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Original article

Balance rehabilitation and dual-task ability in older adults

Courtney D. Hall, PT, PhD [a,b,*], Lisa Heusel-Gillig, PT, DPT [b]

[a] *Atlanta Veterans Administration, Rehabilitation Research and Development Center of Excellence (151R), 1670 Clairmont Road, Decatur, GA 30033, USA*
[b] *Department of Rehabilitation Medicine, Emory University, 1441 Clifton Road NE, Atlanta, GA 30322, USA*

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ABSTRACT

Background/Purpose: Recent evidence suggests that an impaired ability to allocate attention to balance during dual-task situations is a powerful predictor of falls. Increased difficulty under dual-task conditions may result from cognitive or motor impairments or both. The extent to which interventions should be directed at cognitive or motor impairments is unclear. The goal of this study was to examine the extent to which standard balance rehabilitation improves dual-task ability.
Methods: A retrospective chart review of patients without vestibular or neurological disorders who were referred to physical therapy for disequilibrium was performed. Patients were assessed initially and at discharge for balance-related confidence, gait speed, fall risk, sensory integration, and dual-task ability. Balance rehabilitation involved weekly sessions plus home training for strengthening, endurance, center of gravity control training, multisensory training and postural strategy training. Specific dual-task training was not included.
Results: Average age was 75.8 ± 7.5 years, with 49% of participants being female. Participants improved significantly in all outcome measures, including measures of dual-task ability ($p < 0.05$). Percent improvement from initial to discharge assessment was significantly greater for balance confidence, fall risk and sensory integration than dual-task ability.
Conclusion: Standard balance rehabilitation significantly improved all measures of gait and balance, including dual-task measures; however, measures of dual-task ability did not improve to the same extent. Improvements of underlying motor impairments may not adequately address impaired dual-task ability.

1. Introduction

Historically, degradation of balance control in the older adult has been attributed to age-related impairments of the motor and/or sensory systems. As a result, interventions to improve balance ability have focused on improving strength and range of motion, and the use and integration of sensory input for balance. However, current guidelines on fall prevention recognize that cognitive impairment is also a major risk factor for falls.[1] Recent evidence suggests that an impaired ability to allocate attention to balance during dual-task situations is a powerful predictor of falls. One study of assisted living residents revealed that the inability to walk while talking was highly predictive of a future fall: 83% of those who stopped walking while talking experienced a subsequent fall.[2] Similar findings were also found in cognitively intact, community-dwelling older adults.[3]

Potential consequences from falls include physical harm, loss of independence and lower quality of life. In addition, falls can lead to fear of falling resulting in reduced physical activity and disuse disequilibrium. Nearly one-quarter of older adult fallers restrict their activities and up to 50% are fearful of experiencing another fall.[4,5] When balance is not challenged on a regular basis through physical activity, the individual may demonstrate decreased automaticity of postural control, which then requires more cognitive processing. Distractions while walking, such as conversation with a friend, may exceed the available cognitive resources, resulting in degradation of either task—talking or walking—and potentially result in a fall.[6] Using the dual-task paradigm, researchers have demonstrated that the processes underlying postural control utilize cognitive resources and that the demands on those resources increase in the presence of impaired balance (i.e., decreased automaticity of postural control).[7] Thus, for the older adult at risk for falls, maintaining balance requires attention so that fewer resources are available for performing a mental task.

* Corresponding author. Atlanta Veterans Administration, Rehabilitation Research and Development Center of Excellence (151R), 1670 Clairmont Road, Decatur, GA 30033, USA.
E-mail address: chall7@emory.edu (C.D. Hall).

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Increased difficulty maintaining balance under divided attention situations in older adults may result from: (1) inability to shift attention between tasks (cognitive impairment); (2) reduction in attentional capacity (cognitive impairment); (3) increased demand for limited attentional resources associated with impairments in the postural control system (motor impairment); and (4) an interaction of these factors.[8] Research has not clearly identified the relative contributions of cognitive and motor impairments to dual-task ability or whether rehabilitation should focus on the cognitive or motor impairments. For example, one study of community-dwelling older adults demonstrated that fallers had more difficulty walking under dual-task conditions compared to nonfallers; however, fallers and nonfallers were not different on a balance screen for fall risk nor on a measure of general cognitive status.[3] Thus, the extent to which interventions should be directed at cognitive or motor impairments or the interaction of the two is unclear.

The purpose of this study was to examine the extent to which standard balance rehabilitation, focused on improving underlying motor impairments and sensory integration for disuse disequilibrium, would improve the ability to allocate attention to walking during dual-task situations. We hypothesized that patients would demonstrate improvements for outcome measures involving single-task situations [usual gait speed, Dynamic Gait Index (DGI) and sensory organization test (SOT)] and outcome measures involving dual-task situations [modified timed up and go test (TUG)]. We further hypothesized that participants would demonstrate greater improvements for single-task measures than for dual-task measures.

2. Methods

2.1. Participants

A retrospective chart review was performed and included 55 community-dwelling older adults who were referred to the Emory University Dizziness and Balance Center between 2007 and 2009 for balance and gait disorders. Inclusion criteria included: at least 60 years of age, completion of an individualized outpatient physical therapy program, and availability of initial and discharge gait and balance assessment including dual-task assessment. Exclusion criteria included vestibular dysfunction or progressive neurologic pathology, such as Parkinson's disease or multiple sclerosis. Emory University's Institutional Review Board approved the protocol and all participants gave informed written consent for use of their clinic data.

2.2. Protocol

All patients underwent initial and discharge assessment by a licensed physical therapist. During physical therapy assessment, balance-related confidence, usual gait speed, DGI and SOT were assessed. In addition, the modified TUG with cognitive and manual conditions was assessed. Fall history, age, gender and comorbidities were collected as part of the medical history. Patients underwent customized gait and balance physical therapy with a daily home exercise program (HEP).

2.3. Outcome measures

Balance-related confidence was measured using the Activities-specific Balance Confidence (ABC) scale.[9] Participants rated perceived confidence across a continuum of 16 activities (e.g., walking in the house, on stairs and on an icy surface) on a scale from 0% (no confidence) to 100% (completely confident). The ABC has good test–retest reliability.[9] Overall average balance-related confidence was reported.

Usual gait speed was determined by instructing participants to walk at their normal pace over a 9-m pathway. The time taken to walk the middle 6 m was measured using a stopwatch, and gait speed was calculated.[10]

Fall risk was determined using the DGI, which assesses an individual's ability to modify gait in the presence of external demands.[11] The 8 items of the DGI include walking with changing speed, head turns, walking over and around obstacles and stair climbing. Scoring of the DGI is based on a 4-point scale from 0 (severe impairment) to 3 (normal ability) with a maximum total score of 24. A score of 19 or less indicates risk for falling.[11] The DGI has excellent interrater and test–retest reliability.[11]

Ability to use sensory input for balance was assessed using computerized dynamic posturography (NeuroCom International, Portland, OR, USA). Sensory input is systematically altered during the SOT and an equilibrium score is calculated for each condition. Scores range from 0 to 100, with 0 indicating a fall and 100 perfect stability (i.e., no postural sway). SOT consists of six conditions, the first three involving a stable support surface with eyes open (condition 1), eyes closed (condition 2) and sway-referenced surround (condition 3), and the last three involving a sway-referenced surface with eyes open (condition 4), eyes closed (condition 5) and sway-referenced surround (condition 6). SOT composite score is a weighted average of the six conditions and has good validity and reliability.[12]

Dual-task ability was measured using the modified TUG, which includes three conditions: no secondary task (TUG-baseline), cognitive task (TUG-cognitive) and manual task (TUG-manual).[13] Patients were instructed to stand up from a chair, cross a line on the floor 3 m away as "quickly and safely" as possible, turn around, walk back to the chair and sit down. Timing began when the therapist said "Go" and stopped when the patient sat down. For the cognitive condition, patients were instructed to count backwards by 3 s from 100 while walking as quickly as possible. The manual condition involved carrying a cup of water while walking as quickly as possible. For each of the dual-task conditions, patients were instructed to place equal emphasis on the walking and secondary (either cognitive or manual) task.

2.4. Intervention

Participants were seen weekly for balance and gait training, as well as progression of HEP. Static balance training included maintaining balance with altered base of support with vision and somatosensory cues altered. Dynamic balance exercises included voluntary weight shifts and performance of ankle, hip and step strategies. Gait training included walking with narrow base of support, altered gait pattern, head turns, varied speed, starts and stops, and avoiding obstacles. Strengthening exercises included sit to stand transfers without the use of the arms, and appropriate lower extremity exercises as determined by manual muscle testing. All participants were provided a written HEP consisting of strengthening, balance and gait exercises designed to improve postural stability and mobility with progressively more challenging tasks. Walking for endurance was also included in the HEP. The customized HEP was based on identified impairments and was progressed according to ability and level of assistance at home.

2.5. Data analysis

Outlier analysis was performed on the outcome measures of interest and data more than three standard deviations outside the mean were removed from further analysis. The effect of balance

Table 1
Outcome measures[a]

Measures	Initial	Discharge	Percent Change[b]: Initial to Discharge
ABC (%)	59.2 ± 17.1	74.9 ± 12.7	37.5 ± 51.3
Usual gait speed (m/s)	0.75 ± 0.15	0.87 ± 0.19	18.7 ± 30.1
DGI (/24)	15.3 ± 3.0	19.2 ± 2.2	29.9 ± 27.2
SOT (/100)	53.6 ± 12.4	63.0 ± 13.3	31.4 ± 27.2
TUG-baseline (s)	12.2 ± 3.0	10.4 ± 2.3	12.8 ± 15.6
TUG-cognitive (s)	16.9 ± 5.0	13.1 ± 3.6	20.3 ± 17.9
TUG-manual (s)	14.3 ± 3.8	12.4 ± 13.3	11.5 ± 20.2
DTC-cognitive[c] (%)	40.3 ± 32.9	25.5 ± 22.8	–
DTC-manual[d] (%)	17.3 ± 17.1	18.6 ± 18.0	–

[a] Data presented as mean ± standard deviation.
[b] Percent change = [(initial – discharge) ÷ initial] × 100.
[c] DTC-cognitive = [(Discharge TUG-cognitive – Initial TUG-cognitive) ÷ Initial TUG-cognitive] × 100.
[d] DTC-manual = [(Discharge TUG-manual – Initial TUG-manual) ÷ Initial TUG-manual] × 100.
ABC = Activities-specific Balance Confidence scale; DGI = Dynamic Gait Index; SOT = sensory organization test; TUG = timed up and go test; DTC = dual-task cost.

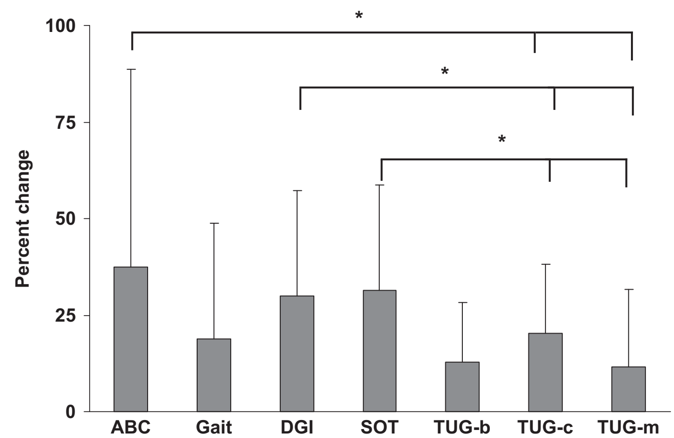

Fig. 1. Calculated percent change in the outcome measures. $^{*}p < 0.05$. ABC = Activities-specific Balance Confidence scale; Gait = preferred gait speed; DGI = Dynamic Gait Index; SOT = sensory organization test; TUG = timed up and go test; TUG-b = TUG-baseline; TUG-c = TUG-cognitive; TUG-m = TUG-manual.

rehabilitation on the outcome measures was examined using one-way repeated measures multivariate analysis of variance ($p < 0.05$). The within-subject factor was time (initial and discharge evaluation), and the dependent variables of interest were ABC, gait speed, DGI, SOT, TUG-baseline, TUG-cognitive, and TUG-manual. Significant multivariate findings were followed-up with appropriate univariate statistics ($p < 0.05$).

Dual-tasks costs (DTC) were calculated for both TUG-cognitive and TUG-manual relative to TUG-baseline. DTC was used to quantify the change in performance from single- to dual-task conditions. A positive value indicates worse performance under dual-task conditions, while a negative value indicates better performance under dual-task conditions. The effect of balance rehabilitation on DTC for TUG-cognitive and TUG-manual was examined using one-way repeated measures multivariate analysis of variance ($p < 0.05$). Significant multivariate findings were followed-up with appropriate univariate statistics ($p < 0.05$).

To compare the extent of improvement between single-task and dual-task conditions, percent change was calculated for each outcome measure and paired samples *t* tests were performed ($p < 0.05$).

3. Results

3.1. Participants

After outliers were removed, analysis was based on data from 49 patients with a mean age of 75.8 ± 7.5 years (range, 61–89 years). There were essentially equal numbers of men ($n = 25$) and women ($n = 24$). Sixty-nine percent did not use an assistive device, 21% used a cane and 10% used a walker. On average, participants completed 3.7 physical therapy visits (range, 2–10). One-third of participants ($n = 17$) reported falling in the previous year.

3.2. Effects of balance rehabilitation on outcome measures

There was an overall significant effect of balance rehabilitation on all outcome measures ($F_{7, 15} = 12.406$, $p < 0.001$). At discharge, patients demonstrated significant improvements in balance-related confidence, usual gait speed, DGI, SOT, and modified TUG (baseline, cognitive and manual; Table 1). There was a significant reduction in DTC from baseline to discharge ($F_{2, 46} = 4.650$, $p = 0.014$). Only DTC for TUG-cognitive contributed to the significant effect ($p = 0.004$).

Examination of the percent change from baseline to discharge revealed that ABC, DGI and SOT all improved to a significantly greater extent than the dual-task conditions of modified TUG ($p < 0.05$; Fig. 1; Table 1). Improvements in usual gait speed compared to TUG-cognitive and TUG-manual did not differ ($p > 0.05$).

4. Discussion

Despite the fact that an inability to divide attention while walking is a major risk factor for falls, few studies have examined whether interventions can improve an older adult's ability to walk under dual-task conditions. Furthermore, no studies have examined whether such improvement would translate into a reduction in falls. The purpose of this study was to examine whether standard balance rehabilitation that focused on the underlying gait and balance impairments would improve gait under dual-task conditions. Based on considerable evidence, we hypothesized that balance rehabilitation would result in improved balance and gait under single-task conditions.[14–16] Indeed, the data from this study provide additional support that targeted balance rehabilitation is effective. Importantly, the data also support our hypothesis that balance rehabilitation would result in improved gait under dual-task conditions. To our knowledge, this is the first study to demonstrate that standard balance rehabilitation for older adults with impaired balance results in improved gait under dual-task conditions. The data suggest that improvements in underlying balance and gait impairments resulted in increased automaticity, allowing more attentional resources to be allocated to the cognitive task.

The findings of improved balance and gait under single-task conditions following targeted intervention were expected and are in agreement with previous research. Usual gait speed under single-task conditions improved by an amount that exceeded the threshold for substantial improvement (>0.10 m/s),[17] although the average gait speed at discharge (0.85 m/s) remained well below estimates for healthy older adults.[10] Fall risk as measured by the Berg Balance Scale and DGI has been shown to improve with individualized balance rehabilitation.[15,16] In these studies, DGI total score improved 20–37% and Wolf and colleagues[16] found that 65% of participants achieved at least a 3-point improvement in total score. While no minimal clinically important difference in DGI score has been established, normal variability of the total score in patients with impaired balance is 3 points;[18] thus, to indicate an actual change in ability, the total score should improve by at least 3 points. Participants in the current study made gains similar to those in previous studies: an average of 30% improvement in DGI with 75% of participants demonstrating at least a 3-point increase in DGI total score. The approach to balance rehabilitation in the current study was individualized physical therapy sessions in conjunction with a customized HEP to be performed daily. While compliance with the HEP was not directly measured, a similar sample of patients was found to be at least moderately compliant with a daily HEP, with only 5% demonstrating less than 33% compliance.[19] Thus, the total dosage of balance and gait exercises in the current study was at least 3 days per week for 4 weeks, a similar amount of training that participants in the Wolf et al. study underwent.[16] Further research on the dose effects, including frequency and duration, of balance rehabilitation is warranted.

In addition to improved balance and gait, participants in this study also demonstrated an increase in balance-related confidence. This finding is of considerable importance given that self-perception of capability is more predictive of physical activity level than actual balance ability.[20,21] Poor balance-related confidence is associated with reductions in physical activity,[20] which in turn can lead to impaired balance due to disuse. By improving balance-related confidence, there is a greater likelihood that participants will remain physically active after completion of therapy to maintain gains achieved through rehabilitation. The current findings of increased balance-related confidence are similar to those of Shumway-Cook et al.,[15] but in sharp contrast to Wolf et al.[16] who did not find a significant change in overall fear of falling as measured by visual analog scale. The differences in the findings among studies may relate more to the properties of the outcome measures than to the efficacy of balance rehabilitation: dichotomous (yes/no) questions about fear of falling have been shown to have little utility[20] and visual analog scale measures that allow for a continuous rating of self-perceived balance ability have only moderate reliability.[18]

An important issue in the design of effective balance interventions is that Silsupadol et al. found that balance-related confidence did not improve with dual-task training.[22] As in the current study, they did find that balance confidence improved with single-task training. The authors hypothesize that the constant challenge of the dual-task training paradigm may have undermined participants' balance confidence. Training to build balance-related confidence may need to begin with single-task training so that mastery is achieved early on and then move onto dual-task training to progress the balance challenge.

The novel finding of this study was that standard balance rehabilitation (i.e., single-task training) resulted in improved gait under dual-task conditions. Studies have shown that dual-task performance by older adults can be improved; however, the majority of research has been in non-balance-related tasks.[23,24] In the cognitive domain, there is substantial evidence that older adults benefit from practice performing dual tasks.[23] Kramer and Larish clearly demonstrated that the ability to coordinate multiple cognitive tasks and flexibly allocate resources could be improved through specific cognitive training.[24] Studies involving dual-task performance of balance-related tasks also indicate improvements following dual-task training in both healthy older adults and those with chronic stroke.[25,26] Since these studies involved at least some dual-task training, the research design does not allow for identification of which specific approach (single- or dual-task training) is necessary to improve gait under dual-task conditions.

To date, one research group has compared single-task training to dual-task training.[22,27] Participants were randomly assigned to balance training under single-task conditions or balance training under dual-task conditions with either fixed priority instructions (equal attention to posture and cognitive tasks) or variable priority instructions (attention switched between posture and cognitive task). All three groups improved usual gait speed under single-task conditions and fall risk as determined by the Berg Balance Scale. However, only the dual-task training groups improved gait speed under dual-task conditions. In contrast, participants in the current study with single-task training demonstrated significant improvement in timed gait under dual-task conditions. Silsupadol et al. did find that a measure of balance control, inclination angle, improved with either single- or dual-task training.[27] The implications of this finding are not clear since this measure has not been related to fall risk. Potential explanation of the differences between the studies could be related to either the participants or training. Participants in the current study had significantly greater balance and gait impairments compared to the sample in the Silsupadol et al. studies.[22,27] Our participants had much slower gait speed (0.75 m/s *vs.* 1.1 m/s), indicating greater mobility disability as well as being at higher risk for falls. In terms of differences in training, the current study explicitly incorporated training of gait speed variation (i.e., speeding up and slowing down), whereas there is no indication that gait speed was explicitly trained in Silsupadol et al.'s studies. Thus, for individuals with significantly impaired balance and gait, single-task training resulted in improved gait under dual-task conditions. The research design of the current study does not allow us to compare the effects of single- and dual-task training in this population. Much remains to be studied in older adults with significantly impaired balance to identify optimal training parameters and to determine whether balance rehabilitation that incorporates dual-task training would confer additional benefits beyond those of single-task training.

Data from this study and Voelcker-Rehage and Alberts support the notion that training-related changes in dual-task performance can be explained, at least in part, by increased automatization of the motor tasks.[28] Single-task training of the underlying motor impairments in both studies led to improved dual-task performance involving a motor task. In the current study, DTC for the cognitive task was reduced with balance rehabilitation. At discharge, participants were better able to maintain usual gait speed in the presence of a cognitive task than they were at initial evaluation. This reduction in costs may reflect an increase in automaticity of postural control because of improved balance and gait and support the task automatization model.[29] These findings suggest that practice of the individual tasks frees up cognitive resources that become available for processing the cognitive task. The findings of these studies do not support the task integration model, which proposes that dual-task training is necessary to induce improvement in dual-task performance.

It is interesting to note that DTC for the manual task did not change with balance rehabilitation. In fact, the DTC for the manual task was considerably less than for the cognitive task. Lundin-Olsson et al. demonstrated that a time difference of at least 4.5 s between TUG-baseline and TUG-manual is an indicator of frailty and identifies older fall-prone individuals.[30] The average time difference for the current sample was approximately 2 s, indicating a relatively healthy sample and that the addition of a manual task did not provide a significant distracter.

This study examined the effects of balance training on dual-task ability using an observational research design. As such, there were limitations, which included lack of a control group, utilization of a single measure of dual-task ability, and no follow-up testing to evaluate whether participants maintained improvements in dual-task ability. In addition, it is known that cognition affects ability to dual-task and our participants were not formally assessed for mental function; although ability to participate in therapy implies at least a minimal level of mental ability.

In summary, this study demonstrated that by addressing the underlying gait and balance impairments, dual-task ability can improve without specific dual-task practice in a group of older adults with impaired gait and balance. However, measures of dual-task ability did not improve to the same extent as other gait and balance measures. Improvements of underlying motor impairments may not adequately address impaired dual-task ability. Further research is warranted to determine whether balance rehabilitation should incorporate dual-task practice to optimize improvements in balance and gait.

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