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Spatial and temporal gait parameters in Alzheimer's disease and aging

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Abstract

This study compared spatial and temporal gait parameters in patients with mild stage of Alzheimer's Disease [AD] and matched normal controls [NC]. Forty patients with mild AD and 34 NC were asked to walk over-ground, and subsequently on a (harness-secured) treadmill, both at preferred speed. Overground gait-velocity, cycle-time, cadence, stride-length, stride-width and double-support time were averaged over a minimum of three traverses on an automated walkway [GAITRite]. Cadence, cycle-time and double-support time was obtained on the treadmill using footswitches. The groups were well matched on baseline characteristics. The AD group were significantly slower on the Timed-up-and-go task compared to NC [$p < 0.05$]. AD patients differed significantly from the NC on their over-ground gait velocity [99 ± 19 cm/sec vs 119 ± 15 cm/sec, $p < 0.0001$], cadence [101 ± 9 steps/min vs 109 ± 9 steps/min, $p < 0.001$] and stride-length [118 ± 18 cm vs 131 ± 17 cm, $p < 0.01$]. Preferred speed on the treadmill was significantly slower in the AD group than the NC group [60 ± 20 cm/sec vs 74 ± 23 cm/sec, $p = 0.01$], but at their preferred constant belt speed, no significant differences were observed in gait parameters collected on the treadmill. Patients with mild AD may have subtle changes in gait compared to NC which relate to temporal gait characteristics. At a steady belt-speed on the treadmill, these differences in temporal measures are no longer seen suggesting that early gait changes in AD relate to step-timing and gait-speed.

INTRODUCTION

Patients in the moderate to severe stages of Alzheimer's Disease (AD) have a slower gait than healthy elderly [2,19]. However, there is no consensus yet on subtle gait differences, if any, in mild-stage AD. Recent studies suggested that gait slowing may occur in the early

stages of AD [4,6,18] while others suggest that gait is unchanged in early AD [1,11]. In fact, if gait impairment is present early in the course of dementia, the underlying etiology is thought not to be AD[17]. On routine clinical assessment including standardized scales such as the Tinetti balance and gait scale, mild AD patients are similar to age-matched controls [2] but on more challenging bed-side gait measures patients with mild stage AD are noted to perform poorly[13].

Gait dysfunction is an important risk factor for falls[15]. Certain changes in gait such as decrease in stride-length, slower gait speed, and widened step-width are associated with normal aging [12]. However, specific gait parameters such as slower velocity and reduced double-support time are considered to be independent predictors of falling [7]. There is little information on specific gait differences in mild AD patients and healthy older adults. Ascertaining differences in gait parameters in patients with mild AD and healthy older adults may help to improve our understanding of the relationship between gait and falls in early AD. Furthermore, constraining gait by fixing the gait speed may help ascertain whether gait differences if any between the two groups are related to gait speed alone.

This study aimed to compare spatial and temporal parameters on over-ground gait and treadmill-controlled gait parameters at preferred speed in mild stage-AD and healthy normal controls [NC]. The hypothesis for this experiment was that patients with AD would be slower than NC but that there would be no changes in over-ground spatial parameters between the groups. Furthermore, enforcing a steady velocity on a treadmill would minimize any differences in temporal parameters in the two groups.

METHODS

Participant population

Patients with AD and community-dwelling healthy elderly controls [NC] were recruited from a longitudinal study based in a university cognitive neurology clinic. All participants consented to undergo standardized neuroimaging and neuropsychological assessments annually for up to three years. Patients additionally underwent a thorough clinical assessment prior to inclusion in the study. Patients had to meet diagnostic criteria for probable AD [10]. Patients with evidence of gait impairment on history or clinical assessment or with clinical suspicion of coexistent neurodegenerative disorders that affect gait such as Lewy body disease were screened out. Normal controls [NC] performed within normal limits on all cognitive tests and were in stable healthy condition. All participants gave informed consent to the protocol which was approved by the Research Ethics Board (Reference # 0091998).

Potential participants between ages of 60 and 80 years who were able to walk independently for 15 minutes without any discomfort were screened within six months of their magnetic resonance imaging [MRI] for the following exclusion criteria: for patients that met NINDS-ADRDA criteria for probable AD: an MMSE ≤ 20 , and, for both groups: presence of gait impairment, major depression, other neurological disorders, recent hip-fractures, significant arthritis, clinically significant joint deformity, recent hip/knee replacement, sedative medication use, dependence on alcohol and/or neuroleptics drugs, use of assistive devices

such as cane/walker and significant finding on neurological examination which could interfere with walking ability such as muscle weakness or neuropathy. Cognitive tests used for this study were the Mini-mental Status Examination [MMSE][5] and the Mattis Dementia Rating Scale [MDRS] [9].

Assessments

Assessments included history of falls, concomitant medical conditions, exercise history, medications, a general physical and neurological examination at the time of gait assessment, and measurements of body-mass index, leg-length, mid-calf girth, blood pressure and resting heart rate. Timed-up-and-go [TUG] test[14], the Unified Parkinson's Disease Rating Scale [UPDRS][8] and Tinetti gait scale[16] were also scored. As white matter disease has been associated with gait characteristics such as gait speed[3], the presence and severity of white matter disease was scored on the Age-related White Matter Change [ARWMC] scale[20].

Gait apparatus

Over-ground gait parameters—Gait was measured on a 12 × 2 feet automated walkway [GAITRite®, CIR Systems, PA] using the GAITRite Gold, Version 3.2b software for reconstruction of each traverse across the walkway. Participants were asked to walk the length of the walkway at their most comfortable pace. To discard the acceleration and variability during gait-initiation, participants began their strides 3 feet away from the edge of walkway. Three traverses across the walkway were obtained for each participant and an average of velocity, cadence, stride length, stride-width, cycle time and double-support time were utilized for this analysis.

Controlled gait parameters—Controlled gait parameters were captured using footswitches [B&L Engineering] placed in the insoles of participant's shoes as they walked on a motorized treadmill [Biodex™ RTM400, Biodex Medical Systems, Inc., NY]. Foot-switch data was digitized at the rate of 500 samples per second through an analog-to-digital converter. Digitized signals were processed using a software program [Labview®, National Instruments, Austin, TX]. All participants were secured in a harness [The Biodex Unweighing System®, Biodex Medical Systems, Inc. NY] that was strapped across their chest for safety reasons. Treadmill speed was set to individual comfort level without any inclination to the angle of the treadmill belt. Participants underwent a period of training and acclimatization for about ten minutes on the treadmill with footswitches in place prior to gait recording. Data was captured for 65 seconds after which the treadmill speed was gradually decreased to zero. The temporal parameters obtained from the treadmill for analysis were cadence, stride-time, double-support time, variability in stride-time and double-support time.

Statistical analysis

Depending on the character of the data variable, Student's *t* test and Chi-square tests were used to compare the two groups. Statistical analysis was conducted using SPSS software [Version 11.5, Chicago, Illinois].

RESULTS

Baseline characteristics

These are highlighted in Table 1. Forty patients with mild stage AD were compared with 34 normal controls [NC]. There were no significant differences between the two groups in their age, gender distribution, body-mass index, leg-length, mid-calf girth, waist circumference, blood-pressure and heart rate. As expected, the AD group were significantly more impaired than the NC group on the MMSE [25 ± 3 vs 29 ± 1 , $p < 0.001$] and the Dementia Rating Scale [120 ± 11 vs 141 ± 2 , $p < 0.001$] consistent with mild stage of the disease. Functional assessment of the AD group was further indicative of mild stage of disease severity.

On the TUG, the AD group were significantly slower than the NC group [12 ± 4 vs 9 ± 3 , $p = 0.001$] but there were no difference in their Tinetti gait scale scores [11 ± 0.6 vs 11.9 ± 0.2 , $p = 0.1$]. On the UPDRS scale ranging from 0 to 144, the differences in UPDRS score in the mild AD and NC group was statistically significant [7 ± 8 vs 2 ± 4 , $p = 0.005$]. There were no significant difference in AD [18%] and NC [15%] groups on the occurrence of one or more falls in the one-year prior to their study participation. The differences in the severity of white matter changes as measured on the ARWMC scale were not statistically significant between the two groups [$p = 0.1$]. All patients recruited for this study were stabilized on one of the three cholinesterase inhibitors for the treatment of their AD.

Over-ground gait parameters

These are highlighted in Table 2. Amongst the temporal parameters, the AD group had a slower velocity [99 ± 19 cm/sec vs 120 ± 15 cm/sec, $p < 0.001$], reduced cadence [101 ± 9 steps/min vs 109 ± 10 steps/min, $p < 0.001$], longer double support time [0.35 ± 17 msec vs 28 ± 6 msec, $p = 0.03$] and a longer cycle time [1.19 ± 0.11 sec vs 1.09 ± 0.11 msec, $p = 0.002$] than the NC group. Amongst the spatial parameters, the AD group had a shorter stride-length [118 ± 18 cm vs 131 ± 17 cm, $p < 0.001$] than the NC group. The stride-width was similar in the two groups [9 ± 3 cm vs 10 ± 3 cm].

To account for differences in the UPDRS in both groups, the UPDRS score was entered as a covariate in a MANOVA analysis. The statistically significant differences in gait velocity [$F = 11$, $df = 1, 67$, $MS: 2914$, $p = 0.001$] and cadence [$F = 10$, $df = 1, 67$, $MS: 976$, $p = 0.002$] persisted. Hence, the differences could not be solely attributable to mild bradykinesia in the AD group. As there were no differences in the two groups on the severity of white matter changes, the ARWMC score was not included as a covariate in this analysis.

Controlled gait parameters

From the original sample of 40 AD patients and 34 NC, a subset consented to measuring their gait parameters on the treadmill [32 AD and 22 NC]. The treadmill results are highlighted in Table 3. Both groups preferred a slower treadmill-belt speed compared to their over-ground velocity, but preferred speed on the treadmill for the AD group was significantly slower than the over-ground speed [59 cm/sec vs 75 cm/sec, $p = 0.009$]. No significant differences in cadence, cycle time and double-support time were seen in the two groups on the treadmill.

DISCUSSION

Key findings of this study are that when sensitively measured on a gait analysis device, over-ground temporal (velocity) and spatial (stride-length) parameters are significantly different in mild AD patients from that healthy elderly. Additionally, enforcing a constant speed on a motorized treadmill minimizes any significant differences in temporal gait measures in the two groups. Specifically, patients with AD compared to NC, walked significantly slowly with a lower cadence, a longer cycle-time and shorter stride-length. There are a few studies that have studied gait-speed in mild AD.

Studies show that gait velocity in patients with mild stage AD is no different than of age-matched healthy older adults[6,11]. Studies that have attempted to study gait in mild AD using pragmatic scales such as the Tinetti balance and gait scale [2] or by clinical assessment of gait[1] have also found no evidence of gait slowing. In this sample, gait slowing was noted on the Timed-up-and-go task but further differences in gait parameters became apparent on the more sensitive computerized gait-mat analysis, revealing that over-ground gait-velocity and cadence are reduced in mild stage of AD. The patients with mild AD also had reduced stride-length [$118\pm19\text{cm}$] compared to NC [$131\pm16\text{cm}$] but were identical on their stride-width. Gait velocity correlates strongly with stride-length and cadence and the decrease in stride-length with a trend towards a longer double-support time in our AD sample may be indicative of generalized gait-slowness rather than changes in spatial parameters. Therefore, these findings suggest that motor slowing may already be present in the early stages of AD before becoming clinically apparent as the disease progresses to the later stages.

Secondly, we also observed that when a steady gait-velocity was enforced on participant's gait on the treadmill, the two groups appeared similar in their temporal characteristics and the significant difference in cadence between the two groups was lost. The variability in stride-time and double-support time also appeared to be similar in the two groups under these circumstances. These findings suggest that on the treadmill, the constant belt-speed reduced the temporal degree of freedom and therefore minimized variability in the temporal domain. It is also possible that the treadmill enforced attention to gait by serving as an external cue to maintain a constant step-timing. The fact that the between-group differences in gait parameters are nullified when on the treadmill is noteworthy.

These findings may have several clinical implications. First, the statistically significant differences in gait velocity in the AD group suggest that changes in gait accompany cognitive decline early in the disease consistent with other reports [4,18]. Gait slowing, which doubles the likelihood of a fall [7], suggest that monitoring gait parameters in patients with AD early in the course of their disease may help identify those at risk for falls. Second, there is a limited amount of data on use of treadmill in patients with AD. In this study, mild AD patients showed comparable gait characteristics to the NC suggesting that walking on a treadmill secured in a harness may be well tolerated in early stage of AD. Hence, this study suggests that exercise involving treadmill in patients in the mild stage AD might be worthwhile. White matter changes have been associated with gait-speed in elderly [3] but our two groups did not differ significantly on the severity of white matter disease. However,

the impact of white matter disease on gait parameters in this sample is beyond the intended objectives of this study.

This study has certain limitations. This study was a clinic-based study and gait measurements performed in the laboratory may not be generalized to gait performance outside this setting. We used a body-weighted support system as a safety-harness ensuring that the system worked without unloading any body-weight. Though the safety harness was not restrictive in anyway, the fact that it may have averted alterations in body sway and other characteristics that influence gait parameters on the treadmill, cannot be denied but not doing so would mean inflicting a risk of fall in our older adult participant.

To summarize, we found that our sample of high-functioning community-dwelling patients with mild stage AD had significantly different over-ground gait parameters compared to a well-matched group of healthy controls at their preferred-pace, specifically demonstrating a slower gait-velocity, lower cadence and a shorter stride-length. We also found that when a steady preferred-velocity was enforced on a motorized treadmill, there were no statistically significant differences between the two groups. These findings suggest that subtle changes in gait appear in the early stage of AD and are detectable with sensitive gait analysis measures. These differences appear to relate primarily to temporal characteristics of gait as enforcing a constant velocity reverses these differences on the treadmill.

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TABLE 1

Baseline Characteristics of AD and NC groups

	<i>AD [n=40]</i>	<i>NC [n=34]</i>	<i>p value</i>
<i>Age</i>	74±8	73±8	0.5
<i>Gender [Female %]</i>	55	45	0.2
<i>MMSE</i>	25±3	29±1	<0.0001
<i>DRS score</i>	119±10	141±2	<0.0001
<i>ARWMC score [total]</i>	8±6	6±5	0.1
<i>Timed-up-and-go [sec]</i>	12±4	9±3	0<.0001
<i>Falls in the previous year</i>	6	4	0.5
<i>Unified Parkinson's Disease Rating Scale</i>	7±8	2±4	0.005
<i>Body mass Index</i>	25±5	26±5	0.5
<i>Leg length [cm]</i>	91±6	90±7	0.7
<i>Mid-calf diameter [cm]</i>	35±4	37±4	0.6
<i>Systolic BP [mm HG]</i>	127±18	123±29	0.5
<i>Diastolic BP [mm HG]</i>	71±9	74±17	0.3
<i>Resting Heart rate</i>	73±9	71±7	0.1

TABLE 2

Over-ground Gait Parameters in AD and NC

	<i>AD[n=40]</i>	<i>NC[n=34]</i>	<i>p value</i>
<i>Velocity [cm/sec]</i>	99±19	119±18	<0.001
<i>Cadence [steps/min]</i>	101±9	109±10	0.001
<i>Stride length [cm]</i>	118±18	131±17	0.002
<i>Cycle Time [sec]</i>	1.2±0.1	1.1±0.1	0.001
<i>Stride-width [cm]</i>	9.4±3.4	10±3.2	0.8
<i>Double Support time [sec]</i>	0.35±0.2	0.28±0.1	0.03

TABLE 3

Gait Parameters on Motorized Treadmill in AD and NC

	<i>AD[n=32]</i>	<i>NC[n=22]</i>	<i>p value</i>
<i>Belt speed [cm/sec]</i>	60±20	74±23	0.02
<i>Cadence [steps/min]</i>	96±12	103±14	0.08
<i>Cycle time [sec]</i>	1.3±0.2	1.2±0.2	0.1
<i>Double-Support time [sec]</i>	0.19±0.08	0.17±0.05	0.4
<i>Coef. variation in cycle-time [SD/mean]*100]</i>	3%	3%	0.4
<i>Coef. variation in double-support [SD/Mean]*100]</i>	10%	8%	0.2