dwelling older adults (mean age = 70.3 years, *SD* = 4.7 years) from elderly community centers in Hong Kong. The experiment included assessments on participant's characteristics and walking trials. During walking trials, each participant was invited to walk at a self-selected pace along a 6-m walkway. Internal focus instructions (Internal condition), external focus instructions (External condition), or no instruction (Control condition) were given in a randomized order for three trials per condition, giving a total of nine walking trials. Spatial and temporal gait parameters were measured.
Results: Results showed significantly higher body sway and variability of swing and stance time under Internal condition relative to External and Control conditions. Moreover, reduced velocity and shorter steps were demonstrated under Internal condition relative to External and Control conditions.
Discussion: External focus instructions did not improve gait stability in older adults when compared to Control condition. Internal focus instructions appear to compromise gait stability. Future research should investigate if walking instructions that refer to body movements explicitly compromise gait rehabilitation for older adults in clinical settings.

Keywords: Attention, Falls and mobility problems, Locomotion, Rehabilitation

Falls in older adults can result in severe injuries including hospitalization, hip fractures, and death (Kannus et al., 1999). Even without causing serious injury, falls can have significant physical and psychological consequences on individuals such as (self-inflicted) reduction in mobility level, increased fear of falling, and decrease in quality of life (Tinetti, Mendes de Leon, Doucette, & Baker, 1994; Tinetti & Williams, 1997). As walking is the most common daily living activity and the most often reported activity during a fall (Hausdorff, Rios, & Edelberg, 2001; Prudham & Evans, 1981), maintaining stability while walking is an essential precondition for older adults avoiding falling (Hausdorff et al., 2001). It has been identified that one of the major risk factors for falls is gait instability (Granata & Lockhart, 2008). As a result, developing strategies that can potentially improve walking performance and stability in older adults is necessary to reduce their chances of falling.

A potential approach to improve walking performance and stability among older adults comes from research in motor control and learning. It has been consistently demonstrated that an individual's focus of attention has an important influence on the performance of various motor skills, including postural control and balance in older adults (Chiviacowsky, Wulf, & Wally, 2010; McNevin & Wulf, 2002; Wulf, Höß, & Prinz, 1998; Wulf, Landers, Lewthwaite, & Töllner, 2009; Wulf, McNevin, & Shea, 2001; Wulf & Prinz, 2001). Specifically, instructions that direct an individual to focus on the environmental effects of their movement(s) (external focus) have been shown to lead to a more effective motor performance than directing an individual's focus to his or her own body movements (internal focus) or no focus instructions (Wulf, 2007). For instance, in a study that looked at the differential effect induced by internal and external focus of attention on balance in older adults, participants were instructed to stand on a stabilometer and try to balance on a tilting platform to make it as horizontal as possible (Chiviacowsky et al., 2010). The internal focus instruction was to focus on maintaining their feet in a horizontal position, whereas the external focus instruction was to focus on maintaining the markers on the platform horizontal. A significantly better balance performance (i.e., increase the time in balance by maintaining the platform within ±5° of horizontal) was found in participants from the external focus group compared to those from the internal focus group. The results from this study indicate that the effectiveness of adopting an external focus of attention is generalizable to older adults, albeit in a relatively static task.

Huxhold, Li, Schmiedek, and Lindenberger (2006) demonstrated that when individuals were instructed to stand still and concurrently perform a simple cognitive task, attention is presumably divided and diverted away from postural control to a suprapostural task (similar to the effect of external focus). However, when individuals were instructed to stand still without performing any cognitive task (single-task baseline), the focus of attention was directed toward the postural control task itself (similar to the effect of internal focus). This research provided evidence that a concurrent secondary perceptual task with low complexity and low cognitive demands (external focus) improved postural performance in both young and older adults when compared to a simple standing task, despite the fact that age-related declines in cognitive functioning and attentional capacity are evident in older adults. However, when given a more cognitively demanding working memory task that increased attentional demands, postural control was affected in older adults negatively. Later, Lövdén and colleagues conducted a study based on a similar concept, but in the domain of walking (Lövdén, Schaefer, Pohlmeyer, & Lindenberger, 2008). It was shown that walking variability was reduced when older adults were walking while concurrently performing a simple cognitive task (watching a random series of digits) compared to when they were walking without a concurrent task. The findings suggest that focusing on an external stimulus, provided by the secondary cognitive task, is beneficial to walking stability (on a treadmill). Conversely, directing attention inwardly and trying to control postural sway under single-task condition is detrimental to automatic motor control processes.

Previous literature suggests that falls in older adults mostly occur in dynamic (as opposed to static) settings (Hausdorff et al., 2001; Maki, 1997). However, most studies that vary internal and external attentional focus have only examined its effect on static balance ability and postural control among older adults. So far, there has been little discussion about the effects of attentional focus on performance related to dynamic walking stability. To the best of our knowledge, only one recent study has examined its effect on walking stability in older adults using a treadmill where constant perturbations were applied to participants (de Melker Worms et al., 2017). No significant difference between internal and external focus conditions was found on parameters related to gait stability. However, no control condition was included for comparison and the use of treadmill limited the ability to comprehensively reflect walking in normal/solid grounds. Thus, our present study aims to examine the effect of attentional focus instructions on gait stability during level-ground walking among older adults.

Kinematic variability is an index that can reflect movement stability (Newell & Corcos, 1993). Regarding walking movements, low variability of gait characteristics such as stride time, swing time, stance time, and stride length indicates consistency in limb movements and the largely automatic process of rhythmic gait control associated with gait safety (Dubost et al., 2006; Newell & Corcos, 1993). On the contrary, increased gait variability has been identified as a predictor of falls and considered an indication of reduced gait stability and safety (Heiderscheit, 2000; Maki, 1997). Another index to represent movement stability is body sway. Larger sway is often interpreted as poorer stability in terms of postural control (Perrin, Jeandel, Perrin, & Béné, 1997). Consequently, this study attempted to use gait variability as well as body sway (indicated by the range of lateral sway in sternum and pelvis regions) as main outcome measures to indicate walking stability under different attentional focus conditions. We hypothesized that increased gait stability (indicated by reduced gait variability and decreased body sway) in older adults would be found under external focus condition relative to an internal focus or control condition. Our second hypothesis was that reduced gait stability (indicated by greater gait variability and increased body sway) in older adults would be observed under internal focus condition relative to an external focus or control condition.

Method

Participants

In this study, 140 (100 women and 40 men) community-dwelling healthy older adults participated. Previous research by Wong and colleagues reported an effect size of 0.31, which suggests a total sample size of approximately 140 participants can provide adequate power for the study (Wong, Masters, Maxwell, & Abernethy, 2009). They were recruited from different elderly community centers in Hong Kong by convenience sampling (mean age = 70.3 years, range = 65–90 years, *SD* = 4.7). All participants were independent in ambulation without walking aids. Participants were excluded from the study if they had any history of cerebral vascular disease or any neurological impairment. Participants were also excluded if they had static visual acuity worse than 20/40 vision (assessed by the Tumbling-E eye chart) or a score of less than 24/30 on the Chinese version of the Mini-Mental State Examination which indicates mild-to-severe cognitive impairment (Chiu, Lee, Chung, & Kwong, 1994). All participants were volunteers and all gave their informed consent before participating in the study. The study was approved by the host university's institutional review board (reference no. EA1501054).

Apparatus and Task

The task required participants to walk along a 6-m level-ground walkway with their natural, self-selected pace under different attentional focus conditions. A walking path of similar length has been used in previous research, which was sufficient to determine associations between step width variability and falls in older persons (Brach, Berlin, VanSwearingen, Newman, & Studenski, 2005). A 27 in. light-emitting diode monitor with a stand that linked with a computer was positioned at the end of the walkway as the destination of each walking trial. It provided visual information for External condition. A six-camera 3D motion-capture system (ProReflex Motion Capture Unit 170 120; Qualisys, Sweden) at a sampling rate of 120 Hz was used for acquiring spatial and temporal kinematic data during the walking trials. Nineteen reflective markers were attached onto specific anatomical landmarks of participants (see Supplementary Figure 1). The location of the markers was obtained to compute gait parameters of each stride (e.g., range of body sway and variability of gait characteristics) during walking using a bespoke analysis program written in MATLAB (R2015b; MathWorks Inc., United States).

Procedure

A within-subject design was used to evaluate possible differences among conditions. Before the start of the walking trials, clinical baseline measurements were collected to assess participants' functional balance, functional mobility, and falls efficacy (Table 1). Functional balance was evaluated using the Berg Balance Scale (BBS) where higher scores represent better balance ability (Berg, Wood-Dauphine, Williams, & Gayton, 1989). A score of 45 or below out of 56 is a recognized criterion for identifying fall risk in older adults (Lajoie & Gallagher, 2004). Timed Up and Go Test (TUG) was also used to evaluate functional mobility for community-dwelling older adults (Podsiadlo & Richardson, 1991). A time of more than 14 s to complete TUG indicates high risk of falling for community-dwelling frail older adults (Shumway-Cook, Brauer, & Woollacott, 2000). For psychological measures, falls efficacy was assessed by the Falls Efficacy Scale, 13 items (FES-13; Hellström & Lindmark, 1999). Falls efficacy was defined as the degree of self-confidence of individuals to take part in usual daily activities without falling (Tinetti et al., 1994). A higher score (from a total possible score of 130) represents higher confidence or efficacy.

Table 1. Participant Characteristics

Variables	Participants in this study (*n* = 140)
Age (years), mean (*SD*)	70.3 (4.7)
Females, *n* (%)	100 (71.4)
MMSE-C, mean (*SD*)	29.1 (1.3)
BBS, mean (*SD*)	54.7 (1.4)
TUG (s), mean (*SD*)	10.95 (2.18)
FES-13, mean (*SD*)	116.4 (13.6)

Note: MMSE-C = Mini-Mental State Examination (Chinese version); BBS = Berg Balance Scale; TUG = Timed Up and Go Test; FES-13 = Falls Efficacy Scale (13 items).

Each participant first performed three practice trials along the walkway to familiarize themselves with the laboratory environment. A total of nine walking trials were subsequently performed, with three repetitions of three different attentional focus instructions. The order of attentional focus conditions was randomized across participants. For every walking trial regardless of condition, participants would hear a general instruction "You can start walking now" at the beginning, indicating they could start walking. For External condition, the specific instruction given to participants before the start of the trial was "Please focus on the random series of digits ranging from 1 to 9 that will be presented on the computer monitor at your destination during walking." Each number, with the approximate dimension of 5.5 in. × 8.5 in. presented on the monitor, lasted for at least 2 s before changing to ensure there was enough time for participants to read the numbers. The numbers were equally visible from the beginning and end of the walkway. For Internal condition, the specific instruction given to participants was "Please focus on your body movements during walking." For Control condition, no other specific instruction was given to the participants. Reminders of attentional focus instruction were given to participants prior to the start of each walking trial. The monitor was only switched on under the External condition so that it would not influence participants' attention during the other conditions.

Data Analysis

For gait parameters, marker position data were filtered with a low-pass third order Butterworth filter at 20 Hz. Heel contact was determined from the local vertical minimum of the heel marker. Toe off was defined as the significant departure from local vertical minimum of the toe marker. Basic gait parameters included stride time, stance time, swing time, percentage of double support time, stride length, step length, and step width. A stride was defined as heel-to-heel contact of the same foot. Stride time was defined as the interval between two consecutive heel strikes of the same foot. Stance time was defined as the interval from heel strike to toe off of the same foot. Swing time was defined as the interval from toe off to heel strike of the same foot. Double support time (DST) was defined as the interval during which both feet were on the ground simultaneously (expressed in percentage of 2 × DST/stride time). Stride length was defined as anterior–posterior (A-P) distance between two consecutive heel strike positions of the same foot. Step length was defined as A-P distance between two consecutive heel strike positions of the opposite feet. Step width was defined as medial–lateral (M-L) distance between two consecutive heel strike positions of the opposite feet. Movement of the sternum in M-L direction was recorded by a sternum marker. Movement of the pelvis in M-L direction was calculated by using a virtual marker generated by taking the mean of the right and left greater trochanter. The range of M-L excursion of the sternum and pelvis were computed. Variability measures were defined as the standard deviation (*SD*) of respective gait parameters. All kinematic data of the first and final meter of the walkway were trimmed to account for gait onset and termination (Brach et al., 2005). For all spatial and temporal gait parameters, mean and standard deviation were averaged bilaterally across the three trials within each corresponding condition and entered into the following statistical analyses next.

Statistical analysis was performed using SPSS, version 23.0 (level of significance was set a priori at $p < .05$). All gait parameters were compared across the three attentional focus conditions (Internal, External, and Control) using a series of one-way analysis of variance (ANOVA) with repeated measures (RM-ANOVA). All post hoc tests (pairwise comparisons) were performed with Bonferroni correction.

Results

Gait Stability–Body Sway

For M-L ranges of excursion of pelvis and sternum (Figure 1), there were significant main effects of attentional focus condition [pelvis: F (2, 278) = 8.73, $p < .001$; sternum: F (2, 278) = 12.69, $p < .001$]. Post hoc analysis revealed that ranges of excursion of both pelvis and sternum were significantly higher under Internal relative to External and Control conditions (all $ps < .05$). No significant differences were found between External and Control conditions (all $ps > .05$).

Gait Stability–Variability of Gait Characteristics

For variability of all temporal gait characteristics (DST, stance time, swing time, and stride time; Figure 2), there were significant main effects of attentional focus condition [DST: F (1.80, 249.66) = 4.05, $p = .02$; stance time: F (1.90, 264.51) = 15.01, $p < .001$; swing time: F (2, 278) = 25.16, $p < .001$; stride time: F (2, 278) = 3.16, $p = .04$]. Post hoc analysis revealed that variability of stance time and swing time were significantly greater under Internal relative to External and Control conditions (all $ps < .001$). However, variability of DST and stride time did not significantly differ in any condition (all $ps > .05$). No significant differences were found between External and Control conditions for any variable (all $ps > .05$).

For variability of spatial gait characteristics (Figure 3), there were significant main effects of attentional focus condition for variability of stride length, F (2, 278) = 3.21, $p = .04$. However, post hoc analysis revealed that variability of stride length did not significantly differ in any condition (all $ps > .05$). There were no significant main effects of attentional focus condition for variability of step length and

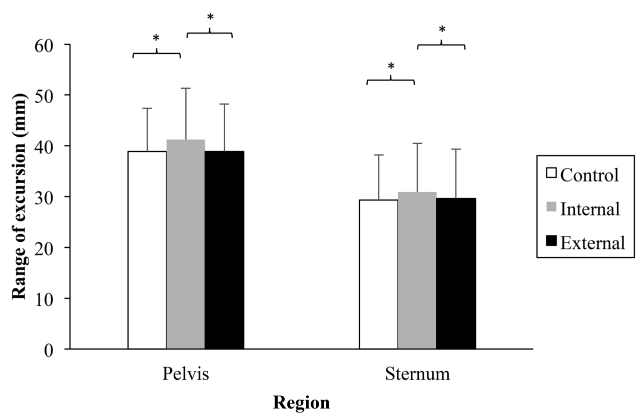

Figure 1. Range of medial–lateral (M-L) excursion of the pelvis and sternum region (mm) under Control, Internal, and External conditions. *$p < .05$.

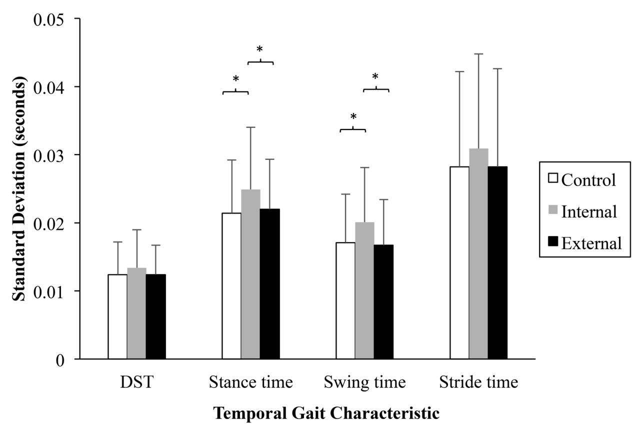

Figure 2. Variability of DST (double support time), stance time, swing time, and stride time under Control, Internal, and External conditions expressed in standard deviation (in seconds). *$p < .05$.

step width: F (2, 278) = 0.35, p = .70 and F (2, 278) = 2.78, p = .06], respectively.

General Gait Parameters

For all temporal gait characteristics (DST, stance time, swing time, and stride time; Table 2), there were significant main effects of attentional focus condition [DST: F (2, 278) = 17.18, p < .001; stance time: F (2, 278) = 73.95, p < .001; swing time: F (2, 278) = 49.37, p < .001; stride time: F (2, 278) = 75.69, p < .001]. Post hoc analysis revealed that all temporal gait characteristics were significantly longer under Internal relative to External and Control conditions (all ps < .05). No significant difference was found between External and Control conditions for any variable (all ps > .05).

For all spatial gait characteristics (step length, step width, and stride length; Table 2), there were significant main effects of attentional focus condition [step length: F (1.74, 242.43) = 31.09, p < .001; step width: F (1.761, 244.77) = 7.01, p = .002; stride length: F (2, 278) = 37.05, p < .001]. Post hoc analysis revealed that both step length and stride length were significantly shorter under Internal relative to External and Control conditions (all ps < .05), and significantly shorter under External relative to Control condition (all ps < .001). Step width was significantly larger under Internal and External relative to Control condition (all ps < .05), but did not significantly differ between Internal and External conditions (p = .35).

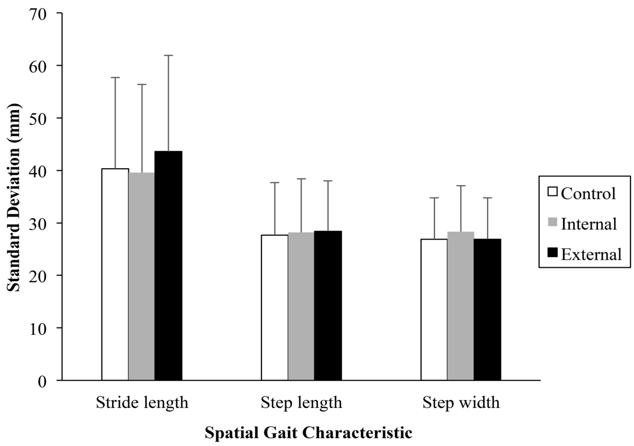

Figure 3. Variability of stride length, step length, and step width under Control, Internal, and External conditions expressed in standard deviation (mm).

Discussion

In this study, the effect of attentional focus instructions on gait performance was examined in older adults. Specifically, we investigated whether previously demonstrated benefits of adopting external focus instructions could be translated to community-dwelling older adults during level-ground walking (indicated by reduced gait variability and decreased body sway).

We predicted that decreased body sway and gait variability would be observed under External condition compared to Internal or Control conditions. Our main findings did not entirely support this hypothesis. We found that body sway (as indicated by M-L range of excursion of pelvis and sternum) and variability of stance time and swing time were significantly lower under External condition relative to Internal condition, but they did not differ between External and Control conditions.

The current results demonstrated no significant difference between External and Control conditions. They suggest that, under control trials, older adults in this study adopted an attentional focus more akin to External rather than the Internal condition. Nevertheless, the results imply that the benefits of explicitly giving external focus instructions on natural walking performance may not be as strong as those observed in previous attentional focus studies. One possible explanation could be that human locomotion is regarded as a "well-practiced" and largely automatic daily task for healthy older adults that can be performed effectively without conscious effort and attentional control in most situations (Malone & Bastian, 2010). It is only when older adults have poor balance and movement difficulties, or are faced with novel situations (i.e., negotiating obstacles for the first time) that they would actually reflect about

Table 2. General Gait Parameters for All Participants Under Control, Internal, and External Conditions

	Control	Internal	External
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
DST (%)	30.7 (3.5)	31.4 (3.5)	31.0 (3.4)
Stance time (s)	0.719 (0.075)	0.745 (0.085)	0.722 (0.079)
Swing time (s)	0.377 (0.033)	0.385 (0.036)	0.376 (0.034)
Stride time (s)	1.098 (0.100)	1.132 (0.113)	1.100 (0.1.07)
Stride length (mm)	1,181.3 (143.2)	1,148.0 (137.2)	1,162.0 (146.2)
Step length (mm)	592.8 (69.9)	575.8 (72.1)	583.0 (71.7)
Step width (mm)	67.20 (24.75)	70.50 (25.40)	6.11 (24.22)

Note: DST = double support time.

walking and consciously control the movement mechanics (i.e., reinvest) to ensure safety (Masters & Maxwell, 2008; Wong, Masters, Maxwell, & Abernethy, 2008). Older adults in our study obtained relatively high scores in BBS (mean = 54.7, *SD* = 1.4), indicating high independence and good balance ability with low fall risk (Berg et al., 1989). It is probable that they did not perceive our control walking task as novel and difficult, which allows them to walk without consciously controlling their movement and consequently allocate more attention to the external environment (Wong et al., 2009). When considering the effects of internal focus instructions, results showed a significant reduction in gait stability when compared to both External and Control conditions. On the basis of previous observations in the literature, it is not surprising to observe maladaptive effects of internal focus relative to external (Chiviacowsky et al., 2010; McNevin & Wulf, 2002; Wulf et al., 1998, 2009, 2001; Wulf & Prinz, 2001). Yet, our data also indicate that giving internal focus instructions could compromise gait to a greater extent compared to giving no instruction at all. This is in line with results from previous studies that have collectively shown that consciously directing attention to one's own movements is detrimental for motor performance (Baumeister, 1984; Wulf & Weigelt, 1997). It is possible that when given internal focus instructions, older adults in our study consciously monitored and controlled their limb movements, which disrupted natural coordination of a highly practiced movement (i.e., walking) and limited allocation of attention to the external environment, thus causing disruption to walking performance (Masters & Maxwell, 2008; Wong et al., 2009).

Regarding the general gait characteristics, our findings suggest that older adults tend to walk with slower speed and shorter steps under the Internal condition relative to External and Control conditions. These particular changes in walking patterns, such as reduced velocity and reduced step length, have been frequently and characteristically observed in older adults (Elble, Thomas, Higgins, & Colliver, 1991; Hausdorff, Edelberg, Mitchell, Goldberger, & Wei, 1997). It is widely acknowledged that such adaptations to gait represent a more cautious and conservative gait strategy (Menz, Lord, & Fitzpatrick, 2003; Winter, Patla, Frank, & Walt, 1990) in an attempt to prioritize and enhance balance, improve gait stability, and decrease fall risk (Kang & Dingwell, 2008). Ironically, such attempts did not appear to be successful because walking stability is compromised, as demonstrated in our findings.

Instructions that refer explicitly to the performer's body movements (internal focus) are commonly used in clinical practice such as physical therapy that involves the acquisition or relearning of motor skills. Various previous studies have used observational methods to examine the use of attentional focus instruction and feedback in physical therapy when practicing poststroke rehabilitation (Durham, Van Vliet, Badger, & Sackley, 2009; Johnson, Burridge, & Demain, 2013). The findings indicated that physical therapists frequently provided internally focused instructions or feedback to patients and prompted them to be aware of their body movements. Thus, therapists and clinicians might try to consider the potential negative impact of attentional focus strategies they use in their communication with patients on motor performance and learning, as it might not be the most effective approach in view of the current evidence. Yet, further research is still necessary to validate whether internal focus of attention impairs gait rehabilitation in patient populations.

One potential limitation of this study is that our straight level-ground walkway for participants was only 6-m long. Increasing the walking distance could provide better estimates for the variability measures that could indicate walking stability (Owings & Grabiner, 2003). Another limitation regarding the experimental setup is that the monitor at the end of the walkway was only switched on during the External condition. Although potentially minor, this is, nonetheless, a confound between test conditions and cognitive demands across the three conditions. Also, when participants were asked to perform a walking task but were provided no instructions to perform another cognitive task (Control condition), we assumed that the only task load they were carrying concerned walking. This assumption is potentially problematic because we could neither suppress, nor measure, task-relevant or task-irrelevant thoughts that participants may have engaged with. Consequently, differences in walking performance between Control and other conditions could be related to changes in the cognitive task load and/or the type of cognitive task (Fraizer & Mitra, 2008). It is possible that performance in each trial might have been influenced by "carryover effects" from the preceding trial. In response to this concern, we statistically compared performance in control trials that followed Internal and External conditions by one-way ANOVA. No significant results were observed ($p > .05$), thus indicating that the impact of this potential confound is likely to be minimal. In addition, most of our participants recruited from the community had good balance ability and functional mobility. Therefore, it is not recommended to extrapolate or generalize our findings to those older adults that are frailer, have higher risk for falls, and are not physically active in the community. Future studies on older adults with fall history or higher risk of falls, together with our current novel findings, would further enhance the scientific contribution and applied impact of this research. In addition, similar experimental protocols with different, possibly more challenging, walking tasks might be conducted.

Conclusion

This study demonstrates that inducing external focus did not enhance gait stability in community-dwelling older adults when compared to no instruction. However, instructions that induced internal focus had a detrimental effect on gait stability. Therefore, health professionals might exercise caution when using instructions and/or feedback that explicitly refer to body movements (internal focus) in practical settings such as gait rehabilitation and fall prevention programs for community-dwelling older adults, considering the negative impact of internal focus of attention on walking stability.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

There are no conflicts of interest for any authors to report.

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