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Backward walking measures are sensitive to age-related changes in mobility and balance

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ABSTRACT

Many falls occur from backward perturbations or during transitional movements that require a person to turn and step backwards, suggesting that deficits in backward stepping may negatively impact mobility. Previous studies found significant declines in backward walking (BW) spatiotemporal measures in healthy elderly compared to young adults. No studies to date have examined BW performance in middle-aged adults and in elderly with impaired mobility. This study compared spatiotemporal measures of BW and forward walking (FW) in young, middle-aged, and elderly and in elderly fallers and non-fallers; and compared the strength of the relationship between age and BW and FW spatiotemporal measures to determine the utility of BW performance as a clinical tool for examining safety and mobility. BW measures were significantly more impaired in the elderly ($n = 62$) compared to young ($n = 37$) and middle-aged ($n = 31$) adults and age effects were greater in BW than FW. No significant differences were found between young and middle-aged except for base of support in BW. Stronger correlations were found between age and BW measures than between age and FW measures, particularly correlations between age and BW velocity and stride length. Elderly fallers had greater deficits in BW performance than non-fallers. All elderly fallers had BW velocities <.6 m/s. Clinicians are encouraged to assess BW, particularly BW velocity, as part of mobility examinations.

1. Introduction

Many falls in elderly occur from backward perturbations [1] or during transitional movements that require a person to move backward, such as turning and stepping backwards to sit in a chair [1,2]. These falls may be related to deficits in stepping responses to backward perturbations and difficulties with backward walking (BW). In response to unpredictable backward perturbations, elderly individuals were twice as likely to take compensatory steps to maintain balance compared to young adults [3,4]. Laufer [5,6] found that healthy elderly had significantly greater reductions in gait speed and stride length during BW than young adults. Increased gait variability was found to correlate with increased fall risk in multiple populations [7]. Hackney et al. [8] demonstrated that gait variability was increased in backward compared to FW in healthy elderly and those with Parkinson disease [8]. Several studies have demonstrated that practicing multi-directional stepping either as an exercise program [9,10] or in the form of tango dancing [11] improves mobility. Taken together these findings suggest that the inability to take effective backward steps may predispose the elderly to declines in functional ambulation and to increased risk of falls.

Since the ability to walk backward is a crucial element of mobility function and deficits might be related to a greater risk for backward falls, assessment of BW may be an important clinical tool. Few studies have compared spatiotemporal gait measures in forward (FW) versus BW and only three included elderly participants [5,6,8]. No studies to date have examined the characteristics of BW in middle-aged adults or elderly with declines in functional mobility; thus, it is not known whether the decline in BW is a slow, progressive change related to aging or a more abrupt decline related to cumulative changes in the neuromuscular system.

The purpose of this study was to compare spatiotemporal measures and their coefficients of variation (CVs) of BW and FW (1) in young (18–34 y.o.), middle-aged (35–64 y.o.) and elderly (65 y.o. and older), (2) in elderly fallers and non-fallers; and (3) to compare the strength of the relationship between age and BW and FW measures to determine the utility of BW performance as a clinical measure of safety and functional mobility. We hypothesized that BW spatiotemporal measures would be equivalent between young

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and middle-aged adults and would be significantly more impaired in elderly fallers than non-fallers. We also hypothesized that age would be more closely related to BW spatiotemporal measures than to FW measures. Assessment of BW measures may assist healthcare professionals in decision making for fall prevention interventions, assistive device prescription, and assessment of intervention efficacy in the elderly.

2. Methods

This cross-sectional study was approved by the Institutional Review Board. All participants were consented prior to participation.

A convenience sample of 130 adults, including 37 young, 31 middle-aged and 62 elderly participated in the study. Young and middle-aged participants were recruited from among students and faculty. Elderly participants were recruited at three facilities with independent and assisted living units. Assisted living residents made up 25% of the elderly sample and 50% of the elderly used an assistive device for walking outside their home. Twice as many elderly were recruited to allow further analysis of differences between those with and without a history of reported falls. All participants were able to ambulate >10 feet without an assistive device and/or physical assistance and demonstrated understanding of the purpose of the study. Individuals who were pregnant or had orthopedic or neurologic conditions that altered their walking were excluded.

Spatiotemporal gait measures were collected using the GAITRite System (V3.9, MAP/CIR Inc.). GAITRite measures are valid and reliable in the elderly [12].

Demographic data including pre-existing diagnoses, weekly types and amounts of exercise, self-reported fall history (number of falls in the past 6 months) [13], and assistive device use were collected. Elderly participants were also tested on the Tinetti Mobility Test (TMT) to better describe their functional mobility status [14]. Participants were asked to walk at a comfortable pace across the GAITRite walkway for three trials each of FW and BW. Participants were instructed to walk 2 m before and after the walkway to allow for acceleration and deceleration. Participants completed all trials without an assistive device, wearing a gait belt and were guarded.

2.1. Data analysis

The dependent variables considered in this study included average GAITRite results from trials of each direction. Coefficient of variation (CV) values were calculated to assess the variability of gait measures in BW and FW. Data for each of the gait measures and CVs were analyzed using one-way repeated-measures ANOVA with Tukey's post hoc tests to detect differences between BW and FW and between age groups. The *p*-value was set at .05 to control for type I error rate. Participant age served as the grouping variable in the ANOVA, while BW and FW were the within subject or repeated variable. The group (age) effect, direction (BW/FW) effect and the interaction of the two effects were analyzed. The interaction of age group and direction was tested for all gait variables and their associated CVs to determine if the various age groups performed significantly different in BW and FW.

Correlational analysis was performed to examine the relationship between age and performance in forward and backward gait. Differences in spatiotemporal measures of FW and BW between elderly fallers and elderly non-fallers were determined using independent *t*-tests. This final analysis included only the elderly age group. Statistical analyses were performed using SPSS version 19.0.

3. Results

Young adult [mean age = 24.1 ± 2.5 SD (range 21–31), 10 males], middle-aged [mean age = 47.3 ± 7.9 (range 35–61), four males] and elderly [mean age = 85.3 ± 6.7 (range 66–98), 12 males] individuals participated in the study. Two elderly individuals did not meet inclusion criteria due to health issues and were unable to participate. Ninety percent of elderly participants reported exercising (most commonly walking) at least once a week (mean = 4×/week). Tinetti Mobility Test scores for elderly fallers [$n = 12$; mean age = 86.3 ± 4.7; mean TMT scores = 21.3 ± 5.8 (range 8–28)] were significantly lower ($p < .05$, two tailed Mann–Whitney *U* test) than non-fallers [$n = 50$; mean age = 85.4 ± 7.1; mean TMT = 25 ± 2.8 (range 17–28)] indicating that fallers on average had greater mobility impairments than non-fallers.

In the repeated measures ANOVA, the interaction between the participant's age group and walking direction was significant for the average and CV of gait measures across trials. The *F* statistics and *p*-values for the interaction terms are in Table 1.

3.1. Gait across age groups

Gait parameters varied with age and differed from BW to FW (Table 2). Velocity was similar between young and middle-aged in both BW (1.13 ± .2 m/s; 1.03 ± .2 m/s) and FW (1.49 ± .2 m/s; 1.48 ± .2 m/s), but was significantly ($p < .001$) lower in elderly

Table 1
Interactions by age and direction of gait.

Gait measures	Young mean difference (SD)	Middle-aged mean difference (SD)	Elderly mean difference (SD)	Test statistic for ANOVA interaction term (*F*-statistics)	*p*-Value for ANOVA interaction term
Velocity (m/s)	−.387 (.13)	−.458 (.15)	−.490* (.17)	$F(2,127) = 5.00$	.008
Stride length (cm)	31.43 (8.64)	37.94 (11.19)	46.49$^{*,\infty}$ (14.03)	$F(2,127) = 7.77$	<.001
Base of support (cm)	−4.53 (3.77)	−8.089† (3.67)	−6.81$^{\#}$ (4.25)	$F(2,127) = 15.83$	<.001
Swing percent	1.13 (.57)	1.37 (2.08)	2.98$^{\#,\infty}$ (3.01)	$F(2,127) = 7.20$	.001
Stance percent	−6.60 (4.95)	−1.34 (2.04)	−3.09$^{\#}$ (2.80)	$F(2,127) = 6.57$	.002
Double support percent	−2.62 (2.35)	−2.27 (3.27)	−6.44** (5.04)	$F(2,127) = 7.17$	.001
CV step time	−1.22 (1.37)	−1.65 (2.80)	−5.20$^{\#,\infty}$ (9.20)	$F(2,125) = 6.67$	.002
CV step length	−3.77 (2.68)	−5.27 (3.86)	−12.75** (11.41)	$F(2,125) = 24.38$	<.001
CV swing time	−2.66 (1.82)	−4.39 (2.80)	−8.93** (7.13)	$F(2,125) = 12.50$	<.001
CV double support	−2.21 (1.69)	−2.76 (2.57)	−6.95$^{*,\infty}$ (7.94)	$F(2,125) = 4.84$	.009

Comparison of forward to backward walking interactions demonstrating that across most variables backward walking variables changed more dramatically and these changes were typically significant between the elderly and the young and middle-aged.

* Elderly significantly different than young, $p < .001$.

** Elderly significantly different than young and middle-aged, $p < .001$.

\# Elderly significantly different than young, $p < .02$.

∞ Elderly significantly different than middle-aged, $p < .02$

† Elderly significantly different than middle-aged significantly different than young, $p < .001$.

CV, coefficient of variation.