

The Interacting Effects of Cognitive Demand and Recovery of Postural Stability in Balance-Impaired Elderly Persons

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Background. Although postural recovery is attentionally demanding in healthy elderly persons, an inability to recover balance due to competition for attentional resources between the postural system and a second task could contribute to falls in older adults with poor balance. This study examined the attentional demands of balance recovery from a mild postural disturbance in balance-impaired elderly persons. A second purpose of this research was to determine the effect of performing a cognitive task on the recovery of balance in balance-impaired elderly persons.

Methods. Fifteen healthy older adults and 13 older adults with clinical balance impairment were exposed to balance disturbances by means of sudden movement of a platform on which they stood. A dual-task paradigm where postural recovery served as the primary task and verbal reaction time to auditory tones served as the secondary task was used to assess attentional demand. To determine the effect of the cognitive task on postural recovery, kinetic, kinematic, and neuromuscular measures of a feet-in-place response were investigated.

Results. Balance recovery using a feet-in-place response was attentionally demanding in both groups of older adults and was more demanding in balance-impaired than in healthy elderly persons. With the concurrent performance of a cognitive task, balance-impaired elderly persons took longer to stabilize their center of pressure and regain balance than in a single task, while healthy elderly persons showed no change between conditions. In addition, only balance-impaired elderly individuals had a greater center-of-pressure resultant velocity during recovery in a dual-task compared with a single-task situation.

Conclusions. The ability to recover balance using a feet-in-place response was more attentionally demanding in balance-impaired than in healthy elderly persons. The recovery of balance was also slower and less efficient in balance-impaired elderly persons when simultaneously performing a cognitive task, whereas the ability of healthy elderly individuals to recover was not influenced by concurrent task demands. This suggests that dual-task performance may contribute to postural instability and falls in balance-impaired elderly individuals.

HEALTHY older adults show a marked reduction in the ability to perform a postural and a cognitive task simultaneously compared with young adults. This has been demonstrated as a reduction in the performance of the cognitive task, specifically, an increase in reaction time (1–3). In a number of studies using this paradigm, a decrement in the performance of the postural task has also been found. Greater postural instability when performing dual tasks has been reported in stance (4–6) and during obstacle avoidance in gait (7).

Dual-task paradigms have been used to examine the relative attentional demands associated with different types of postural tasks. Changes in the secondary task are used to infer task-dependent changes in attentional demands. Using this approach, researchers have shown that attentional demands vary as a function of task complexity (2–8), age (1), and balance abilities (8). Brown and colleagues (9) found that recovery of postural stability was attentionally demanding and that attentional demands increased with age. The attentional demands associated with postural recovery in balance-impaired older adults are not known. Thus, one purpose of this study was to compare the attentional de-

mands of postural recovery in balance-impaired versus healthy older adults. We expected that in a dual-task situation, balance-impaired older adults would demonstrate a greater reduction in cognitive task performance compared with healthy older adults, suggesting that attentional demands associated with recovery of stability are greatest in balance-impaired older adults.

Dual-task paradigms have also been used to examine the effects of a secondary task on the efficiency of postural control. In healthy older adults, the ability to recover stability following an external perturbation is affected by the simultaneous performance of a secondary task. Rankin and colleagues (10) compared neuromuscular response characteristics associated with postural recovery using a moving platform paradigm in single- versus dual-task conditions. They found that in the dual-task situation, healthy older adults exhibited a reduced magnitude in the gastrocnemius response, the primary muscle used to regain stability. This could make recovery of balance without taking a step less effective and could explain the greater prevalence of step responses by older adults in a dual-task situation (9). Although recovery of postural stability in dual-task conditions

has been studied in healthy older adults, its relevance to explaining falls in balance-impaired elderly persons is unknown.

It has been suggested that an inability to produce an appropriate postural response due to the competition for attentional resources between the postural system and the cognitive task contributes to falls in older adults with poor balance (11). Older adults with clinical balance impairments either stop (12) or take a longer time to complete a gait task when performed with a secondary task (13). The inability to walk and talk simultaneously was associated with a greater risk of falls in the succeeding 6-month period (14). Further evidence that competition for attention may play a role in instability and falls in balance-impaired elderly persons was reported by Shumway-Cook and colleagues (11). They found that the addition of a simple cognitive task could increase center-of-pressure (COP) motion during quiet stance in older adults with a history of falls. A subsequent study examining the effects of sensory context on attentional demands of postural control found that as sensory conditions became more difficult, balance-impaired older adults who had been able to maintain stability in a single-task context, lost balance in a dual-task context (8).

However, many falls in older adults occur as a result of slips or trips, suggesting the need for studies related to recovery of postural stability in balance-impaired older adults. Thus, a second purpose of this study was to determine the effects of performing a simultaneous cognitive task on the ability of balance-impaired older adults to recover postural stability following a platform translation. We hypothesized that, due to competition for attentional resources, balance-impaired older adults would demonstrate a decrement in postural recovery.

METHODOLOGY

Subjects

Twenty-seven community-dwelling adults aged over 65 years (15 healthy, 72.1 ± 7 years; 12 balance-impaired, 79.2 ± 7 years) volunteered for the study. Exclusion criteria included major sensory impairments and any neurological or musculoskeletal diagnosis that could account for postural instability. Informed consent was obtained from all subjects.

Subjects were classified as balance-impaired if they scored ≤ 50 out of 56 on the Berg Balance Scale (15) and reported a history of postural imbalance. Conversely, subjects were categorized as healthy if they scored ≥ 51 out of 56 on the Berg Balance Scale and did not report a history of imbalance. The Berg Balance Scale is a 14-item scale (each item scored 0–5) that assesses the ability to perform functional balance tasks. It has demonstrated high inter- and intrarater reliability ($r = .98$ and $.99$, respectively) and internal consistency (Cronbach's $\alpha = .96$) in older adults. The maximum score is 56, with a score of ≥ 51 associated with a low risk of falls (16).

Protocol

All subjects underwent a neurological examination, a clinical examination, and an experimental session. A physi-

cal therapist conducted the clinical examination, which included the Berg Balance Scale (15), the Timed Up and Go Test (17), and the Dual-Task Timed Up and Go Test (13). The Trail-Making Test (parts A and B) were performed to indicate overall attentional ability (18), and the Mini-Mental State Examination (MMSE) (19) was performed to describe general cognitive ability. Questionnaires determining medical history and exercise frequency were completed.

In the experimental session, subjects were asked to maintain stability in response to external perturbations in the backward direction under single- versus dual-task conditions. In the dual-task condition, subjects responded vocally to an auditory choice reaction-time stimulus. Subjects completed 15 trials of the balance task only, 3 trials of the cognitive task only, and 15 trials of the two tasks together, in random order. Five trials were performed with the platform moving forward to minimize preparation for the movement. The 30 perturbations (nonlinear ramp-to-parabola waveforms) consisted of 3 each at the velocities of 10, 20, 30, 40, and 50 cm per second. Only the 10-cm-per-second perturbations (peak acceleration 0.13 m/s^2) were analyzed in this study, as balance-impaired older adults began taking steps to recover at the faster perturbation velocities. Subjects were instructed to try to keep their balance by keeping their feet in place and avoid taking a step, but also were told to respond as quickly and accurately as possible in the cognitive task.

The cognitive task consisted of a verbal response ("high" or "low") to two frequencies of tone (500 Hz and 2 kHz) generated by a mixer (Institute of Neuroscience at the University of Oregon) presented for 250 milliseconds in series of 10 through a unilateral headphone transducer. The response was recorded into a microphone attached to the headset. Immediately after each response, the investigator manually triggered the next tone generation. In the dual-task condition, the platform movement was synchronized with the production of a tone, such that it occurred at the same time (± 40 ms to account for variability in movement mechanics) as the presentation of a particular tone in the sequence. The tone in the sequence that triggered platform motion was randomized between trials to eliminate any prediction of plate movement.

Instrumentation

In the perturbation conditions, subjects stood with one foot on each of two electronically synchronized force platforms (Institute of Neuroscience at the University of Oregon). Foot position was standardized (feet parallel, 10 cm apart). The subjects wore a harness attached to an overhead trolley, and an assistant remained by the side of the subject to prevent a fall. A four-camera 120-Hz Peak Performance motion analysis system (Peak Performance Technologies, Inc., Englewood, CO) was used to construct a four-segment, two-dimensional model of body motion (foot, shank, thigh, and head/arms/trunk). Markers were placed on the fifth metatarsal head, lateral malleolus, lateral tibio-fibular joint line, greater trochanter, and superior aspect of the acromioclavicular joint. This was used in conjunction with known anthropometric data to calculate center of mass (COM) (20).

Table 1. Between-Group Differences in Characteristics

Characteristic	Healthy Older Adults <i>n</i> = 14	Balance-impaired Older Adults <i>n</i> = 13
Age, y* (<i>SD</i>)	72.1 (6.7)	79.4 (6.5)
Range	64–86	68–92
Gender, % women	67	77
No. of falls in past year, %		
0	79	46
≥1	11	54
Report imbalance outdoors, %**	0	69
Use aid outdoors, %**	0	46
No. of comorbidities, %**		
0–1	28	0
2–3	36	38
≥4	36	62
No. times exercise/wk, %**		
0–2	21	77
3–4	50	15
≥5	29	8
MMSE* (<i>SD</i>)	29.5 (0.7); range, 28–30	28.5 (1.6); range, 25–30
Trail Making A Test, s* (<i>SD</i>)	15.8 (5.4)	25.7 (8.8)
Trail Making B Test, s* (<i>SD</i>)	29.6 (10.7)	72.6 (60.9)

Note: MMSE = Mini-Mental State Examination.

*Significant difference ($p < .05$) between groups by one-way analysis of variance.

**Significant difference ($p < .05$) between groups by Mann-Whitney *U* test.

Surface bipolar electrodes (1 mm × 10 mm; DE-02, Delsys, Inc, Boston, MA) were placed bilaterally on the agonist muscle, gastrocnemius, and the antagonist muscle, tibialis anterior. All data were collected at 900 Hz by AMLABII (AMLAB International, Australia). Electromyographic (EMG) data were band-pass filtered from 20 to 500 Hz and further analysis was performed in MATLAB (The MathWorks, Inc., Natick, MA).

Data Analysis

To determine whether there was a difference in cognitive task performance between the single and dual tasks, and whether this varied with balance impairment, a repeated-measures analysis of variance (ANOVA) was performed on the first two reaction times following plate motion. Main effects of the group (healthy vs balance-impaired), task (single vs dual), reaction times (one vs two) and trials (1, 2, and 3) were investigated, along with the associated interactions. Difference scores (dual-task – single-task reaction time) were calculated and an ANOVA was performed to determine whether there was a difference in the attentional demand of recovery between healthy and balance-impaired older adults. The cognitive task response accuracy (probability of making an incorrect response) was determined across groups using a generalized estimating equation, or GEE, due to the discrete nature of the data and the repeated-measures design (21). The significance level was set at $p < .05$ for all analyses.

To determine whether the addition of a secondary task resulted in a significant change in the postural recovery, a repeated-measures ANOVA was performed. Individual analyses determined differences in COP or COM measures

Table 2. Between-Group Differences in Clinical Balance Measures

Performance Measures	Healthy Older Adults <i>n</i> = 15	Balance-impaired Older Adults <i>n</i> = 13
Berg Balance Scale [†] *	54.9 ± 1.5	46.7 ± 3.0
Range	51–56	42–50
Timed Up and Go (TUG), s*	6.8 ± 1.2	11.2 ± 2.5
Motor Dual-Task TUG, s*	7.8 ± 1.4	13.1 ± 3.8
Cognitive Dual-Task TUG, s*	8.1 ± 1.6	16.2 ± 3.4
Functional reach distance, cm*	31.1 ± 5.3	20.7 ± 4.6
Lateral reach distance, cm*	15.4 ± 4.3	10.2 ± 3.5
Single-leg stance time, s*	20.0 ± 11.6	2.7 ± 3.0

Note: Values are mean ± *SD*.

*Significant difference ($p < .05$) between groups by one-way analysis of variance.

[†]Maximum score of 56.

across groups, tasks, and trials. Several measures indicative of stability following platform perturbation were calculated with MATLAB. These included the time for the COP and COM to return to a stable velocity (within 3 *SDs* of the pre-motion velocity for 25 milliseconds); the peak *x*, *y*, and resultant velocity of the COP over 2.5 seconds; and the maximum range of COP motion over 2.5 seconds.

A repeated-measures ANOVA was also performed to determine whether the addition of a secondary task resulted in a significant change in the EMG recovery response. Group, task, and Group × Task interactions were investigated. Univariate analyses were performed if a significant multivariate result was found. The onset time of the EMG signal (>3 *SDs* from baseline for 50 ms) was determined by computer algorithm (22) and checked visually. To determine the magnitude of muscle activity, the root mean squared error was calculated from the onset of activity for 100 milliseconds and normalized to a 200-millisecond baseline. A ratio of shank muscle activity (gastrocnemius: tibialis anterior activity) was calculated to provide an index of distal coactivation.

RESULTS

Demographic information and results from the clinical examination are reported in Tables 1 and 2. Balance-impaired older adults were significantly older, performed less well on clinical balance tests, reported imbalance and used an aid outdoors more frequently, exercised less frequently, reported more comorbidities, demonstrated poorer attention ability (high scores on the Trail-Making Test), and had lower overall cognitive functioning (MMSE) than the healthy older adults.

Because there was a significant difference in age between groups of older adults, a repeated-measures analysis of covariance with age as a covariate was also performed. No differences in significance between the analyses were found; thus, age did not influence the between-group results reported for healthy versus balance-impaired subjects. The data presented in this study include only feet-in-place responses.

The Attentional Demands of Postural Recovery

The first question in this study asked if attentional demands associated with recovery of stability were greater in

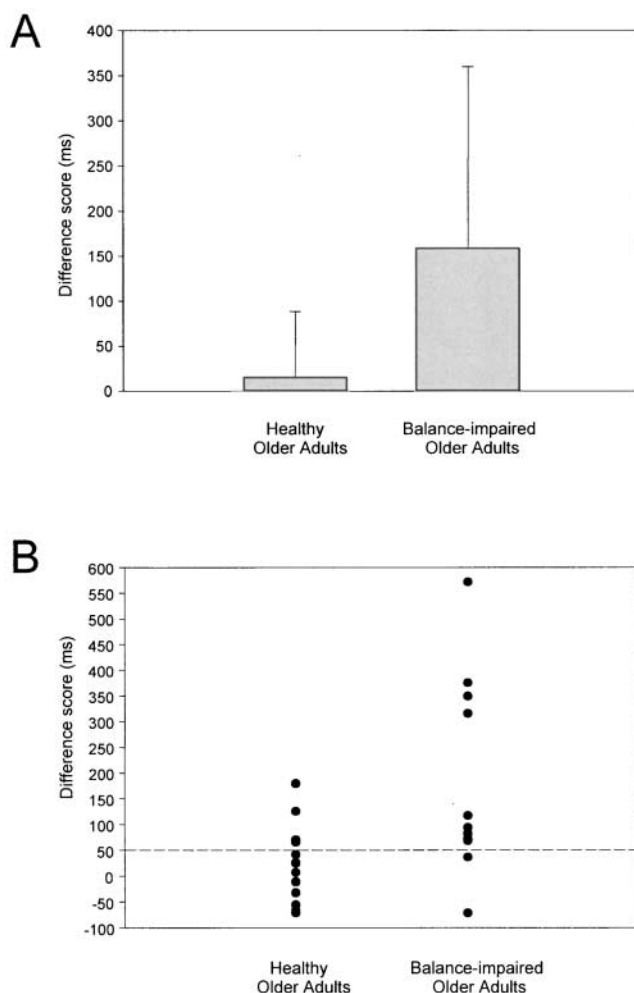


Figure 1. Difference in reaction times between dual and single tasks (dual – single) of the first reaction time following plate motion. **A**, mean data; **B**, individual data.

balance-impaired older adults compared with healthy older adults. To determine this, differences in cognitive task performance between single (prior to platform perturbation) and dual conditions (immediately after platform perturbation) were investigated across groups. There was a task effect [$F(1,26) = 6.84, p = .011$], a group effect [$F(1,26) = 7.84, p = .017$], but no Group \times Task interaction in reaction time. Reaction time was longer in the dual task than the single task for all subjects, suggesting that balance recovery is attentionally demanding for older adults.

The difference between the dual- and single-task reaction time was compared between groups to determine if the attentional demand was greater for balance-impaired older adults. Balance-impaired older adults demonstrated a greater difference score [$F(1,26) = 6.56, p = .017$], and therefore a longer reaction time in a dual task, for the first postperturbation reaction time. The dual-task reaction time was at least 50 milliseconds longer than the single task in 75% of balance-impaired older adults, but only in 26% of healthy older adults. This suggests that attentional demands were greater with balance impairment (Figure 1).

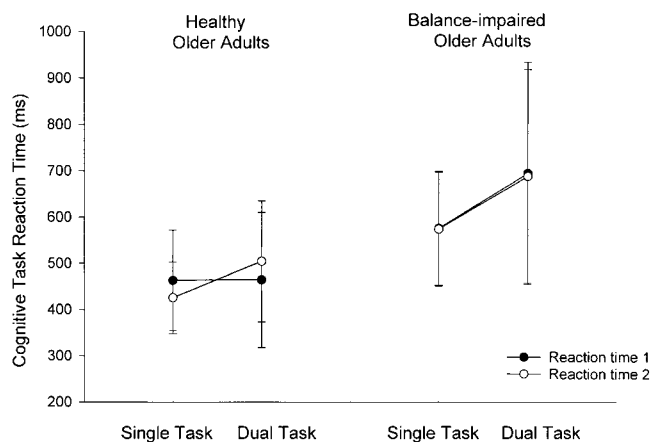


Figure 2. Verbal reaction time for the first two time periods following plate onset in healthy and balance-impaired older adults in single- and dual-task conditions.

When the first two postperturbation reaction times were investigated individually, a difference between the healthy and balance-impaired older adults was found. For both responses of the balance-impaired subjects, the dual-task reaction time was longer than with the single task (Figure 2). In contrast, the initial response of the healthy older adults was not affected by task, whereas the second response was longer in the dual-task situation. This suggests that in healthy older adults, the initial response to instability may be less attentionally demanding than the later portions of the postural response. In contrast, in balance-impaired older adults, the whole balance response appears to be attentionally demanding.

The inaccuracy measures revealed a significant task [$F(1,488) = 34.31, p < .001$] and group effect [$F(1,488) = 12.16, p < .001$], but no Group \times Task interaction. All subjects had significantly more mistakes with an added balance task than when performing the cognitive task alone. The probability of making an incorrect response increased significantly from single to dual tasks, and from healthy to balance-impaired older adults.

Influence of a Cognitive Task on Postural Recovery

The second question of this study addressed the effect of a secondary cognitive task on the ability to recover balance in older adults with and without balance impairments. To address this question, characteristics of the muscle response, COP, and COM were analyzed across tasks for each group.

COP parameters.—Investigation of the COP variables (time to stabilization, peak velocity, and range of COP motion) revealed a main effect of group [$F(1,26) = 6.34, p < .019$] and task [$F(1,26) = 4.82, p = .043$], but no Group \times Task interaction [$F(1,26) = 2.13, p = .158$]. The main effects were then investigated for each variable.

As shown in Figure 3, in balance-impaired older adults, the time to stabilization (COP return to preperturbation velocity levels) in the dual-task condition was significantly longer ($p = .008$) in comparison with the single-task condi-

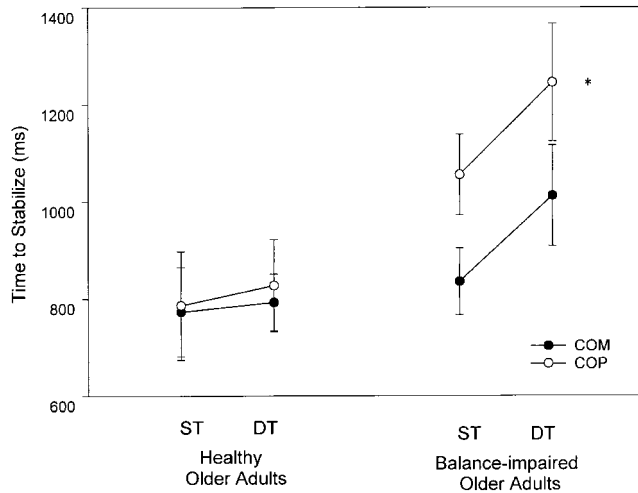


Figure 3. Mean (\pm SEM) values of the time taken for the center-of-pressure (COP) and center-of-mass (COM) velocity to return to a preperturbation level in healthy older adults and balance-impaired older adults in single and dual tasks. ST = single task; DT = dual task. * $p < .05$.

tion. In contrast, there was no task difference in the time to stabilization in the healthy older adults. The balance-impaired took longer than the healthy older adults to stabilize in both tasks. An example of the time to stabilization of

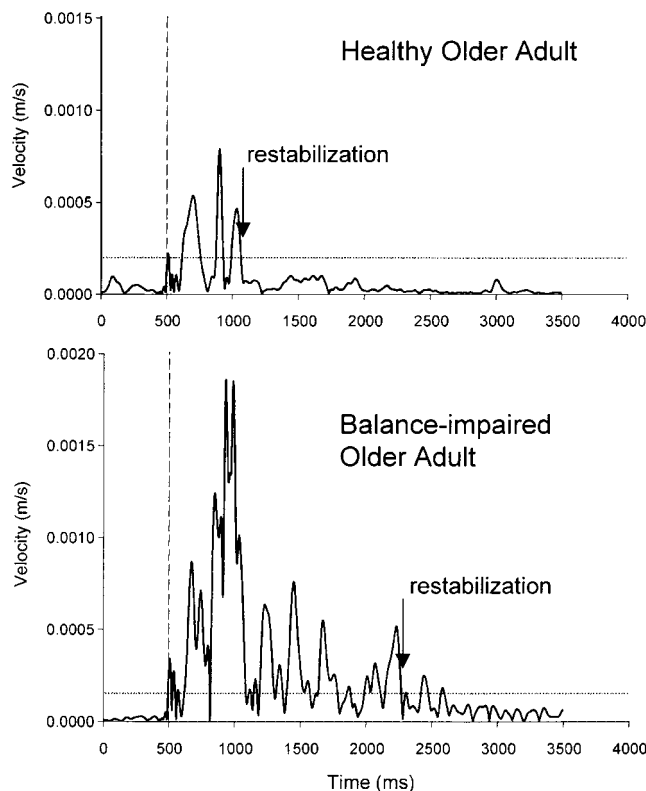


Figure 4. Time for the center of pressure to stabilize in a healthy and a balance-impaired older adult in a dual task.

a single healthy and a balance-impaired subject is shown in Figure 4.

The peak COP velocity reached during recovery was then investigated in order to infer the efficiency of the neuromuscular response in slowing the forward momentum of the body induced by the perturbation. Balance-impaired older adults had a greater COP resultant velocity during recovery in a dual-task situation, compared with a single-task situation (Figure 5; $p = .022$). This suggests that, compared with healthy older adults, balance-impaired older adults were less efficient in recovering stability in the dual-task condition.

The peak range of the COP excursion during recovery was then investigated as a measure of efficiency of recovery. No task differences were found for the balance-impaired older adults. In contrast, in the antero-posterior direction, the healthy older adults demonstrated a smaller COP excursion in the dual-task compared with the single-task condition ($p = .016$). This suggests that in the dual-task condition, healthy older adults may constrain COP excursion more than in the single-task condition. In the medio-lateral direction, no task effect was found.

COM excursion.—COM measures are often considered a better global measure of postural stability than COP. Although COP reflects the sum of muscle forces acting against the surface, the effect of these forces is reflected in COM movements. Investigation of the COM variables revealed a group effect [$F(1,26) = 10.61$, $p = .003$], but no task effect ($p = .187$). There was a trend for the balance-impaired older adults to take a longer time to stabilize their COM in a dual-task situation in comparison with the single task (Figure 3).

Muscle responses.—The repeated-measures ANOVA of the EMG onset and magnitude variables for the gastrocnemius muscle revealed a significant group effect [$F(1,26) = 7.11$, $p = .013$]; thus, interactions and univariate effects were investigated. Because there were no differences in

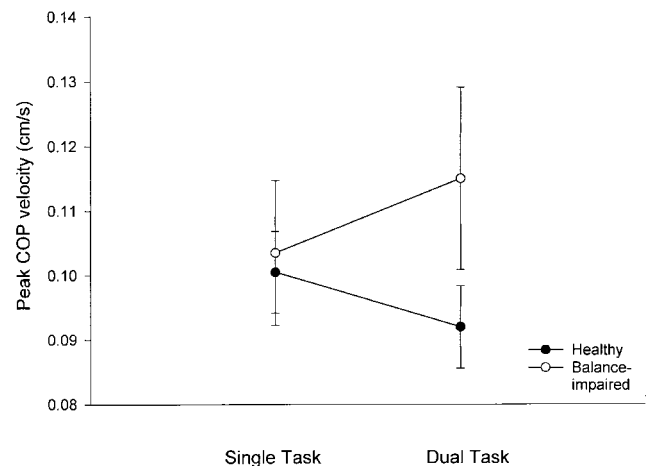


Figure 5. Peak resultant center-of-pressure (COP) velocity (\pm SEM) from plate onset for 2.5 s in single and dual tasks for healthy and balance-impaired older adults.

EMG onset or magnitude between the right and left sides, data were combined.

Investigation of gastrocnemius muscle onset times revealed a significant group effect [$F(1,26) = 8.32, p = .008$], but no significant task, or Group \times Task interaction. Gastrocnemius onset was slower in the balance-impaired compared with the healthy older adults; however, there was no difference in onset times between tasks. Thus, performance of a secondary task did not affect the onset latency of the neuromuscular response.

The magnitude of postural muscle activity from the onset of activity for 100 milliseconds revealed a significant group effect [$F(1,26) = 5.40, p = .029$], but no task effect or Group \times Task interaction. Although balance-impaired older adults demonstrated lower response magnitudes compared with the healthy older adults, there was no effect of task on muscle response amplitude.

Coactivation of agonist and antagonist muscles increases stiffness at a joint and is a strategy, albeit an inefficient one, used to increase stability. There was a significant difference in coactivation levels (gastrocnemius/tibialis anterior) between groups in the single ($p = .043$) and dual ($p = .026$) tasks. Although balance-impaired older adults demonstrated greater co-contraction than healthy older adults, their coactivation was equivalent in both conditions. In contrast, in healthy older adults, there was a significant task effect on coactivation, with a greater coactivation level in the dual task than in the single task.

DISCUSSION

The Attentional Demand of the Feet-in-Place Response

One purpose of this study was to compare the attentional demands of postural recovery in balance-impaired versus healthy older adults. We expected that in a dual-task situation, balance-impaired older adults would demonstrate a greater reduction in cognitive task performance compared with healthy older adults, suggesting that attentional demands associated with recovery of stability are greatest in balance-impaired older adults. Supporting our hypothesis, recovery of stability was found to be attentionally demanding in both groups of older adults, but more attentionally demanding in balance-impaired older adults.

A second purpose of this study was to determine the effects of performing a simultaneous cognitive task on the ability of balance-impaired older adults to recover postural stability following a platform translation. We hypothesized that due to competition for attentional resources, balance-impaired older adults would demonstrate a decrement in postural recovery in the dual-task conditions.

The aspects of postural control most influenced by the performance of a second task were the time for the COM and COP to stabilize. The time for balance-impaired older adults to stabilize COP in the dual task was significantly longer in comparison with the single task, while healthy older adults showed no change between tasks. The peak COP velocity reached during recovery was then investigated in order to infer the efficiency of the neuromuscular response in slowing the forward momentum of the body induced by the perturbation. Again, only balance-impaired

older adults had a greater COP resultant velocity during recovery in a dual-task situation, compared with a single-task situation, suggesting that compared with healthy older adults, they were less efficient in recovering stability in the dual-task condition.

There was also a trend for the balance-impaired older adults to take a longer time for their COM to stabilize to a preperturbation level in a dual-task compared with a single-task condition, with COM changes being close to those of the COP. These smaller changes in COM between the two conditions may be due to the fact that the COP must actually move out beyond the COM in recapturing balance after a perturbation. Thus, these movements tend to be slightly larger than COM changes when recovering balance.

Contrary to our hypothesis that range of the COP excursion during recovery would be higher during the secondary task for balance-impaired older adults, we found no significant change in excursion in the balance-impaired group. This supports previous work by Stelmach and colleagues (6), who also found that the time to restabilize the COP was influenced more by the addition of a cognitive task than the total range of motion when investigating age-related changes in balance recovery.

Interestingly, in the dual-task condition, COP excursion used to recover from the postural threat was smaller than in single-task conditions for healthy elderly individuals. This unexpected result suggests that dual-task conditions may result in tighter constraints on postural control in healthy populations, as a strategy to ensure stability. For example, an earlier study (9) showed that, in dual-task conditions, healthy elderly persons stepped when the COM was closer to the center of the base of support than in single-task conditions, suggesting they used a more conservative balance strategy (stepping when COM was well within the base of support) with a second task. This is consistent with research by Andersson and colleagues (23), who reported that under quiet-stance conditions, patients with peripheral vestibular disorders and poor balance reduce sway amplitude when performing a secondary mental task. Thus, certain populations may use a strategy to constrain their motion to better cope with the additional demand.

This increased constraint on the COP displacement in healthy older adults for the dual-task condition may be correlated with their significantly greater co-contraction of muscles at the ankle joint in this condition. This strategy of co-contracting agonist and antagonist muscles at a joint increases joint stiffness and has been observed in both less skilled performers and in older adults when constraining movement during postural tasks (24).

Performance of a secondary task did not affect the onset latency or magnitude of the primary neuromuscular response responsible for recovery. This is unlike the results of Rankin and colleagues (10), who reported a reduced postural muscle response magnitude in older adults when performing a dual task. This difference could be due to methodological issues, in that the postural or the cognitive task may not have been as attentionally demanding in the current study as in previous studies. Rankin and colleagues (10) used a math task that could be more demanding than the auditory reaction time task used in this study. In addition, the

perturbations investigated in this study were of a lower velocity than in Rankin's study, to accommodate the poorer balance abilities of the balance-impaired elderly subjects.

This study affirms and extends results from previous research demonstrating the deleterious effects of performing a secondary cognitive task on postural control in balance-impaired older adults (8,11–14). This reduction in balance ability could result from several factors. First, it could be due to a reduction in total attentional capacity, which limited the amount of attention the subjects could direct to the task of postural recovery. General capacity theory suggests there is a finite amount of processing space available in the brain to perform tasks (25). If there was a reduction in overall capacity in older adults with balance impairments that did not permit sufficient attention to be directed to both tasks, then reduced abilities in both tasks could be expected. We found that the balance-impaired older group showed significantly lower scores on the Trail-Making Tests, suggesting that they had reduced attentional abilities.

Alternatively, the postural response used by balance-impaired older adults may have a greater attentional demand than the response made by the nonimpaired adults. Older adults with a deterioration in one or more systems required to maintain balance may need to allocate a greater proportion of attention to postural control to achieve the same level of stability as a nonimpaired adult. Although the balance-impaired older adults in this study demonstrated a clinical decrement in balance ability, we can only surmise that these changes required a greater allocation of attention to balance. Similarly, we have evidence that the balance-impaired older adults demonstrated changes in their postural response (longer time to recover) that could require the allocation of additional attention to recover balance. Thus, the inability of balance-impaired older adults to maintain high levels of performance on both tasks when performed simultaneously could be due to both a reduction in attentional capacity and a change in the allocation of attention to the tasks. To determine whether attentional misallocation is a contributor to the inability to perform dual tasks, studies where attention is specifically directed to each task are required.

Finally, changes in balance ability in quiet stance have been associated with increased anxiety (4). Performing dual tasks may be a more stressful situation, and this could lead to a reduction in balance ability. Older adults with an admitted balance problem may have found the experimental situation more stressful than did the nonimpaired adults. However, the perturbations studied here were very small, and all subjects were able to maintain balance with no foot motion and minimal upper-limb response.

Limitations

Balance-impaired older adults were less healthy, reported more comorbidities, and exercised less frequently. Thus, differences we found may be due to differences in health and exercise status between the groups. In addition, they demonstrated poorer attention ability and lower overall cognitive functioning. The greater demand postural recovery posed for the balance-impaired older adults could be related

to their reduced cognitive ability, in addition to their balance impairment.

Clinical Applications

It is known that many factors contributing to balance control show deterioration in older adults and place them at risk of falling. We have found evidence of decrements in the postural stability of balance-impaired older adults when performing tasks requiring both cognitive processing and control of balance. Clinical applications include the development of intervention strategies for balance-impaired older adults in which postural tasks are first practiced alone, then simultaneously, with a secondary cognitive task in order to improve the ability of older adults to balance under these attentionally more challenging conditions.

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