Age-Related Differences in Stride-to-Stride Variability During Dual Task Walking: A Pilot Study

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ABSTRACT

Purpose: Increased stride-to-stride variability during walking characterizes gait instability and predicts falling in older individuals. Walking while executing a cognitive task is also associated with increased risk of falling. In this pilot study we examined whether stride variability during dual task walking increases in older individuals. **Method:** Five older (82 ± 6 years) and 4 younger (23 ± 2 years) women walked under each of 2 conditions: (1) walking at a self-selected velocity and (2) walking at a self-selected velocity while incrementally counting backwards. We used GAITRite® instrumentation to measure variability in stride velocity with the coefficient of variation. **Results:** Stride variability did not differ significantly between the groups during normal walking, but was significantly greater in older women during dual task walking ($p=.014$). **Conclusion:** Cognitively demanding activity during walking appears to increase stride variability, and therefore increase gait instability, in older women.

Key Words: gait, stride velocity, stride variability, dual task, elderly

INTRODUCTION

Gait instability is characterized by increased variability from one stride to the next and is common in many older adults, even in absence of pathology.[1] In individuals with neurological pathology, deficits in the central nervous system's ability to coordinate motor outputs are largely responsible for gait instability.[2] In older individuals without apparent neurological pathology, it is not entirely clear why gait instability occurs. Regardless of the cause, gait instability can be quantified. While several walking parameters (eg, reduced gait velocity, reduced stride length, and increased double support time) may reflect gait instability and are associated with fear of falling, markers of stride-to-stride variability best represent gait instability.[3] Of the various gait parameters that characterize stride-to-stride variability and gait instability, variability in stride velocity appears to be the strongest predictor of falling in older people.[3]

Traditionally, stability in standing or walking has been considered an automatic or reflex controlled task requiring motor responses to sensory stimuli, but requiring minimal cognitive resources. In contrast, more recent evidence suggests that maintaining stability during either standing or walking requires both cognitive and sensorimotor processes.[4-7] Dual task paradigms are used to examine the effect of cognitively demanding tasks on primary activities such as standing or walking. In young adults (age 25-42 years), a small but statistically significant change in double limb support time occurs when fine motor and memory tasks are performed while walking.[5] Among older individuals, postural stability during standing is reduced while performing secondary activities such as a backward digit recall task.[6] Additional research suggests that stepping responses to external perturbations during cognitively demanding tasks occur earlier in older individuals than in younger adults, which may contribute to the greater threat of instability and incidence of falls in older individuals.[7] Lundin-Olsson et al[8] suggest that many falls in older individuals with balance impairments occur not during normal walking conditions, but rather when they are walking and simultaneously performing a secondary task such as talking or manipulating an object. Regarding the parameters that reflect gait instability, stride variability increases in individuals with Parkinson disease[9] and Alzheimer disease[10] when they walk while being cognitively challenged. The influence of cognitive activity on stride variability, however, has not been studied in the otherwise well-elderly.

The present pilot study was undertaken to assess whether the influence of cognitive activity on gait differs between younger people and older people and to provide a foundation to support further research into the effects of dual task performance on fall risk and gait instability in the otherwise well-elderly. The first purpose was to examine changes in gait velocity that reflect general variations in dynamic gait kinematics. The second, but primary, purpose was specifically to examine whether changes in stride variability would occur in older subjects, as compared with younger subjects. We hypothesized that stride variability would be greater in older subjects than younger subjects during a dual task walking condition.

METHODS

Participants

Five women between the ages of 74 and 86 comprising an older group of subjects participated in this study (mean age = 82 years, SD = 6 years). Each participant was a self-reported healthy, community-dwelling resident of Mount St. Francis, a residence for active and retired women-religious members of the Order of the Sisters of Saint Francis in Dubuque, IA. Exclusion criteria consisted of chronic or acute musculoskeletal or neuromuscular pathology that restricted independent walking, a self-reported history of falling within the past year, and dependence on an assistive device (eg, cane or walker) for independent walking. Four healthy women between the

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ages of 21 and 25 comprising a younger group of subjects participated in this study as a comparison group (mean age = 23 years, SD = 2 years). All participants provided informed consent. The Clarke College institutional review board approved the study.

Instrumentation

Data were collected with GAITRite® instrumentation (CIR Systems Inc., Clifton, NJ). The GAITRite® system consists of a 3.66-meter electronic walkway with software for data acquisition and processing. Over 13,000 pressure sensors are embedded within the walkway. As subjects walk across the mat, spatial and temporal gait data are collected. Data are sampled at a frequency of 80 Hz, then processed and stored by an IBM compatible computer using GAITRite® Gold software. GAITRite® instrumentation has been reported to have high reliability (ICCs ≥ 0.85) and high concurrent validity when compared with video-based motion analysis systems (ICCs ≥ 0.93) for spatial and temporal parameters of gait such as velocity, cadence, and stride length.[11,12]

Procedures

For the normal walking trials, subjects were instructed to walk at self-selected speeds across the walkway. Under the dual task walking condition, subjects were instructed similarly but in addition they verbally counted backward from 100, subtracting in increments of 3, 4, or 6. The cognitive task we incorporated was similar to the backward-counting-by-3 task used in previous studies[6,13] to manipulate the attentional demands of subjects during a motor task. Additionally, to reduce potential practice or learning effects from trial to trial, a different integer was used for each trial. The order in which each integer (3, 4, or 6) was assigned for each trial in the dual task (backward counting) condition was selected randomly by the investigator. Each subject therefore walked under the same dual task conditions. Since we were interested in the potential effects of the cognitive task on changes in gait dynamics and gait instability, and were not necessarily concerned with subjects' performance on the cognitive task itself, we did not evaluate performance on the cognitive task.

Subjects initiated each walking trial one meter in front of the walkway, ambulated over the walkway, and terminated the trial one meter beyond the walkway to reduce potential effects of gait initiation and termination on the instrumented walkway. Each walking trial therefore occurred over a distance of more than 5.5 meters. In the dual task condition subjects started counting backwards as they initiated their walking trials and continued the task until they terminated the trial. Three walking trials under each condition were recorded.

The length of the walkway allowed us to collect between 3 and 8 strides during any individual trial, depending on a subject's stride length. While step lengths can vary between right and left sides during walking, a stride is composed of one right step and one left step (or conversely, one left step followed by one right step) and as a result little variation occurs in stride length between right and left sides. We therefore collapsed right and left strides across each of three trials within a walking condition for our data analysis, which allowed us to analyze between 9 and 24 strides for each subject in each condition. Gait variability takes on a fractal organization in healthy individuals,[14] meaning stride to stride variability over a small number of strides is statistically similar to variations that occur over thousands of strides. Therefore, analyzing an individual's stride variability over even as few as 9 strides is statistically comparable to analyzing stride variability over thousands of strides.

One investigator walked beside the elderly subjects and adjacent to the walkway during the dual task condition to provide support if a loss of balance occurred. Data from such trials were not included in the analysis, and subjects were asked to repeat the trial.

Gait velocity (cm/s) was measured directly from the footfalls recorded with the GAITRite® instrumentation. The velocity of individual strides was also recorded with the GAITRite® instrumentation. Stride velocity (cm/s) was calculated as stride length divided by stride time. Stride length is defined as the linear distance (in cm) between successive heel contacts of the same foot. Stride time is defined as the duration (in seconds) over which one stride occurs.

Data Analysis

We operationally defined gait instability in this pilot study as variability in stride velocity. We quantified variability in stride velocity as the percentage coefficient of variation (CV) across multiple strides collected from 3 walking trials within each walking condition. CV is determined by the equation

$$CV = (s/\overline{X})\text{x}100$$

where s = standard deviation and $\overline{X}$ = mean. The *CV* quantifies the magnitude of variability in stride velocity with respect to each subject's mean value, and is most meaningful as an outcome measure when comparing the variability of distributions, such as the variability between 2 groups of subjects or across repeated measures.

Descriptive data (mean ± standard deviation) across walking conditions were calculated. Since data were collected from a small number of subjects in this pilot study, we analyzed group differences in velocity and stride variability with nonparametric Mann-Whitney *U* tests and we analyzed within group differences in velocity and stride variability between the 2 walking conditions with nonparametric Wilcoxon signed-ranks tests (α=.05).

RESULTS

Gait velocity data are presented in Table 1. The older subjects walked more slowly than the younger subjects during both walking conditions (*U*=0, p=.014). Each subject (Figure

Table 1. Gait Velocity (cm/s) during Normal and Dual Task Walking

Walking Condition	Younger Subjects Mean ± SD	Older Subjects Mean ± SD
Normal Walking	130.5 ± 16.0	77.9 ± 16.3[a]
Dual Task Walking	109.5 ± 9.4[b]	58.7 ± 19.4[a,b]

[a] Gait velocity was significantly lower in the older group than younger group across conditions (*p*=.014).

[b] Within groups, gait velocity was significantly lower in the dual task condition than normal condition (*p*=.008).

1), whether younger or older, walked more slowly in the dual task walking condition than in the normal walking condition (z=-2.7, p=.008).

Examples of dual task effects on variability in stride velocity are illustrated in Figures 2 and 3. In the younger subject (Figure 2), little variability in stride velocity is observed in either walking condition. In the older subject (Figure 3), while stride velocity is reduced compared to the younger subject, similar variability is observed in the normal walking condition. In contrast, when walking under the dual task condition variability in stride velocity is increased dramatically.

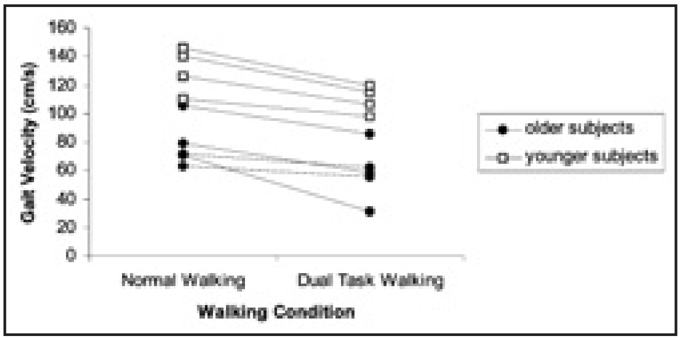

Figure 1. Gait velocity (cm/s) of each subject in the normal and dual task walking conditions.

Overall (Table 2), stride variability did not differ between younger subjects and older subjects during the normal walking condition (U=5.5, p=.260). During the dual task walking condition, however, stride variability was significantly greater among older subjects than younger subjects (U=0, p=.014). Stride variability increased significantly in the dual task condition among the older subjects (z=-2.0, p=.043). Each older subject's variability in stride velocity was higher in the dual task walking condition than in the normal walking condition (Figure 4). Variability in stride velocity did not differ statistically between the 2 walking conditions among the younger subjects (z=0, p=1.000).

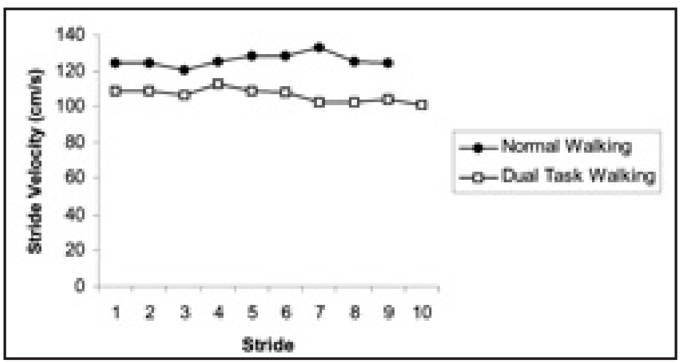

Figure 2. Characteristic example of stride velocity in a 25 year old woman. Her coefficient of variation (CV) was 2.8% in the normal walking condition and 3.4% in the dual task walking condition.

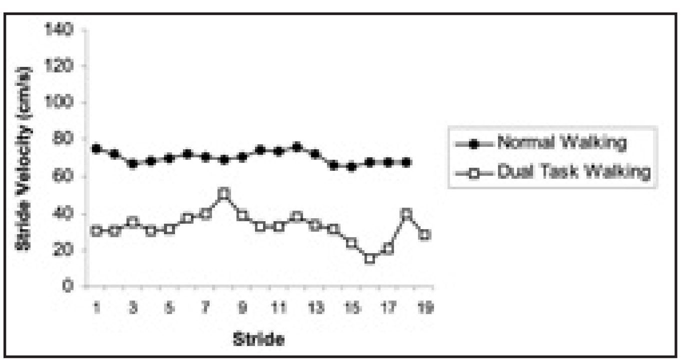

Figure 3. Characteristic example of stride velocity in an 86 year old woman. Her coefficient of variation (CV) was 4.6% in the normal walking condition and 23.6% in the dual task walking condition.

Table 2. Variability in Stride Velocity (% CV) during Normal and Dual Task Walking

Walking Condition	Younger Subjects Mean ± SD	Older Subjects Mean ± SD
Normal Walking	3.6 ± 1.7	4.9 ± 0.5
Dual Task Walking	4.5 ± 2.0	16.4 ± 7.2[a,b]

[a] Variability in stride velocity was significantly higher in the older group than younger group in the dual task condition (p=.014).

[b] Within the older group, variability in stride velocity was significantly higher in the dual task condition than normal condition (p=.043).

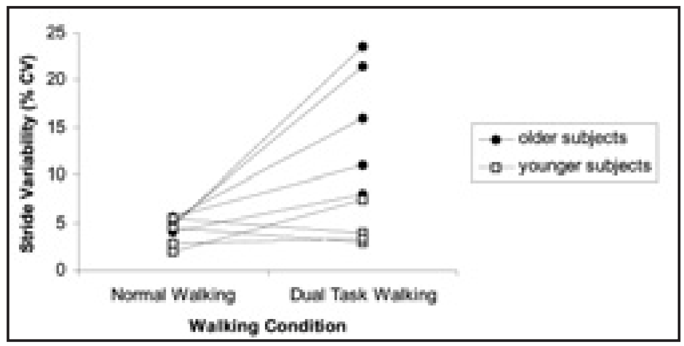

Figure 4. Variability in stride velocity (% CV) of each subject in the normal and dual task walking condition.

DISCUSSION

This pilot study provides evidence that cognitively demanding activity during walking reduces gait stability in well-elderly women. An increase in variability from one stride to the next, whether the measure reflects variability in step length,[15] variability in stride time,[1,2,9,10,14] or variability in stride velocity,[3] reflects an impaired ability to regulate stride-to-stride variations in gait timing. The increase in stride variability therefore reflects gait instability. We chose to analyze specifically subjects' variability in stride velocity because of the various gait parameters reflecting gait instability; it appears to be the most powerful predictor of future incidence of falls in elderly individuals.[3] As the older women in our pilot study walked and counted backward their variability in stride velocity increased significantly relative to minimal changes that occurred among younger women. Lundin-Olsson et al[8] and others have suggested that cognitive activity during walking may increase the risk of falling in older individuals. While the present pilot study did not examine risk of falling, results concur that cognitive activities during walking do reduce gait stability in older women. It is interesting to note, however, that 2 of the older participants required contact guard assistance by the investigator during 1 trial in the dual task walking condition to protect against falling.

While the effects of cognitive activity on walking in the well-elderly have not been studied specifically in previous investigations, results of this pilot study are consistent with studies that examined similar tasks.[5-7,9,10] Invariably, cognitive activity seems to have greater effects on stability among older individuals than younger individuals. We therefore believe that gait instability associated with cognitive activity during walking needs to be considered by clinicians and researchers alike who work with individuals with impaired balance or with those who may be at elevated risk of falling. While the pilot nature of our study may preclude clinically-implementable propositions, the results lay a foundation for further research to provide a greater understanding of the relationship between cognitive activities, or attention-splitting activities, and motor tasks such as walking in otherwise well-elderly individuals. A potential clinical suggestion may be that therapists should include cognitive challenges during gait training, balance training, or other forms of exercise designed to reduce an individual's fall risk.

Interpreting the results of the present pilot study is limited by its small sample size and relatively nonspecific inclusion and exclusion criteria. Each older subject described herself as a community-dwelling, healthy woman without a history of falls and without pathology that restricted independent walking. There are, however, potentially many other factors not addressed in pretest screening that may have otherwise classified the subjects as being at risk for falling or as being susceptible to gait instability. Examples include cognitive status,[16] medication history,[17,18] other measures of static or dynamic balance,[16] and other measures of physical function such as the ability to rise from a chair.[19] For instance, some of the data in our study suggest that the older subjects we studied may not have been entirely void of fall risk. Reduced gait velocity is not necessarily a predictor of gait instability or a risk factor for falls, but may be a symptom of a person's fear of falling.[3] The older subjects in our pilot study walked more slowly (approximately 78 cm/s) than similar healthy, community-dwelling subjects in other studies (approximately 100 cm/s).[15,20] On the other hand, the average gait velocity observed among the older subjects in our study is very comparable to the average gait velocity (approximately 79 cm/s) of older subjects classified as 'fearless nonfallers' by Maki.[3] Nevertheless, the preliminary results from our pilot study justify more in-depth investigation. Namely, will the finding that variability in stride velocity increases in well-elderly women during a dual task walking condition hold true for larger sample sizes and generalize to different populations?

Assuming that gait instability during dual task walking may be a sensitive measure for predicting falls in older individuals, another question to be examined is whether the gait instability associated with dual task walking can be modified by intervention. Maki[3] and Hausdorff et al[20] suggest that gait stability improves with exercise, but the question has not been examined under dual task walking conditions. Perhaps the greater question is whether interventions designed to improve postural stability and reduce risk of falls will improve stability during walking, particularly when simultaneously walking and performing cognitively demanding tasks.

CONCLUSION

Subjects, whether younger or older, walk more slowly in a dual task walking condition than in a normal walking condition. Older subjects walk in a dual task condition with greater variability in stride velocity, which indicates reduced stability. This finding may be relevant to the examination of, and interventions for gait deficits among elderly persons.

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