Efficacy of Gaze Stability Exercises in Older Adults With Dizziness

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Background and Purpose: The purpose of this study was to determine whether the addition of gaze stability exercises to balance rehabilitation would lead to greater improvements of symptoms and postural stability in older adults with normal vestibular function who reported dizziness.

Methods: Participants who were referred to outpatient physical therapy for dizziness were randomly assigned to the gaze stabilization (GS) group (n = 20) or control (CON) group (n = 19). Dizziness was defined as symptoms of unsteadiness, spinning, a sense of movement, or lightheadedness. Participants were evaluated at baseline and discharge on symptoms, balance confidence, visual acuity during head movement, balance, and gait measures. The GS group performed vestibular adaptation and substitution exercises designed to improve gaze stability, and the CON group performed placebo eye exercises designed to be vestibular neutral. In addition, both groups performed balance and gait exercises.

Results: There were no baseline differences ($P > .05$) between the GS and CON groups in age, sex, affect, physical activity level, or any outcome measures. Both groups improved significantly in all outcome measures with the exception of perceived disequilibrium. However, there was a significant interaction for fall risk as measured by Dynamic Gait Index ($P = .026$) such that the GS group demonstrated a significantly greater reduction in fall risk compared with the CON group (90% of the GS group demonstrated a clinically significant improvement in fall risk versus 50% of the CON group).

Discussion and Conclusions: This study provides evidence that in older adults with symptoms of dizziness and no documented vestibular deficits, the addition of vestibular-specific gaze stability exercises to standard balance rehabilitation results in greater reduction in fall risk.

Key words: *dizziness, gaze stability exercises, elderly*

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Dizziness is among the most prevalent symptoms for which people seek medical help, and the incidence of dizziness increases with age.[1] Estimates of the number of older adults who experience chronic dizziness vary widely from 13% to 38%.[2] Successful management of dizziness is an important issue because dizziness is a major risk factor of falls and can lead to functional disability.[3,4]

Both natural age-related decrements of vestibular function and pathological loss of vestibular function result in symptoms of dizziness and increased fall risk. It has been established that vestibular exercises decrease dizziness, improve postural stability, and improve visual acuity during head movement in individuals with vestibular hypofunction.[5–9] In addition, vestibular rehabilitation results in significant reduction in fall risk as measured by Dynamic Gait Index (DGI) in individuals with unilateral vestibular hypofunction.[10] Thus, vestibular exercises may be beneficial for the older individual with symptoms of dizziness who is at risk of falls but does not have a vestibular pathology.

Research suggests that the vestibular rehabilitation is an effective exercise approach for individuals with a primary symptom of dizziness.[11,12] Yardley et al[11] found that the vestibular rehabilitation was more effective than usual medical care in reducing symptoms and improving postural stability in individuals with chronic dizziness. The role of vestibular pathology in the outcome of these studies is not clear. Less than one-third of participants had a specific (vestibular) diagnosis; additionally, the data were not analyzed in a manner that differentiated dizziness as a result of vestibular and nonvestibular etiology. Therefore, it is not clear whether vestibular rehabilitation is an effective exercise approach only for individuals with vestibular pathology or might also be beneficial for the client with nonspecific dizziness.

The purposes of this study were (1) to determine whether the addition of gaze stability exercises to balance rehabilitation would lead to greater improvements of symptoms, postural control, and gait in older adults with normal vestibular function, and (2) to identify factors that predict rehabilitation outcomes including symptoms and fall risk at discharge.

METHODS

Design

This study was a prospective, randomized, single-blind clinical pilot study. Participants were blinded as to exercise group assignment. Emory University's Institutional Review

Board and the Atlanta Veterans Affairs Medical Center approved the protocol, and all participants gave informed consent.

Participants

Thirty-nine patients who were referred for dizziness to outpatient physical therapy at Emory University Dizziness and Balance Center consented to participate in the study. Dizziness is an imprecise term used to describe a variety of symptoms. Dizziness was defined as symptoms of unsteadiness, spinning, a sense of movement, or lightheadedness.[2] Participants were randomly assigned to the gaze stabilization (GS) group or control (CON) group. Inclusion criteria included being at least 60 years of age, documented balance or mobility problems, and normal vestibular function. Exclusion criteria included a Mini-Mental State Examination (MMSE) score <24/30 and progressive medical issues that would affect mobility. Age, sex, comorbidities, and history of fall were collected as part of the medical history.

Protocol

Potential participants were evaluated by a neurologist specializing in dizziness. The physician assessed integrity of the vestibular and oculomotor systems, and screened for any progressive neurologic problems. Normal vestibular function was defined by the absence of corrective saccades with rapid head thrusts in either direction and by <25% asymmetry between right and left sides and >5 degree/sec slow-phase eye velocity in response to bithermal caloric testing.

At the initial visit, potential participants were evaluated on balance confidence and balance and gait measures, and were instructed in a customized home exercise program (HEP) for balance and gait. Most participants consented at the second visit at which time they completed study assessments and were taught eye exercises for their assigned group. Participants were seen weekly for balance and gait training and progression of HEP. Participants recorded compliance with eye exercises on a weekly calendar and verbally reported compliance with balance and gait exercises. Compliance with balance and gait HEP was defined as low (<33%), moderate (33%–75%), and high (>75%) based on verbal report. At discharge, all assessments were repeated.

Measures of Affect and Activity

We measured depression (15-item Geriatric Depression Scale[13]), anxiety (State-Trait Anxiety Inventory[14]), health-related quality of life (12-item Health Survey[15]), and physical activity (Physical Activity Scale for the Elderly[16]) because these factors can impact participation in exercise interventions and therefore influence the treatment outcome.

Outcome Measures

The Disability Rating Scale is a self-report scale ranging from 0 (no disability) to 5 (long-term severe disability).[17] Participants selected the statement that best described how they felt. The Disability Rating Scale has validity[17] and excellent test-retest reliability.[18]

The Visual Analog Scale (VAS) was used to quantify perceived severity of symptoms (higher scores indicate worse symptoms).[18] Differences in severity of dizziness before and after 1 minute of head turns (DZ VAS) and of disequilibrium between sitting and walking (DIS VAS) were reported. The expression of DZ VAS and DIS VAS scores was similar to dynamic visual acuity (DVA), which is expressed as the difference between visual acuity with head stationary and head moving. VAS scores have moderate test-retest reliability.[9,18]

The Activities-specific Balance Confidence (ABC) Scale was used to measure confidence in balance across a continuum of 16 activities.[19] Confidence in balance is rated on a scale from 0% to 100% with higher scores reflecting less fear of falling and greater confidence in balance. The overall average is reported and has good test-retest reliability.[19]

Visual acuity during head movement (DVA) was measured using customized computerized software.[20] Participants identified letters while turning the head from side to side between 120 and 180 degree/sec. DVA, the difference in acuity with the head stationary versus with the head moving, is reported as the average of rightward and leftward scores; higher scores indicate worse visual acuity. Reliability of computerized DVA is good ($r = 0.83–0.87$).[20]

Preferred gait speed was determined by instructing participants to walk at their usual pace over a 9-m pathway.[21] The time that it took to walk the central 6 m was measured using a stopwatch. Gait speed has excellent test-retest reliability ($r = 0.90$).[21] Fall risk was determined using the DGI. A maximum total score of 24 is possible, and a total score of ≤19 indicates risk of falling.[22,23] The DGI has excellent interrater and test-retest reliability.[22] At discharge from rehabilitation, participants were classified into one of two fall risk groups: Low Risk defined as DGI score of >19/24 or At Risk defined as DGI score of <19/24.

Computerized dynamic posturography was used to assess the use of sensory input for balance. Sensory input is systematically altered during the sensory organization test (SOT), and the average sway within each condition is calculated. The SOT composite score has validity and good reliability.[24]

Intervention

Gaze Stability Exercises

The GS group performed vestibular adaptation and substitution exercises designed to improve gaze stability (Table 1).[8] Vestibular adaptation exercises are designed to increase gaze stability through long-term changes in the gain of the remaining vestibular system in response to input. Adaptation exercises require the individual to fixate on a visual target during either horizontal or vertical head movement. Substitution exercises are designed to foster the use of other eye movement strategies in order to substitute for lost vestibular function and maintain visual fixation. Substitution exercises require the individual to perform eye-head movements between targets with the goal of seeing clearly during those tasks. Total time for eye movement exercises did not exceed 30 minutes per day.

Eye Movement Exercises

Participants in the CON group performed placebo eye exercises designed to be vestibular neutral. The CON group performed saccadic eye movements without visual targets against a plain white wall while keeping the head stationary

TABLE 1. Eye Movement Exercise Progressions for GS and CON Groups

Week	GS	CON	Duration (min)	Frequency (per day)	Total (min)
1	Adaptation: ×1 viewing, distant/near targets, horizontal/vertical	Saccadic eye movements, no target, distant/near, horizontal/vertical	1	3 times	12
2	Adaptation: ×1 viewing, distant/near targets, horizontal/vertical; substitution: eye-head movements between near targets, horizontal/vertical	Saccadic eye movements, no target, near, horizontal/vertical/diagonal; saccadic eye movements, no target, distant, horizontal/vertical	1	3 times	18
3	Adaptation: ×1 viewing, distant/near targets, horizontal/vertical; substitution: eye-head movements between near targets, horizontal/vertical	Saccadic eye movements, no target, distant/near, horizontal/vertical/diagonal; saccadic eye movements, no target, seated, near, horizontal	1–2	3 times	27
4	Adaptation: ×1 viewing distant/near targets, horizontal/vertical; substitution: eye-head movements between near targets, horizontal/vertical	Saccadic eye movements, no target, distant/near, horizontal/vertical/diagonal	1–2	3 times	24–27

Abbreviations: GS, gaze stabilization; CON, control.

(Table 1).[8] Total time for eye movement exercises did not exceed 30 minutes per day, and it was matched to the time the GS group spent performing gaze stability exercises.

Balance and Gait Training

Both the GS and CON groups were provided a written HEP consisting of balance and walking exercises designed to improve postural stability and mobility with progressively more challenging tasks. Balance exercises included maintaining stability in standing with vision and somatosensory cues altered, dynamic weight shifting and performing ankle, hip, and step strategies. Gait activities included negotiating uneven terrains and obstacles, walking with slow head turns focusing on objects, varied speed (speeding up and slowing down), and unpredictable starts and stops. Walking for endurance was included in the HEP. The customized HEP was based on identified impairments and progressed according to ability and level of assistance at home.

Data Analysis

Data were summarized using descriptive statistics. To determine the effect of GS group activities on the outcome measures, 2 × 2 repeated-measures univariate analysis of variance were performed with time (baseline and discharge) and group (GS and CON) as the repeated and between-subjects factors, respectively. Significance was set at $P < .05$ for all analyses. Effect sizes, using the standardized response mean (SRM), were calculated to determine the magnitude of change from baseline to discharge.[25] SRM is the mean change score for each group divided by the standard deviation of the mean change. Small, moderate, and large effects were identified based on standard criteria of 0.2, 0.5, and 0.8, or greater.[25]

To identify factors associated with rehabilitation outcome, we performed regression analyses. To identify factors associated with symptoms of dizziness (DZ VAS) and disequilibrium (DIS VAS) at discharge, we performed forward stepwise linear regression analyses, and for fall risk at discharge, we performed forward stepwise logistic regressions. Bivariate correlations were used to determine which variables were significantly correlated with DZ VAS and DIS VAS scores at discharge, fall risk at discharge (1 subject who was not initially at risk was not included in the analysis), and significant reduction in fall risk (defined as a change of at least 3 points in the DGI[18]). Only variables that accounted for at least 16% of the variance ($r > 0.4$) were included in the regression analysis. Potential predictor variables include age, MMSE, comorbidities, affect, physical activity, exercise compliance, group, initial symptoms, and initial performance on outcome measures. Data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL).

RESULTS

Participant Characteristics

Data analysis was based on 37 participants (2 did not return for their final visit). The basic characteristics of participants at baseline assessment are summarized in Table 2. Participants in the CON group were compliant with the eye exercises 80% of the time, whereas the GS group was compliant 60% of the time ($P = .04$). In terms of compliance with balance and gait HEP, 1 participant from each group had low compliance, 40%–45% had moderate compliance (CON = 9/20; GS = 7/17), and one half (CON = 10/20; GS = 9/17) had high compliance ($\chi^2 = 0.97$).

There were no baseline group differences ($P > .05$) in age, sex, or number of comorbidities (Table 2). There were no baseline group differences on measures of affect or physical activity level ($P > .05$; Table 2). There were no baseline group differences on any outcome measures ($P > .05$; Table 3).

Efficacy of GS Exercises

There was a significant main effect of time indicating that both groups improved significantly ($P < .05$) in all outcome measures, with the exception of the DIS VAS score, after rehabilitation (Table 3). The DIS VAS score did not change during the course of the study. There was no significant main effect of group ($P > .05$) for any of the outcome measures. The only significant interaction was for fall risk as measured by DGI ($P = .026$). Fall risk was reduced to a greater extent in the GS group compared with the CON group

TABLE 2. Participant Characteristics at Baseline

Variable	GS (n = 20)	CON (n = 17)	*P* or χ^2
Age (y)			
Mean (SD)	73.6 (6.5)	74.5 (8.5)	.71
Range	61–85	60–91	
Gender			
Women/men (n)	17/3	11/6	.15
Falls in previous year (n)			
No falls/at least 1 fall	7/13	4/13	.45
Assistive device use (n)			
None/cane/walker	18/1/1	12/4/1	.25
No. of PT visits			
Mean (SD)	4.4 (0.8)	4.5 (0.8)	.77
No. of comorbidities	3.2 (1.7)	3.5 (1.8)	.52
Geriatric Depression Scale score	3.4 (2.9)	3.3 (3.4)	.89
Anxiety Inventory scores			
State	38.3 (10.6)	35.7 (9.6)	.47
Trait	34.6 (10.9)	33.2 (10.2)	.71
Physical Activity Scale for the Elderly score	78.0 (39.6)	79.8 (54.6)	.91

Group differences are indicated by significance value (*P* for continuous data or χ^2 for nominal data).

Geriatric Depression Scale, higher scores indicate more feelings of depression; State-Trait Anxiety Inventory, higher scores indicate more feelings of anxiety; and Physical Activity Scale for the Elderly, higher scores indicate greater amounts of regular physical activity.

Abbreviations: GS, gaze stabilization; CON, control; PT, physical therapy; SD, standard deviation.

(Fig. 1). One CON group participant had a normal DGI score at baseline; however, the interaction remained significant ($P = .046$) with that participant removed from analysis. Importantly, 90% of the GS group demonstrated a clinically significant improvement in fall risk versus 50% of the CON group ($\chi^2 = 0.008$).

The magnitude of change in the DZ VAS score was small for the GS group and moderate for the CON group (SRM = 0.4 and 0.7, respectively). The magnitude of change in the DIS VAS score was small for both the GS and CON groups (SRM = 0.4 and 0.3, respectively). The magnitude of change for DGI and SOT was large for both the GS group (SRM = 2.0 and 1.4, respectively) and CON group (SRM = 1.2 and 1.9, respectively). The magnitude of change in the ABC Scale score, DVA, and gait speed was moderate for the GS group (SRM = 0.6, 0.7, and 0.6, respectively) and small for the CON group (SRM = 0.3, 0.2, and 0.3, respectively).

Factors Predicting Rehabilitation Outcome

No variables were highly correlated with DZ VAS score at discharge, therefore regression analysis was not performed. Only initial ABC was highly correlated with DIS VAS score at discharge and explained 16% of the variance in regression analysis.

Seven variables—MMSE, trait anxiety (because of issues of collinearity, state anxiety was not included in the analysis), physical activity, compliance with balance and gait HEP, ABC Scale score, preferred gait speed, and DGI—were highly correlated with fall risk at discharge and were included in the regression analysis. The final model included compliance with HEP and MMSE scores of 32 participants (compliance data were missing for 5 participants). The odds ratio for compliance with HEP was 0.06 ($P = .011$) and for MMSE, it was 0.31 ($P = .028$). In other words, an individual who was highly compliant with the HEP (versus moderately compliant) was much less likely to be at risk of falls at discharge. Similarly, an individual with higher cognitive function had lower odds of being at risk of falls at discharge.

The only variable that was highly correlated with significant improvement in DGI at discharge was group. The odds ratio for group was 9.0; ie, the GS group was 9 times more likely to experience a significant improvement in DGI versus the CON group.

TABLE 3. Mean (SD) of Outcome Measures

Measure	GS Baseline	GS Discharge	CON Baseline	CON Discharge
ABC (%)[a,b]	64.6 (19.8)	73.7 (12.7)	63.6 (20.8)	70.3 (20.5)
DVA (LogMAR)[a,c]	0.20 (0.08)	0.14 (0.07)	0.21 (0.10)	0.19 (0.08)
Gait speed (m/s)[a]	0.73 (0.21)	0.85 (0.15)	0.76 (0.27)	0.85 (0.24)
DGI (/24)[a,d]	14.2 (3.1)	18.9 (1.8)	16.1 (2.6)	18.9 (3.0)
SOT (/100)[a]	51.2 (12.8)	63.9 (10.4)	46.3 (7.3)	62.9 (12.0)
VAS (/10)				
DZ[a]	1.9 (2.8)	0.8 (1.6)	2.1 (2.7)	0.7 (1.2)
DIS	2.9 (3.0)	1.6 (1.5)	2.7 (2.3)	1.6 (1.5)
Disability Scale (/5)[a,e]	2.6 (0.8)	1.2 (0.9)	2.1 (0.7)	1.0 (0.8)

There were no significant group differences.

[a] Indicates significant baseline-discharge improvement in both groups: ABC Scale: $P = .018$; DVA: $P = .016$; Gait speed: $P = .020$; DGI: $P < .001$; SOT: $P < .001$; DZ VAS: $P = .019$; Disability: $P < .001$.

[b] ABC: higher scores indicate more confidence in balance.

[c] DVA: lower values of the logarithm of minimum angle of resolution (LogMAR) indicate better visual acuity.

[d] Significant time × group interaction: $P = .026$.

[e] Disability Scale: lower score indicates lower perceived disability.

Abbreviations: GS, gaze stabilization; CON, control; ABC, Activities-specific Balance Confidence Scale; DVA, dynamic visual acuity; DGI, Dynamic Gait Index; SOT, sensory organization test; VAS, visual analog scale; DZ, dizziness; DIS, disequilibrium.

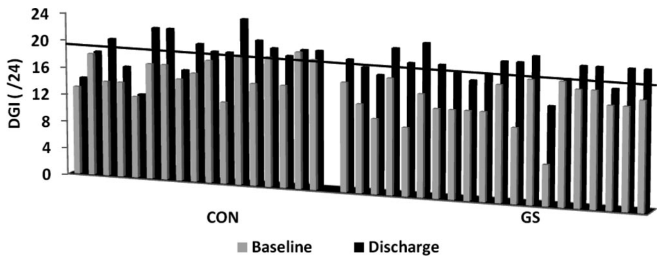

FIGURE 1. Dynamic gait index scores for individual participants. Grey bars indicate scores at baseline and black bars indicate scores at discharge. The line is positioned at a DGI score of 19, which is considered at risk for falls. Scores falling above the line indicate participants who are at low risk for falls. Abbreviations: CON, control; GS, Gaze Stabilization.

DISCUSSION

Both groups improved in measures of dizziness, balance-related confidence, gait speed, fall risk, and SOT after an intervention of balance and gait exercises plus eye movement exercises. This finding was expected, given the substantial evidence that targeted interventions improve underlying gait and balance impairment.[26,27]

To our knowledge, this is the first study to demonstrate that adding vestibular adaptation and substitution exercises to standard balance rehabilitation results in greater reduction of fall risk in older adults without vestibular pathology. In this study, 90% of participants in the GS group demonstrated at least a 3-point improvement in DGI total score compared to 50% of the CON group. Although 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. This finding is consistent with recent evidence of the efficacy of vestibular rehabilitation in older adults. Two studies suggested that vestibular rehabilitation results in significant improvements in symptoms of dizziness, balance confidence, and mobility in older adults without vestibular pathology.[28,29] However, both studies compared subjects who performed vestibular adaptation plus balance and gait exercises to subjects who were simply encouraged to perform their daily activities. Neither study provided the information needed to identify which specific exercise approach (ie, vestibular adaptation or balance and gait) was a necessary component to treat nonvestibular dizziness.

The strength of this study is that vestibular-specific gaze stability exercises are compared with vestibular-neutral exercises while all participants received balance rehabilitation. Thus, we can specify that the addition of vestibular adaptation and substitution gaze stability exercises led to the larger reduction in fall risk. One possible mechanism leading to differential improvement is the adaptation of the vestibulo-ocular reflex through performance of specific vestibular exercises. This hypothesis is based on the larger magnitude of change in DVA for the GS group (moderate effect size) versus for the CON group (small effect size). Herdman et al[8,9] found that the vestibular rehabilitation improved DVA in patients with vestibular hypofunction. A second possibility is that participants in the GS group became more accustomed to head movements, one of the elements in the DGI test. This seems less likely because both groups walked with head turns as part of the HEP. Further study to examine underlying mechanisms is warranted.

Prediction of Rehabilitation Outcome

We could not predict discharge DZ VAS score with the variables that were measured. It may be that other variables such as coping strategies or locus of control are important to understand the perception of dizziness.[30] Only balance-related confidence predicted discharge DIS VAS score. This finding would be expected given that both measures are related to self-perceived balance ability: DIS VAS score is a rating of steadiness while sitting and walking, whereas the ABC Scale score requires rating of confidence in balance in specific situations. The more specific measure of self-perceived balance (ABC Scale score) improved after rehabilitation, whereas DIS VAS score did not. This difference in findings may relate more to the properties of the measures than the actual change in self-perceived balance.

We found that compliance with the balance and gait HEP predicted fall risk at discharge. In this study, compliance was broadly defined as low (<33%), moderate (33%–75%), and high (>75%) based on verbal report. The finding underscores the importance of consistent practice of balance and gait exercises for maximum improvement. This finding is consistent with tShumway-Cook et al[26] who demonstrated that patients who attended <75% of therapy sessions and exercised less than 4 days per week improved less than those who were fully adherent to therapy.

We also found that cognitive status predicted fall risk status at discharge despite the fact that MMSE was >24/30 for all participants. Higher mental function was predictive of being at low risk of falls at discharge. The modest correlation between compliance with HEP and MMSE ($r = 0.36$) suggests that it is not simply because individuals with higher cognitive function performed the balance and gait exercises more frequently. There is growing evidence of a strong association between cognitive function and the ability to walk while performing a secondary task.[31] It may be that the additional demands of specific items of the DGI (eg, walking with head turns) require additional cognitive resources.

Limitations

This was a pilot study and so the number of participants was limited. As a result, we were not able to identify mechanisms underlying change in outcome measures. We cannot completely rule out that our participants may have had subtle vestibular deficits because we did not test all components of the vestibular system. Additional vestibular function testing would be required to identify vestibular deficits of the otoliths, high-frequency aspects of posterior semicircular canals, or anterior or posterior semicircular canals. The findings of this study are limited to short-term outcomes. Many participants preferred to be discharged with an HEP after 4 visits instead of continuing therapy even though they had not reached a plateau; therefore, most of the participants only completed the first 2 to 3 weeks of the eye movement progression before discharge. We believe that 6 weeks of treatment would be ideal based on significant changes in DVA after 5 to 6 weeks in previous research.[8,9]

Finally, although we were able to calculate compliance with eye exercises, many participants forgot to return the HEP calendars. Furthermore, the groups neither recorded compliance with balance and gait exercises nor were they asked whether they concentrated more on eye movement or balance and gait exercises. Participants were asked each week how many days they had performed their HEP and this was recorded; however, participants may have overreported compliance to the therapist.

CONCLUSIONS

The addition of vestibular-specific exercises to standard balance rehabilitation resulted in greater reduction of fall risk in older adults with dizziness and no documented vestibular deficits. Compliance with HEP and cognitive status predicted fall risk outcomes in these patients. These results support the use of vestibular exercises as a component of exercise programs for elderly individuals who may be at risk for falls.

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