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Does an externally focused dual-task mitigate real-time conscious postural control in older adults?

Devon K.T. Li, BSc [1], Toby C.T. Mak, Ph.D. [1,2], and Thomson W.L. Wong, Ph.D., RPT [1,2*]

[1] School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China.

[2] Department of Rehabilitation Sciences, Faculty of Health and Social Sciences, The Hong Kong Polytechnic University, Hong Kong SAR, China.

*Corresponding author:
Dr Thomson W.L. Wong
Department of Rehabilitation Sciences,
Faculty of Health and Social Sciences,
The Hong Kong Polytechnic University,
Hung Hom, Kowloon, Hong Kong SAR, China.
Tel: 852 2766 6717
Fax: 852 2330 8656
E-mail: thomson.wong@polyu.edu.hk
ORCID: http://orcid.org/0000-0002-6267-9034

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This study first examined whether real-time conscious postural control (reinvestment) and postural sway increase with different postural difficulties on a compliant surface among older adults. The second objective was to investigate the effect of an externally focused dual-task on real-time reinvestment and postural sway under a relatively challenging standing position. Thirty-two community-dwelling older adults (mean age = 72.09, SD = 4.18 years) were recruited. Participants performed balance tasks in four standing positions (25 seconds in each position twice in a randomised order) on a balance foam pad. The four positions included wide-based standing on foam (WBF), narrow-based standing on foam (NBF), tandem-based standing on foam (TBF) and tandem-based standing on foam with an externally focused dual-task (TBFE). Throughout all the balance tasks, participants' real-time reinvestment and body sway were indicated by the Alpha2 T3-Fz Electroencephalogram (EEG) coherence and the total sway length (TSL), respectively. Our results revealed no significant difference in real-time reinvestment among different standing positions while postural sway increased from WBF to NBF and reduced from NBF to TBF. We also demonstrated that when performing a relatively challenging standing task on a compliant surface, an externally focused dual-task (TBFE), compared to a baseline single task (TBF), can neither mitigate real-time reinvestment nor improve balance performance in community-dwelling older adults with good balance capability. Potential explanations and implications for these results are discussed.

Keywords: external focus; dual task; conscious control; standing; task difficulty

Introduction

Older adult falls are recognised among the major public health concerns. About 30% of community-dwelling older adults aged 65 or above suffer at least one fall incident annually (Yoshida, 2007). Falls in older adults can have severe consequences; approximately 10% of falls have led to serious injuries such as traumatic head injuries or bone fracture, and about 30% of falls have led to soft tissue injuries such as bruises and sprains (Tinetti et al., 1995; Chu et al., 2006).

Researchers have attempted to explore the major causes and mechanisms behind older adult falls in terms of their psychological and cognitive factors. A propensity of conscious movement control was suggested as a potential cause, which involves older adults consciously controlling and monitoring their originally automatic movement executions typically under movement difficulties or anxiety (Masters et al., 1993). The above scenario has often been described as 'reinvestment' (Masters & Maxwell, 2008). The Theory of Reinvestment suggests that if a person attempts to consciously control an originally automatic movement, it could cause movement disruption and breakdown (Masters & Maxwell, 2008). For instance, Mullen and Hardy (2000) found that in expert golfers, the backswing and downswing time increased when they were asked to focus on the movement mechanism (conscious monitoring of movements) as compared to when no instruction was given. In another study conducted by Gray (2004), it was demonstrated that when expert baseball players monitored their own movements and actions during a batting task, there was increased movement fluctuation and movement disruption as compared to movements performed under normal conditions.

Reinvestment is recognised as hazardous in older adults as it may increase the risk of falling by means of imposing movement regression and disruption; it has been discovered that high level of conscious movement control is associated with high fall risk in older adults (Wong et al., 2008; Wulf, 2013; Young et al., 2016). The Movement Specific Reinvestment Scale (MSRS) is conventionally used to assess trait reinvestment propensity (Masters et al., 1993, 2005). It was discovered that older fallers have a significantly higher score in the Chinese version of the MSRS (MSRS-C), compared to older non-fallers (Wong et al., 2008). Older fallers were also found to display an increased awareness of their own limbs' movements while walking as compared to older non-fallers (Wong et al., 2008, 2009).

In the recent decade, researchers objectively assessed real-time reinvestment based on the Alpha2 Electroencephalogram (EEG) coherence between the T3 and Fz regions of the scalp. Alpha2 T3-Fz EEG coherence has been utilised in several studies to investigate brain activities of real-time reinvestment in different sports (Chuang et al., 2013; Zhu et al., 2010, 2011). T3 is located at the left temporal region and is responsible for verbal-analytical processing, whereas Fz is at the frontal midline region and is responsible for motor planning. The communication between the verbal–analytical region (T3) and motor planning region (Fz) implicates motor planning with explicit verbal rules (i.e. reinvestment). In a study conducted by Zhu et al. (2011) with golf putting motor tasks, participants who scored higher on the MSRS displayed higher Alpha2 T3-Fz EEG coherence, implying a positive association between trait reinvestment and real-time reinvestment. Other recent studies have also used the Alpha2 T3-Fz EEG coherence to indicate real-time reinvestment and investigate different motor tasks and conditions for older adults (e.g., Chow et al., 2019; Mak et al., 2021).

In particular, Chu and Wong (2019) conducted a study which examined how real-time reinvestment changes with standing task difficulty (i.e. from wide-based standing on foam (WBF) to narrow-based standing on foam (NBF) to tandem-based standing on foam (TBF)) in healthy older adults. They found that the Alpha2 T3-Fz EEG coherence increased significantly with perceived standing task difficulty (measured by a Visual Analogue Scale (VAS)), appearing to support the Theory of Reinvestment where higher difficulty is likely to induce more conscious control in movements. Yet, their conclusion might be limited by the lack of objective measurement to indicate the task difficulty (e.g., postural performance). Hence, **our first objective** was to examine whether consistent results of Chu and Wong (2019)'s study can still be found with the use of an objective measurement of postural sway to reflect standing task difficulty among community-dwelling older adults; real-time reinvestment and postural sway increase along the same trend with standing task difficulty (i.e. from WBF to NBF to TBF).

Given the emerging evidence suggesting that older adults are more prone to reinvest in real-time under challenging postural and gait conditions (Chu & Wong, 2019; Mak et al., 2021), it is imperative to explore ways that could potentially mitigate the involvement of conscious control and thus improve performance in posture and gait. Numerous studies have illustrated that an individual's focus of attention could influence motor performance. Wulf (2013) reviewed previous researches spanning over a decade and found evidences that consistently demonstrate how an external focus of attention (i.e., when an individual is instructed to focus on their own movement effects on environment or apparatus during movement execution) enhanced motor performance and learning when compared to an internal focus of attention (i.e., when an individual is instructed to focus on their own body movement during movement execution) (Wulf et al., 1998). Various studies have examined the effect of attentional focus on balance performance. Generally, enhanced balance performance has been resulted from a performer's attention being externally directed, such as toward the platform or disk when standing still on an inflated rubber disk (Wulf et al., 2008; Wulf et al., 2004) or movable platforms (Landers et al., 2005; Laufer et al., 2007). Zachry et al. (2005) argued that an external focus, as opposed to an internal focus, can direct attention away from conscious postural control and enable relatively high automaticity in movement control (e.g., efficiency in muscular activity and motor unit recruitment).

To date, there is little research that has examined how attentional focus influence real-time reinvestment during postural and gait tasks. Ellmers et al. (2016) observed that Alpha2 T3-Fz EEG coherence was significantly higher when young adults directed their attention internally in a voluntary sway task, compared to an external focus and baseline conditions. The insignificant result of an external focus condition might be a consequence of the lack of difficulty during the relatively simple postural sway task for young adults. Mak et al. (2021) recently consolidate this view by demonstrating significantly lower Alpha2 T3-Fz EEG coherence under an external focus condition when older adults were performing a relatively more challenging walking task. Apart from mitigating real-time reinvestment, they also discovered a beneficial effect on walking performance (represented by gait speed) under the external focus condition. Yet, the association between an external focus and real-time reinvestment during standing postural task, particularly in older adults, still remains not fully addressed. As such, **our second objective** was to investigate the effect of an externally focused dual-task on real-time reinvestment and balance performance in a difficult/challenging standing position by older adults. We adopted the externally focused dual-task that has been used in previous studies (e.g., Morioka et al., 2005; Paul et al., 2009) and asked older participants to hold a tray with a cup filled fully with water while performing a balance task with tandem stance simultaneously on a foam pad.

For the first objective, it was hypothesized that real-time reinvestment increases (indicated by Alpha2 T3-Fz EEG coherence) and balance performance decreases (indicated by increased postural sway) with the difficulty of standing balance tasks (i.e. from WBF to NBF to TBF) among older adults (Hypothesis 1). For the second objective, when older adults perform an externally-focused dual-task (TBFE) compared to TBF (as a baseline), we expected the TBFE to shift the older participants' focus of attention externally and promote the movement automaticity by reducing real-time reinvestment (indicated by Alpha2 T3-Fz EEG coherence) and improving balance performance (indicated by reduced body sway) (Hypothesis 2). Proving our hypotheses would implicate a novel rehabilitation method that helps older adults better maintain their standing balance.

Method

Participants

Thirty-two eligible older adults (mean age = 72.09, SD = 4.18 years; 7 males & 25 females) participated in this study. The majority of the participants had never experienced any fall incident (75%). The inclusion criteria were as follows: (i) aged 65 years or above and (ii) able to stand and walk independently. The exclusion criteria were as follows: (i) obtained a score less than 24/30 in the Chinese version of the Mini-Mental Status Examination (MMSE-C) (Chiu et al., 1994; Folstein et al., 1975), (ii) history of cerebrovascular disease, Parkinson's disease or any other major neurological impairments and (iii) the presence of orthopedics or pain problems that could compromise the maintenance of standing position. The research protocol was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB) (Reference Number: UW 18-695). Written consents were obtained prior to any experimental procedure.

Task and Procedure

Participants were recruited through convenience sampling at different elderly community centres in Hong Kong. All the participants were asked to sign a consent form to ensure that they fully understood their rights as a participant, the ethical issues, and the background and purpose of the study. Participants were then asked about their demographic (e.g. age, gender, medications and fall history) and were required to complete the MMSE-C (Chiu et al., 1994; Folstein et al., 1975) to confirm their eligibility. Eligible participants (*N* = 32) were invited to complete the entire experimental procedure. They were first assessed by the Berg Balance Scale (BBS) (Berg, et al., 1989) to evaluate their baseline balance ability. The scores of this 14-item scale predicted the incidence of multiple falls in older adults (Berg et al., 1992). The BBS has a maximum of 56 points; a lower score indicates higher risk of falling (Berg et al., 1989).

Afterwards, they were required to perform standing balance tasks in four different standing positions on a foam pad (twice for each standing position) in a randomised order. They were instructed to perform each standing position for 25 seconds. The four positions included WBF, NBF, TBF and TBFE. The first three standing positions have been utilised in Chu and Wong's (2019) study. The TBFE required participants to hold a tray with a plastic cup full of water, and they were instructed to avoid spilling during the task (e.g., Morioka et al., 2005; Paul et al., 2009).

After completion of all the standing balance tasks, the participants were asked to fill out the VAS for their perceived difficulty of the standing balance task for all the completed positions. A 100-mm scale was used, with 0 mm representing no difficulty at all and 100 mm the highest level of difficulty of the task (Chu & Wong, 2019; Wewers & Lowe, 1990). Participants were also required to complete the Chinese version of the Falls Efficacy Scale-International (FES-I (CH)) (Kwan et al., 2013) and the MSRS-C (Masters et al., 1993; Masters et al., 2005; Wong et al., 2008) to reflect their baseline characteristics. FES-I (CH) is a valid and reliable scale that evaluates participants' level of concern about falling when carrying out different activities of daily living. The 16-item scale ranges from 16 to 64; a higher score indicates higher concern of falling (Kwan et al., 2013). The MSRS consists of 10 items that require participants to respond to a 6-point Likert scale, which ranges from strongly disagree to strongly agree. The 10 items are divided into two sub-scales: (i) movement self-consciousness and (ii) conscious motor processing. The first one assesses the concern a person has about their own public image when moving and the second one focuses on a person's concern about the mechanics of their movement. The scale ranges from 10 to 60; a higher score represents a higher trait reinvestment propensity.

Measures and apparatus

To obtain the outcome measure for real-time reinvestment, an EEG device (Brainquiry PET 4.0, Brainquiry, The Netherlands) and a real-time biophysical data acquisition software (BioExplorer 1.5, CyberEvolution, US) were used to record the EEG activity at a sample rate of 200 Hz. Electrodes were placed at six scalp locations of each participant with four channel placements (T3, T4, Fz and Fp1), a ground electrode (left mastoid) and a reference electrode (right mastoid), according to the standard international 10–20 systems (Jasper, 1958). Notably, T3 is located at the left temporal region and is responsible for verbal–analytical processing; T4 is in the right temporal region and is responsible for visuospatial processing; Fz is in the frontal midline region and is responsible for motor planning; and Fp1 is in the left zygomatic bone and measures eye blinks (Ellmers et al., 2016). The data analysis focused on EEG coherences of three regions, T3, T4 and Fz, while Alpha2 T3-Fz and T4-Fz EEG coherences were calculated using a biophysical data processing and analysis software (BioReviewer 1.5, CyberEvolution, US). Further, an impedance test was conducted prior to each measurement using a 48–52 Hz filter with a fixed threshold at 20 µV. A low-pass filter (42 Hz) and high-pass filter (2 Hz) were utilised to minimise the potential noise and biological artifacts (e.g., muscle activation or glossokinetic artifacts) from the raw signals. Formerly customised algorithms were used to calculate T3-Fz and T4-Fz coherences in 1-Hz frequency bins (Zhu et al., 2011). Alpha2 T3-Fz EEG coherence was used to measure real-time reinvestment; a higher level of Alpha2 T3-Fz EEG coherence indicates a higher level of real-time reinvestment. On the contrary, Alpha2 T4-Fz EEG coherence assured that any changes found in Alpha2 T3-Fz EEG coherence were not likely due to global activation of the brain. The averages of both Alpha2 T3-Fz and T4-Fz EEG coherences were calculated for each trial and then averaged across the relevant tasks.

For the balance task, participants were required to stand in four different positions on a 19.7” x 16.1” x 2.4” balancing foam pad (Balance Pad Elite, AIREX, Switzerland). To the outcome measure for balance performance, a reflective marker was placed at each participant’s xiphoid process in the sternum. Body sway data was collected by a six-camera 3D motion-capture system (ProReflex Motion Capture Unit [MCU] 170 120, Qualisys, Sweden) at a sampling rate of 120Hz. The root-mean-square of reflective marker’s coordinates on the horizontal (X-Z) plane was calculated in the 25-second task to obtain the total sway length (TSL). Raw data were passed through a low-pass Butterworth filter with a 5Hz cut-off and processed with customised MATLAB (R2015B Mathworks Inc., Natick, USA) scripts to obtain the amount of TSL (mm), with higher TSL representing higher body sway.

Data analysis

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS), version 25.0 (IBM, Armonk, NY, USA). A p-value of $< .05$ was considered statistically significant. Descriptive statistics were computed and normality was checked for each outcome variable before analysis. Normality was not met in perceived difficulty of standing balance tasks

(VAS), body sway (TSL), real-time reinvestment (Alpha2 T3-Fz EEG coherence) and Alpha2 T4-Fz EEG coherence. Therefore, non-parametric analyses were conducted for these variables.

Further, Friedman tests were used to compare the perceived difficulty of standing balance tasks (VAS), real-time reinvestment (Alpha2 T3-Fz EEG coherence) and body sway (TSL) in different standing positions (WBF, NBF and TBF) (Hypothesis 1). Wilcoxon signed-rank tests were used to determine the differences in the perceived difficulty of tasks (VAS), real-time reinvestment (Alpha2 T3-Fz EEG coherence) and body sway (TSL) between TBF and TBFE (Hypothesis 2). The Alpha2 T4-Fz EEG coherence was also examined by the Friedman test for all standing positions (WBF, NBF, TBF and TBFE) to assure that any changes found in the Alpha2 T3-Fz EEG coherence were not likely due to global activation of the brain.

Results

Descriptive statistics for all main variables (Mean ± SD) are presented in Table 1.

Table 1 near here

Different standing positions (WBF vs. NBF vs. TBF) (Hypothesis 1)

Friedman tests were used to compare real-time reinvestment (Alpha2 T3-Fz EEG coherence) in the WBF, NBF and TBF. An overall significant difference was not found ($X^2(2) = 0.813$, $p = 0.666$) (Figure 1).

Figure 1 near here

Friedman tests were used to compare the balance performance (body sway – TSL) in WBF, NBF and TBF. An overall significant difference was found ($X^2(2) = 25.654$, $p < .01$). Post-hoc analysis with Wilcoxon signed-rank tests revealed that the TSL of NBF was significantly higher than that of WBF ($p < .01$) but the TSL of NBF was significantly higher than that of the TBF as well ($p < .05$) (Figure 2).

Figure 2 near here

Friedman tests were used to compare the perceived difficulty of standing balance tasks (VAS) in WBF, NBF and TBF. An overall significant difference was found ($X^2(2) = 19.31$, $p < .01$). Post-hoc analysis with Wilcoxon signed-rank tests revealed that the perceived difficulty of standing balance tasks of the NBF was significantly higher than that of the WBF ($p < .01$). The perceived difficulties of standing balance tasks (VAS) for TBF and NBF were not statistically different. However, an upward trend in the perceived difficulty of standing balance tasks (VAS) from WBF to NBF and then to TBF was found (Figure 3).

Figure 3 near here

TBF vs. TBFE (Hypothesis 2)

The Wilcoxon signed-rank test was used to compare the real-time reinvestment (Alpha2 T3-Fz EEG coherence) between TBF and TBFE. Alpha2 T3-Fz EEG coherence in TBFE did not significantly differ from that of TBF ($Z = -0.131$, $p = 0.896$) (Figure 4).

Figure 4 near here

The Wilcoxon signed-rank test was used to compare the balance performance (body sway – TSL) between TBF and TBFE. TSL in TBFE did not significantly differ from that in TBF ($Z = -1.309$, $p = 0.191$) (Figure 5).

Figure 5 near here

The Wilcoxon signed-rank test was used to compare the perceived difficulty of standing balance task (VAS) between TBF and TBFE. The VAS in TBFE did not significantly differ from that in TBF (Z = -1.245, p = .213) (Figure 6).

Figure 6 near here

Alpha2 T4-Fz EEG coherence in different standing positions

The Friedman test was used to compare Alpha2 T4-Fz EEG coherence in WBF, NBF, TBF and TBFE. An overall significant difference was not found ($X^2(2) = 1.800$, $p = 0.615$), indicating that the changes found in Alpha2 T3-Fz EEG coherence were likely not due to global activation of the brain.

Discussion

The first objective of the present study was to examine whether real-time reinvestment increases (indicated by Alpha2 EEG T3-Fz coherence) and balance performance decreases (indicated by postural sway) with difficulty in standing balance tasks (i.e., WBF to NBF to TBF) among older adults (Hypothesis 1). The second objective was to examine whether real-time reinvestment decreases and balance performance improves in an externally focused dual-task (TBFE) compared to a baseline single task in a relatively challenging standing position (TBF) (Hypothesis 2).

For Hypothesis 1, insignificant results were found in Alpha2 T3-Fz EEG coherence among different standing positions (WBF, NBF and TBF). Significant difference was found in the perceived difficulty (VAS) in standing balance tasks between WBF and NBF. As shown in

Figure 3, the perceived difficulty of standing balance tasks (VAS) significantly increased from WBF to NBF and then mildly from NBF to TBF. The increase likely represents that the perceived difficulty level ranged from the easiest to the hardest from WBF to NBF and then to TBF. Different from Chu and Wong's (2019) study, the present study also adopted an objective measurement for task difficulty at the same time – the measurement of body sway (TSL). In our case, it was observed that the perceived and measured difficulties of tasks were not largely consistent, which could account for the statistically insignificant results in real-time reinvestment. Both the VAS and body sway increased from WBF to NBF. Yet, while the VAS increased mildly from NBF to TBF, body sway decreased significantly from NBF to TBF. The present results imply that it might be physically more challenging for our cohort of older adults to perform NBF than TBF, even though they seemed to perceive the latter as the more difficult/equally difficult task. This inconsistency in the subjective and objective measurements may have led to the overall insignificant results for Hypothesis 1. The current evidence possibly restricts us from fully explaining the potential effects and mechanisms underlying the association between task difficulty and real-time reinvestment in standing balance.

For Hypothesis 2, insignificant differences were found in the perceived difficulty in standing balance tasks (VAS), the Alpha2 T3-Fz EEG coherence, and body sway (TSL) between TBF and TBFE. The statistically insignificant results may have occurred due to several potential factors. For example, the distance of an externally focused dual task from the performer may have affected movement automaticity, indirectly affecting the results for Hypothesis 2. McNevin et al. (2003) argued that an external focus that is further away from body could impose a more beneficial effect on movement automaticity since a more distal focus makes it easier to dissimilar from the body's movement effect. A study examined the accuracy of throwing darts found that when participants were asked to focus on the bullseye (distal), the accuracy was higher than when they were asked to focus on the flight path of the dart (proximal) (McKay & Wulf, 2012). Considering how the present participants were asked to avoid spilling the water from the cup held relatively proximal to their own body, the effect of the external focus may not have effectively promoted movement automaticity as compared to a more distal externally focused task.

Second, we also postulate that the balance tasks conducted in this study may not have been highly challenging for the participants. Previous research only found the effect of an external focus of attention to be effective when the balance task was challenging enough. For instance, an external focus was only effective in improving balance performance when participants were maintaining balance on unstable surfaces/platforms (Chiviacowsky et al., 2010; Shea & Wulf, 1999; McNevin et al., 2003; Wulf et al., 2004, 2001; Wulf & McNevin, 2003; Wulf et al., 2007**)** but not on normal surfaces (Wulf et al., 2007). Considering that the participants in this study had relatively good balancing ability (a mean BBS score of 54.5 out of 56), even though a balance foam pad was used to increase the difficulty of the standing tasks, TBF itself as a baseline comparison task may not be challenging enough to impose a significant effect on the balance performance when participants were externally focused.

Third, while EEG T3-Fz coherence appears to be related to the use of conscious strategies to control movements, evidence for this method is largely derived from studies investigating motor tasks that involve a single form of task-specific movement, for example, golf-putting, postural sway, darts throwing, etc. (see a review by Parr et al., 2021). In the present study, however, the externally focused dual-task inherently involved two distinct forms of movements; holding a tray with a plastic cup full of water (aiming to prevent spilling) while performing a tandem stance on a foam pad. As such, it is reasonable to suspect whether EEG T3-Fz coherence can effectively differentiate between reinvestment that are relevant to the targeted motor task (e.g., maintaining balance in a tandem stance on a foam pad) and that for a concurrent motor task that are ‘task-irrelevant’ (e.g., holding a tray to prevent water spills). Under a similar premise, the current dual-task involving both upper- and lower-limb tasks should also be taken into consideration. It is logical to surmise that the externally focused task of holding a tray could indeed reduce conscious processes of lower limb movements (i.e., postural control). Nevertheless, the participants might still reinvest or shift the conscious processes towards their upper-limb (task-irrelevant) movements for holding/balancing the tray (motivated by the aim of not spilling the water); resulting in the lack of overall changes in EEG T3-Fz coherences. After all, when both upper- and lower-limb are involved, the neural control of upper limbs is more easily detected through the use of EEG than the lower limb representations due to its occurrence in more lateral, superficial locations of the precentral gyrus (Crossman & Neary, 2014; Julkunen, 2014). As such, while EEG T3-Fz coherence may be useful in broadly indicating real-time reinvestment during a single form of task-specific movements (e.g., golfing, walking, balancing), our observation highlights the possibility that this method might not be sufficiently effective to distinguish between real-time reinvestment of upper- and lower-limb movements.

One should also note that we used an upper body marker that has been adopted in other studies to indicate postural sway (Chow et al., 2019; Leung et al., 2021). Reinvesting in upper body movements to prevent water spills might consequently affect how upper body sways, leading to the lack of improvement in our balance outcome under TBFE. Other studies that observed significant improvement in balance have mostly utilized force plate or markers that capture lower limb control (e.g., Morioka et al., 2005), hence the contradictory findings in the balance outcome. Future research is recommended to utilize more comprehensive measurements for balance in order to fully understand the effect of an externally focused dual-task.

There are potential limitations in this study. First, the baseline balance ability of the participants will have to be considered when interpreting the findings. The BBS scores reveal that participants generally had excellent baseline balance ability and, additionally, their scores of perceived difficulty of the standing balance tasks were generally low for all four standing positions, with the mean score not higher than 4 out of 10. It could thus represent that the participants may not have found the standing balance task challenging enough, resulting in the insignificant findings. Second, even though the participants were instructed to avoid spilling the cup of water while holding the tray while performing TBFE, we cannot claim for certain that their attentional focus was fully directed externally during the task.

A few existing studies have demonstrated evidence that suggests the potential use of EEG T3-Fz coherence in evaluating the progress of movement automaticity in geriatric patients by rehabilitation practitioners during balance/gait training (e.g., Chu & Wong, 2019; Mak et al., 2021). Yet, our findings question the clinical application of this method of analysis in providing an objective indication for real-time conscious postural control in tasks that involve more than one form of movement (e.g., upper- and lower-limb movements). As EEG T3-Fz coherence might not be sensitive enough to also differentiate between task-relevant and -irrelevant movements, researchers and practitioners should carefully consider such factors before applying this method in clinical practice (e.g., in rehabilitation training).

Conclusion

The current findings demonstrate that standing task difficulty (on a compliant surface) has little effect on real-time reinvestment in community-dwelling older adults with good balance ability. In addition, it is suggested that when performing a difficult standing task (on a compliant surface), an externally focused dual-task can neither mitigate real-time reinvestment nor improve balance performance. Follow-up investigations with larger sample sizes and older adults with different balance abilities should be conducted. Future research is recommended to use an alternative externally focused dual-task together with a more comprehensive measurement of balance in order to fully understand the above relationship for clinical use.

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Declaration of interests

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Availability of data and material

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1. Descriptive statistics for all main outcome variables.

	(*N*=32)
Variables	Mean (SD)
Age (years)	72.094 (4.184)
MMSE-C	28.875 (2.121)
BBS	54.938 (1.190)
FES-I(CH)	33.875 (9.550)
MSRS-C(CMP)	15.156 (6.269)
MSRS-C(MSC)	14.531 (6.844)
MSRS-C(Total)	29.688 (11.890)
VAS(WBF)	1.747 (2.090)
VAS(NBF)	3.368 (2.857)
VAS(TBF)	3.877 (3.049)
VAS(TBFE)	3.986 (3.220)
T3-Fz EEG coherence (WBF)	0.276 (0.138)
T3-Fz EEG coherence (NBF)	0.286 (0.160)
T3-Fz EEG coherence (TBF)	0.294 (0.152)
T3-Fz EEG coherence (TBFE)	0.291 (0.142)
T4-Fz EEG coherence (WBF)	0.209 (0.119)
T4-Fz EEG coherence (NBF)	0.233 (0.158)
T4-Fz EEG coherence (TBF)	0.221 (0.136)
T4-Fz EEG coherence (TBFE)	0.208 (0.115)
TSL (WBF)	242.342 (59.931)
TSL (NBF)	335.372 (67.724)
TSL (TBF)	307.669 (85.039)
TSL (TBFE)	292.839 (63.116)

Note. MMSE-C = Chinese version of the Mini-Mental State Examination; BBS = Berg Balance Scale; FES-I(CH) = Chinese version of the Fall Efficacy Scale International; MSRS-C(CMP)= Chinese version of the Movement Specific Reinvestment Scale (Conscious Motor Processing); MSRS-C(MSC)= Chinese version of the Movement Specific Reinvestment Scale (Movement Self Consciousness); WBF = wide-base standing on foam; NBF = narrow-based standing on foam; TBF = tandem-based standing on foam; TBFE= Tandem-based standing on foam with externally-focused dual task; VAS = Visual Analogue Scale; TSL = Total sway length.

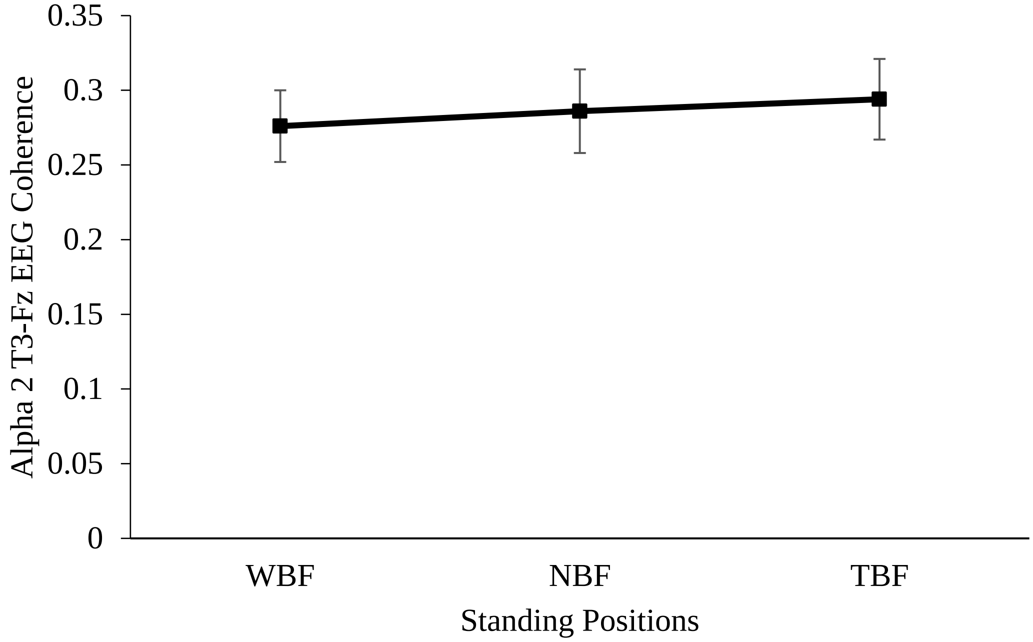
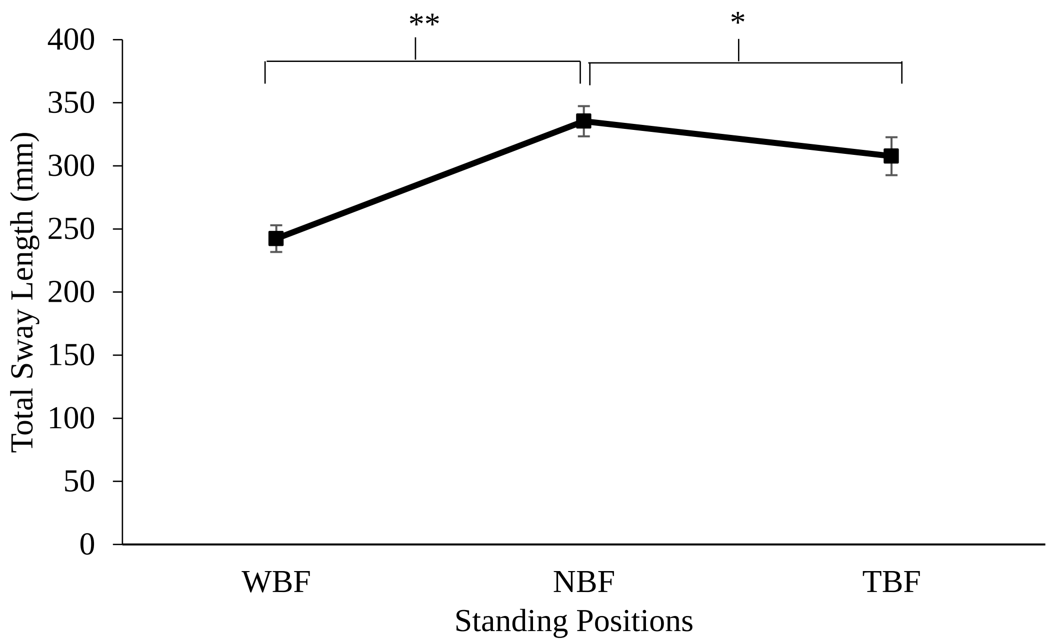

0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Alpha 2 T3-Fz EEG Coherence
WBF
NBF
TBF
Standing Positions

Figure 1.



**
*
400
350
300
250
200
150
100
50
0
Total Sway Length (mm)
WBF
NBF
TBF
Standing Positions

Figure 2.

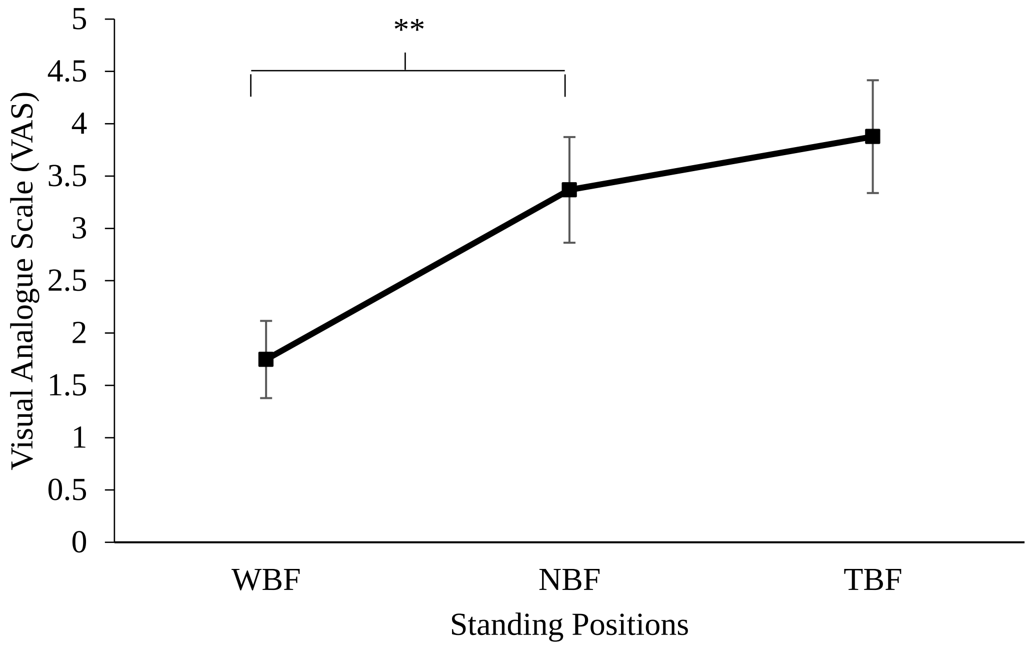
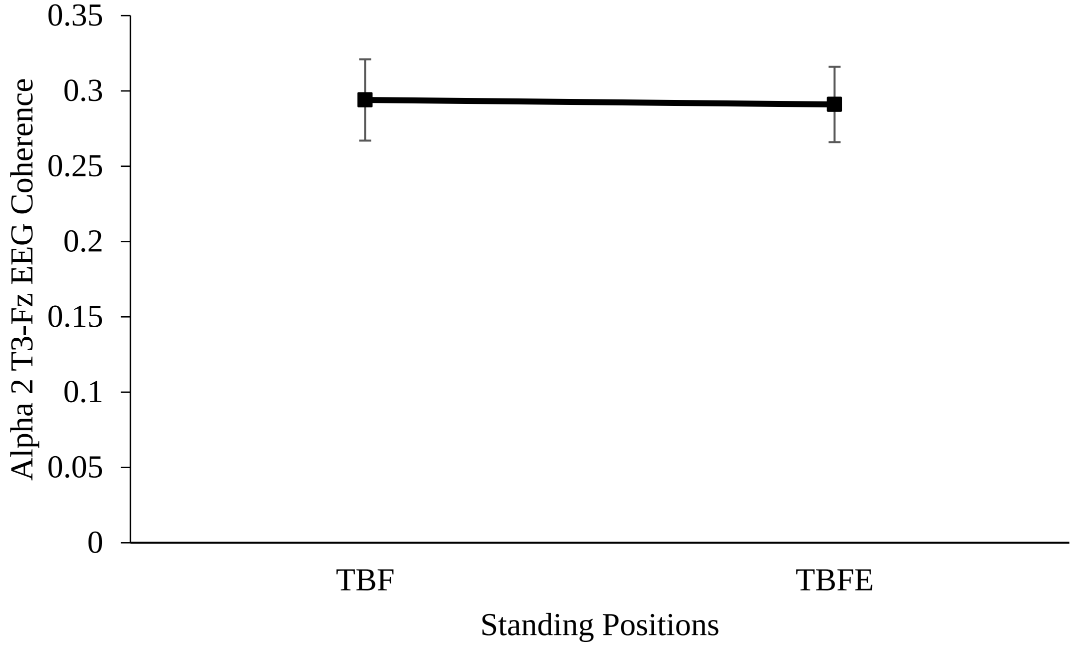

**
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Visual Analogue Scale (VAS)
WBF
NBF
TBF
Standing Positions

Figure 3.


0.35
0.3
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0.2
0.15
0.1
0.05
0
Alpha 2 T3-Fz EEG Coherence
TBF
TBFE
Standing Positions

Figure 4.

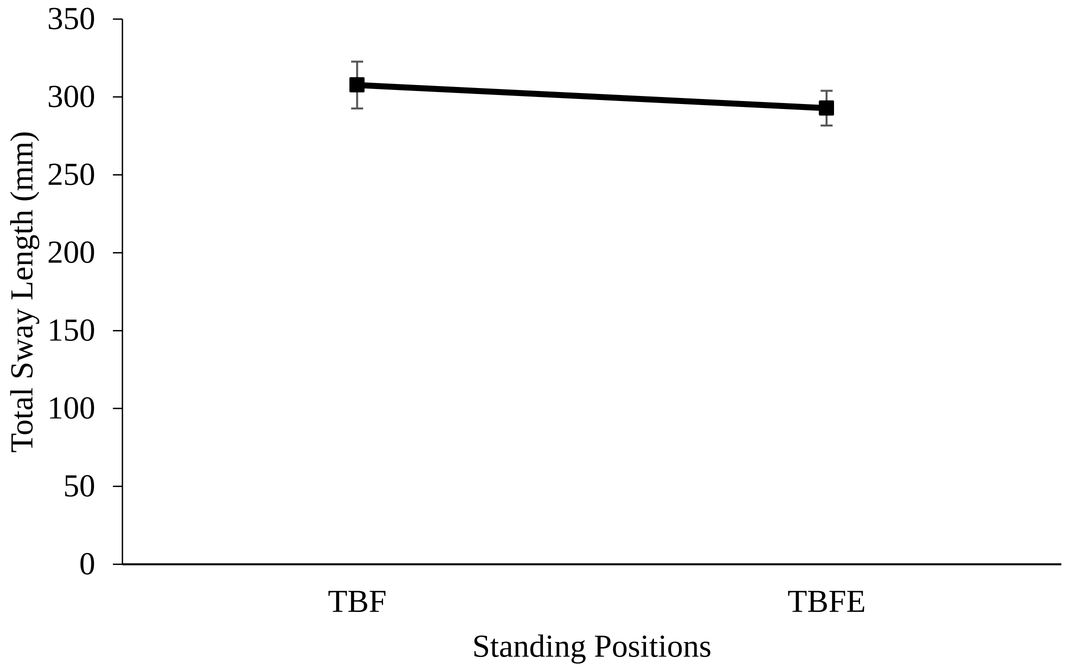
350
300
250
200
150
100
50
0
Total Sway Length (mm)
TBF
TBFE
Standing Positions

Figure 5.

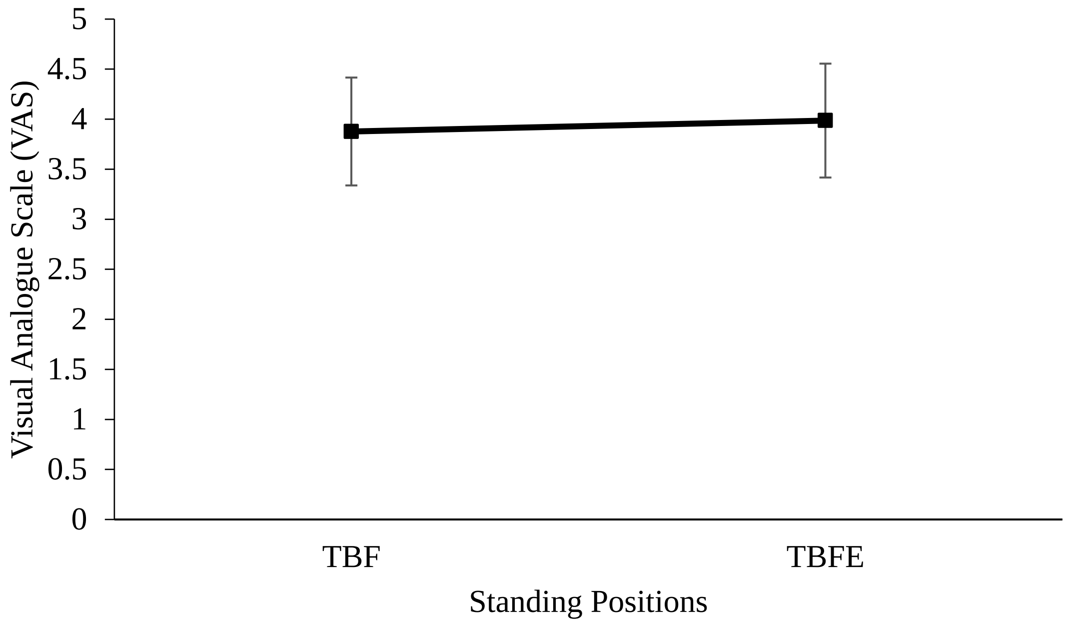
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Visual Analogue Scale (VAS)
TBF
TBFE
Standing Positions

Figure 6.

Figure Captions

Figure 1. Alpha2 T3-Fz EEG coherence in different standing positions.

Figure 2. Body sway (Total sway length) in different standing positions (**p* < .05; ***p* < .01).

Figure 3. Perceived difficulty of standing balance tasks (VAS) in different standing positions (***p* < .01).

Figure 4. Alpha2 T3-Fz EEG coherence in tandem-based standing on foam with and without an externally-focused manual dual task.

Figure 5. Body Sway (Total sway length) in tandem-based standing on foam with and without an externally-focused manual dual task.

Figure 6. Perceived difficulty of standing balance tasks (VAS) in tandem-based standing on foam with and without an externally-focused manual dual task.