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Balance and gait of adults with very mild Alzheimer's disease

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Abstract

Background and Purpose—Studies have shown that adults with Alzheimer's disease (AD) have gait and balance deficits, however the focus has been on those with mild to severe disease. The purpose of this study was to determine if balance and gait deficits are present in those with very mild AD.

Methods—Thirteen adults (72.9 ± 4.7 years old) with very mild AD and thirteen age (72.6 ± 4.6 years old) and gender-matched (10 males, 3 females) participants in a control group without AD performed balance and gait tests. All participants were living in the community and independent in community ambulation.

Results—Participants with very mild AD had shorter times in the sharpened Romberg tests with eyes open ($p < 0.001$) and with eyes closed ($p = 0.007$) compared to participants in the control group. Those with AD also took longer to complete the Timed "Up & Go" Test (TUG), ($p < 0.001$). Gait deficits were found for those with AD as demonstrated by slower velocities in the 10-meter walk at a comfortable pace ($p = 0.029$) and on an instrumented walkway ($p < 0.001$). Stance times were longer for those with AD ($p < 0.001$) and step length was shorter ($p = 0.001$). There were no group differences in the 10-meter walk at a fast pace. The gait velocity of participants in the control group was faster on the instrumented walkway than in the 10-meter walk at a comfortable pace

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($p=0.031$). In contrast, the gait velocity of those with AD was significantly slower on the instrumented walkway than in the 10-meter walk at a comfortable pace, ($p=0.024$).

Discussion—Balance and gait deficits may be present in those in the very early stages of AD. Novel surfaces may affect gait speed in those with very mild AD. Identifying mobility deficits early in the progression of AD may provide an opportunity for early physical therapy intervention, thus promoting continued functional independence.

Conclusions—Adults in the very early stages of AD may show signs of balance and gait deficits. Recognition of these problems early with subsequent physical therapy may slow the progression of further balance and gait dysfunction.

Keywords

dementia; mobility; cognition; balance; gait; executive function

INTRODUCTION

Alzheimer's disease (AD) is the most common type of dementia¹ with an estimated 5.1 million Americans affected with this disease.² The hallmark of AD is progressive cognitive dysfunction, however the concomitant loss of independent and safe mobility³ due to balance and gait dysfunction has been recognized for many years.^{4,5} There are numerous reports that adults with AD, compared to adults without AD, have balance and gait deficits,^{6–12} but it is not clear how early in the disease process mobility deficits may begin to appear. In some studies, participants are not chosen or grouped based on severity, and those included may range from having mild to severe disease.^{6,8,10,11} Reports that do separate participants by severity found that those with moderate but not mild AD had balance deficits^{7,13} or gait deficits.¹³

Definitions of disease severity also vary from study to study. Some have included participants with AD with mild and moderate severity as defined by Mini Mental Status Examination (MMSE) scores, with no consensus on the cut-off values used to distinguish severity levels.^{11,12} Participants with a range of disease severity have been included by stipulating only a minimum MMSE score.¹⁰ In some studies, severity was defined by performance on a functional test,¹⁴ by the Cambridge Examination for Mental Disorders of the Elderly cognitive subsection (CAMCOG),¹³ or there was no description of how severity was defined.^{9,15} Studies, such as that by McGough and colleagues,¹⁶ have examined performance deficits of those with mild cognitive impairment (MCI), a diagnosis separate from AD, or included those who had probable AD.¹⁷

Comparison of mobility performance should control for the age and gender of the participants. A recent meta-analysis found that gait speed varies as a function of age and gender with slower velocities in each decade after 60–69 years of age and women having a slower average velocity than men.¹⁸ Differences related to age and gender also have been reported for the Timed “Up & Go” Test (TUG) and the Romberg balance test, with women and older adults performing poorer on these measures.¹⁹ Studies that have been done on

physical performance measures of those with AD did not match age and gender of the subjects.

The purpose of this study was to compare balance and gait performance in age- and gender-matched individuals without AD to the performance of adults who are in the early stage of AD. The diagnosis and severity of AD was assigned using standardized procedures and tests. We were interested in identifying possible mobility deficits in those with a diagnosis of very mild AD. We hypothesized that adults with very mild AD would have poorer balance and slower gait compared to adults without AD.

METHODS

We recruited 21 adults 60 years of age and older who had a diagnosis of AD and a Clinical Dementia Rating (CDR) of 0.5 or 1.²⁰ Physical performance measures were obtained from 17 of the 21 participants, and 13 of the 17 had a CDR of 0.5 or very mild AD. These 13 participants are included in this analysis.

Participants with AD were recruited from the University of Kansas Alzheimer's Disease Center. The diagnosis and severity of AD were provided by a board certified neurologist specializing in AD (JB). The determination of early AD was based on clinical methods which included a semi-structured interview of the client and a person who knows the client well, usually a spouse or offspring.²¹ Criteria for AD include the gradual onset and progression of impairment in memory and in at least one other cognitive and functional domain.²² These clinical methods have a diagnostic accuracy for AD of 93%.²³ Severity was determined using the CDR.²⁰ Information gathered by interview for the CDR evaluates six domains including memory, orientation, judgment and problem solving, community affairs, home and hobbies, and personal care.²⁰ Possible severity ratings for dementia include 0.5 for very mild, 1.0 for mild, 2.0 for moderate, and 3.0 for severe. In general, those with a score of 0.5 may have slight difficulties in some or all of these domains. A score of 1.0 indicates more moderate difficulty; a score of 2.0 indicates severe difficulty; and a 3.0 indicates that the individual is essentially unable to perform in these domains.²⁰

Data collection for the cognitive and physical measures was performed at the same visit at two different locations. Testing took approximately 45 minutes; 25 minutes for the cognitive performance testing and 20 minutes for the physical performance testing. All subjects with AD participated in a cognitive training program that was initiated after physical performance measures were obtained. Results of that study are reported elsewhere.²⁴ Thirteen gender- and age-matched (± 2 years) adults who were free of neurological and orthopedic disorders were recruited at another institution and served as a control group. Participants in the control group were recruited from personal contacts of the researchers. All participants were community-dwelling and were able to ambulate in the community without the assistance of another person or an assistive device. A battery of cognitive tests was administered to both groups of participants. This study was approved by the Human Subjects Internal Review Board of Kansas Medical Center for the participants with AD and of The Sage Colleges for the participants in the control group. Subjects provided oral and written consent.

Cognitive Measures

Wechsler Memory Digit Span Forward, Digit Span Backward.²⁵—Participants were presented with a series of random digits from 1 to 9 and were asked to immediately recall the digits in the same order as presented for the Forward Digit Span and in reverse order in the Backward Digit Span. The number of digits was increased by one digit if the participant answered at least one of two trials correctly. Otherwise, the task ended. The longest digit span with at least one correct trial and the number of correct trials were recorded. The Digit Span Forward test is a measure of attention and short-term memory; the Digit Span Backward test is a measure of working memory.²⁶ Scores of 5–7 and 4–5 for the longest span are considered within normal limits for the Digit Span Forward and Backward tests, respectively.²⁶ Both tests have good test-retest reliability with coefficients ranging from 0.66 to 0.89.²⁶

Category Fluency.²⁷—Participants were given a category (e.g., animals) and instructed to name as many items in that category as they could in one minute without using proper nouns, plurals, or different forms of the same word. Each participant performed two trials with two different categories. The categories were the same for each participant. The number of correct items in each category was recorded; the two trials were averaged for the final score. A score of 11 words is the norm for adults 70–79 years of age,²⁸ and the test-retest reliability is high, i.e., .80–.89.²⁹

Letter Fluency.³⁰—Participants were given a letter of the alphabet and instructed to name as many items that began with that letter as they could in one minute. They were instructed that proper nouns, plurals, or different forms of the same word would not count. Each participant performed two trials with two different letters. Letters were chosen randomly from a list of 4 letters. The number of correct items was recorded, and the two trials were averaged for the final score. Letter fluency is thought to be more difficult for adults than category fluency; both are measures of fluency.²⁶ A score of 11–12 words is the norm for adults 70–79 years of age,²⁸ and the test-retest reliability is considered adequate, i.e., .70–.79.²⁹

D-KEFS Trail-Making Test.³¹—The number sequencing, Part A, required the participants to draw lines to connect the numbers 1–25. In Part B participants had to draw lines to connect numbers from 1 to 16 and letters from A to P, alternating numbers and letters (i.e., 1-A-2-B, etc.). Each participant worked with the same templates for the two tasks. Instructions were to complete the task as quickly as possible without making a mistake. The times to complete each task were recorded in seconds. The Trail Making Test is a measure of mental flexibility and switching.³² For adults 70–74 years of age with 12 or more years of education a score of 40 seconds for Part A and 86 seconds for Part B is considered the norm,³³ although the test-retest reliability is low, i.e., < 0.59.²⁹

Mini Mental Status Examination.³⁴—The MMSE is a brief cognitive screening test for dementia and is scored out of a possible 30 points. A cut-off score of 24 has been used to distinguish those with cognitive impairments, although other cut-off scores have been

suggested depending on the purpose of the screen and the demographics of the population tested.²⁶

Physical Measures

Each of the tests of physical performance was done twice with at least 30 seconds rest between trials and between tests. The order of the testing was the same for all participants as listed below. All physical measures were demonstrated to the participants prior to being performed.

Sharpened Romberg Test with Eyes Open.^{35,36}—This is a timed balance test. Participants stood with their feet in tandem and their eyes open as long as they could until they reached 60 seconds, moved their feet, or needed assistance from the researcher who was guarding them. The time the position was maintained was recorded in milliseconds. Sixty seconds was used as an end point so that a ceiling effect could be avoided. The literature reports that the mean time for 60–69 year old females is 56.15 seconds and for 70–79 year old females is 44.13 seconds³⁶ and 46.53 for the first trial and 54.70 for best trial for males 60–90 years old.³⁷ It is a reliable measure for intrarater reliability for older adults (ICC=.70–.83).³⁸ Older females who have fallen average 34.28 seconds on their first attempt and 38.50 seconds on their best attempt.³⁹

Sharpened Romberg Test with Eyes Closed.^{35,36}—This is also a timed balance test made more difficult by having the subjects close their eyes. Participants stood with their feet in tandem and their eyes closed as long as they could until they reached 60 seconds, opened their eyes, moved their feet, or needed assistance from the researcher who was guarding them. The time the position was maintained was recorded in milliseconds. Sixty seconds has been used by previous researchers as an end point.^{36,37} Reports indicate that the mean time for 60–69 year old females is 28.08 seconds and for 70–79 year old females is 19.16 seconds and 15.46 for the first trial and 24.62 for the best trial in males 60–90 years old.^{36,37} Older females who have fallen average 8.24 seconds on their first attempt and 10.51 seconds on their best attempt.³⁹

Timed Up and Go Test (TUG).⁴⁰—The test was given as described by Podsiadlo and Richardson.⁴⁰ The participant was seated in a chair with a back and a firm seat. At the researcher's verbal "go", the subject stood up, walked 3 meters, turned around, walked back and returned to the seated position. The time to complete the task was recorded in milliseconds. A researcher walked alongside each subject to guard against loss of balance. The TUG is a reliable measure for people with AD (ICC 2,2=.985–.988)¹⁴ and for older adults (ICC 3,1=.90)³⁸ and is moderately correlated with the Berg Balance Scale ($r = -.76$) for older adults.⁴¹ The mean time for 60–69 year olds is 8.1 seconds and for 70–79 year olds is 9.2 seconds.⁴² A score of 16 seconds or higher is a predictor for falls for older adults.⁴³

Gait – 10-Meter Walk Test at Comfortable Speed.⁴⁴—A 10-meter straight, unobstructed pathway was marked off with tape at the beginning and end, with additional tape marks 3 meters before and after the 10-meter path. Participants were instructed to walk the 16 meters at a safe and comfortable speed. The researcher timed, in milliseconds, how

long it took to pass between the 10-meter tape marks. A researcher walked alongside each person to guard against loss of balance. Comfortable gait speed using the 6-meter walk test is reliable for people with AD (ICC 2,1=.973-.977)¹⁴ and community dwelling older adults (ICC 3,1=.96).³⁸ Normal gait speed for 60–69 year olds is 1.24m/sec and 70–79 year olds 1.09–1.25m/sec.^{45,46}

Gait – 10-Meter Walk Test at Fast Speed.⁴⁷—The set-up for fast gait speed was as described for comfortable speed although the participants were instructed to walk the 16 meters safely but as fast as possible. Fast gait speeds for 60–69 year-olds average 1.84m/sec and 70–79 year olds average 1.86m/sec. ICC=.97.⁴⁶

Gait Parameters—The GAITRite® system (CIR Systems, Inc., Sparta, NJ) consists of an instrumented rubber mat 4.88 meters long. Participants were told to walk at a comfortable pace beginning 1 meter before and ending 1 meter after the edges of the mat to account for acceleration and deceleration. The researcher walked alongside each person to guard against loss of balance. Measures of interest included velocity, right and left stance time, and right and left step length. Gait velocity measured by the GAITRite® system is reliable for people with AD (ICC 2,2=.973-.977).¹⁴ and for community dwelling older adults (ICC=.95).⁴⁶

Data Analysis

For each participant, the two trials of the performance measures were averaged. Descriptive analyses were done to calculate the group means and standard deviations of cognitive and physical performance measures. The Shapiro-Wilk test was used to determine if the data were normally distributed, and equal variances were not assumed as determined by Levene's Test. Between group analyses were examined with Student independent t-tests or, if the data were not normally distributed, with an Independent Samples Mann-Whitney U Test using SPSS Statistics Version 21. The alpha level was set at $p < 0.05$.

Clinical relevance between groups was determined by the minimal detectable change (MDC) for sharpened Romberg eyes open MDC=15.52 seconds, TUG MDC=2.77, and gait velocity at comfortable speed MDC=.125m/s by converting the standard error of the measurement to MDC scores in previous research on community dwelling older adults done by Gras et al.³⁸ Fast gait speed was based on the MDC=.21m/s in a study by Mangione et al although the subjects in that study were African-American and ours were not.⁴⁸ MDC values were not found for sharpened Romberg eyes closed and gait velocity, stance time or step length on the GAITRite® mat.

RESULTS

Participants had an average age of 72.8 ± 4.5 years; there was no significant difference in age between the two groups as expected, given that they were age-matched ± 2 years. Each group included 10 males and 3 females. The two groups had an average of 16.8 ± 2.9 years of education; there was no significant difference in years of education between groups.

Data were normally distributed and group differences were examined with Student independent t-tests with the exception of the MMSE, the longest sequences of the digit

spans, timed trails scores, and the sharpened Romberg tests. Nonparametric analysis was completed for the data that were not normally distributed. Participants with AD scored significantly lower than the participants in the control group in most cognitive tests including the number of correct trials in the Digit Span Forward and Backward, category fluency, and the Trail-Making Test Part A and Part B (Table 1). Participants with AD had significantly poorer balance than participants in the control group as identified by group differences in the sharpened Romberg test with eyes open, the sharpened Romberg test with eyes closed, and the TUG (Table 2). Participants with AD had significantly slower gait speed than participants in the control group in both the 10-meter walk test at a comfortable speed and on the GAITRite® mat. Stance times were longer for those with AD and step length was shorter for those with AD (Table 2). There were no group differences in the 10-meter walk test at fast speed. Analysis for clinical relevance revealed that the difference in scores for participants with AD compared to the scores for participants in the control group were above the available MDC values for balance and gait measures (Table 3).

A follow-up analysis was done to compare gait speed on the 10-meter walk test at a comfortable speed and speed on the GAITRite® mat for each group. Paired t-tests revealed that the participants in the control group walked faster on the GAITRite® mat (1.49 ± 0.19 m/s) compared to their comfortable 10 meter walk speed (1.40 ± 0.15 m/s), $p = 0.031$. The group with AD walked slower on the GAITRite® mat (1.07 ± 0.21 m/s) compared to their comfortable 10-meter walk speed (1.21 ± 0.25 m/s), $p = 0.024$.

DISCUSSION

To our knowledge, this is the first study to demonstrate that adults with very mild AD, compared to age- and gender-matched adults without AD, have deficits in balance and gait. Our results are consistent with other studies that included participants with more severe AD than those in our study.^{6,12,14} The participants with AD in our study were all living at home, either alone or with a spouse. They all had active social lives; some continued to drive. Despite the fact that they were independent in community ambulation and not at a risk for falls according to our testing, it is evident that these adults with early-stage AD performed differently in balance and gait than the adults without AD.

The participants with AD in our study all had a CDR of 0.5, indicating very mild disease. There are a few studies that have analyzed gait and balance in those with a CDR of 0.5, but the participants in these studies had a diagnosis of MCI not AD.^{6,16,49,50} These reports have mixed results. An association between both gait speed and TUG performance with executive function was found in those with MCI and a CDR of 0.5, but there were no control participants to examine potential group differences.¹⁶ One study found that adults with a CDR of 0.5 and MCI had slower gait velocity than adults without MCI,⁶ but others have found no significant difference in gait velocity between those with MCI and those without MCI.^{49,50} No difference between those with a CRD of 0.5 and MCI and those without MCI was found in TUG scores.⁶ Using standardized procedures for diagnosis of AD and severity, we found significant balance and gait deficits in these individuals with very mild AD. This suggests that the combination of a CRD of 0.5 and a diagnosis of AD may be associated

with more pronounced mobility deficits than reported in the literature for those with a CDR of 0.5 and MCI. A direct comparison of these two groups is warranted.

The mean balance scores for the sharpened Romberg with eyes open and eyes closed were below the norms for the participants with AD and exceeded the MDC value between both groups when tested with eyes open, meaning that a clinical difference between groups was observed. The participants with AD scored below the cut-off time for falls for both eyes open and eyes closed conditions meaning that they are at risk.³⁹ The scores for the TUG were at the norm for 60–69 year olds and slightly faster than the norm for 70–79 year olds but still exceeded the MDC value for clinically relevant change compared to the participants in the control group. Balance has been shown to be affected in people with AD but the criteria used to examine the degree of dementia hasn't included people with very mild AD.^{7,11}

The mean comfortable gait speed of our participants with AD was quite high at 1.21 m/s and within the norm for their age, although they were statistically slower than participants in the control group. In an investigation of the relationship between gait speed and survival in older adults, Studenski and colleagues suggested that a speed greater than 1.0 m/s is associated with an above average life expectancy, with a speed at or above 1.2 m/s associated with an exceptional life expectancy.⁵¹ Although the average gait speed of those with AD was high, 4 of the 13 had speeds less than 1.0 m/s, a speed that may identify people at risk for poor outcomes related to health.⁵²

Although not the focus of this study, we found differences in how each group of participants was affected by walking conditions. Participants in the control group had faster gait velocities on the GAITRite® mat than in the 10-meter walk test. In contrast, those with AD had slower velocities on the 4.88 meter-long GAITRite® mat than in the 10-meter walk test. In both gait tests, participants were told to walk at a comfortable speed. Space was available at the beginning and end of both tests to avoid the effects of acceleration and deceleration. In a recent comparison of the 4-meter walk test to the 10-meter walk test with healthy older adults, there was no significant difference in velocity between these two tests. The authors did conclude, however, that the concurrent validity of the shorter walk is not high enough to allow these two distances to be used interchangeably.⁴⁴ Others have recommended distances that allow at least 20 gait cycles, due to increased variability in gait in older adults.⁵³ This may be particularly important in analyzing gait for those with AD who have increased variability in stride length and step width compared to participants in the control group.⁵⁴

The slower speed for the participants with AD on the GAITRite® mat may also be related to the difference in the surface. Older adults have been known to have a decrease in gait speed with constrained pathways such as an inclined walking surface,⁵⁵ although our healthy older adults actually walked faster on the GAITRite® mat than on the 10-meter walk. Slower gait related to walking on a constrained surface was restricted to those with AD. The current study was not designed to examine the effects of different walking conditions on those in the early stages of AD; more work in this area is needed.

The results of this study cannot be generalized to all adults with very mild AD. Our participants were between 64 and 80 years old. The small number of subjects and the large standard deviations on some of the tests are limitations. Differences in performance may be related to the use of two different sites and two testers for the balance and gait measures. However, the same instructions and protocol were used and followed at both sites. Confounding factors that were not controlled for in this study are the subjects' leg length and height as well as their level of physical fitness. History of falls and lower extremity injuries were not reported.

Physical function in people with AD declines as their cognitive dysfunction progresses.³ Given the progressive nature of AD, it is likely that those with very mild AD will advance to more severe stages of AD. Concomitant with their decline in cognition, balance and gait deficits will become more pronounced. There is also recent evidence that mild deficits in physical performance are predictive of AD,⁵⁶ further supporting the need for early identification of mobility deficits. It has been shown that adults with AD can benefit from exercise interventions to improve mobility.^{57–60} Physical therapy for mobility deficits for those in the very early stage of AD may prove particularly beneficial.

CONCLUSION

Adults with very mild AD demonstrate balance and gait deficits compared to age- and gender-matched adults without AD. We found that those with AD had poorer performance on the sharpened Romberg tests with eyes open and with eyes closed, the TUG, the 10-meter walk test at comfortable gait speed, and gait velocity on the GAITRite® mat. We also found that those with AD had slower gait velocities on the GAITRite® mat than during the 10-meter walk test. The results of this study suggest that adults in the early stage of AD who are functioning independently in the community may have unrecognized balance and gait deficits. Further, their gait speed may be affected by changes in walking conditions which do not seem to affect the gait speed of healthy age-matched adults without AD. Physical therapy interventions in the early stage of AD may be warranted and could be beneficial in maintaining safe, independent community mobility.

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Table 1

Means (Standard Deviations) of Cognitive Measures

Variable	Controls	AD	p value
MMSE (out of 30)	29.0 (1.0)	24.8 (2.6)	<0.001
Digit span forward (longest sequence)	6.4 (1.4)	5.8 (1.0)	0.169
Digit span forward (number of correct trials)	11.5 (2.5)	8.5 (1.7)	0.001
Digit span backward (longest sequence)	4.9 (1.6)	4.0 (1.01)	0.243
Digit span backward (number of correct trials)	8.7 (2.5)	5.5 (1.7)	0.001
Letter fluency	14.2 (5.0)	10.3 (5.0)	0.061
Category fluency	20.2 (2.9)	15.6 (5.4)	0.015
Timed trails A (s)	35.0 (11.1)	66.5 (42.1)	0.004
Timed trails B (s)	88.9 (31.9)	223.2 (187.3)	0.003

Table 2

Means (Standard Deviations) of Balance and Gait Measures

Variable	Controls	AD	p value
Sharpened Romberg eyes open (s)	60.0 (0)	24.5 (20.8)	<0.001
Sharpened Romberg eyes closed (s)	30.4 (26.3)	6.5 (5.8)	0.016
TUG (s)	5.2 (0.7)	8.1 (2.2)	<0.001
Comfortable gait speed (m/s)	1.40 (0.15)	1.21 (0.25)	0.029
Fast gait speed (m/s)	2.05 (0.33)	1.82 (0.45)	0.170
GAITRite velocity (m/s)	1.49 (0.19)	1.07 (0.21)	<0.001
Stance time (s)	0.52 (0.03)	0.71 (0.05)	<0.001
Step length (m)	0.77 (0.07)	0.62 (0.11)	0.001

Table 3

Difference between Groups compared to MDC Scores for Balance and Gait Measures

Variable	MDC Score ^{38,48}	Difference Between Scores
Sharpened Romberg eyes open (s)	15.5	35.5
TUG (s)	2.8	2.9
Comfortable gait speed (m/s)	.13	.19
Fast gait speed (m/s)	.21	.23