

# Gait Variables Differentiating Fallers from Nonfallers

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## ABSTRACT

**Purpose:** This study examined the qualitative and quantitative differences between 2 groups of older adults, fallers and nonfallers. We compared walking differences during over-ground walking to a task of obstacle clearance. **Methods:** Forty-eight community dwelling older adults (18 fallers and 30 nonfallers) participated. The mean age of the participants was  $78.1 \pm 7.2$  years (fallers) and  $75.8 \pm 5.1$  years (nonfallers). Walking differences within and between fallers and nonfallers during a single visit for 6 conditions were examined: (1) baseline walking, (2) slow walking, (3) fast walking, and (4) 5 cm obstacle clearance – approach, during, and exit. Quantitative differences of temporal-spatial walking measures were analyzed using a multifactorial ANOVA adjusted for age, gender, height, and BMI with a Scheffe correction ( $p < 0.05$ ) applied for multiple testing. Qualitative data were analyzed using Chi-square fisher's exact test. **Results:** There were interaction effects for group by walking condition for single support ( $p = 0.002$ ) and step length ( $p = 0.05$ ), while 1<sup>st</sup> double support approached significance ( $p = 0.06$ ). Main Group effects were found during the comfortable walk ( $p < 0.001-0.05$ ) for all 7 gait variables. Qualitatively, the fallers demonstrated increased knee flexion during both over ground walking ( $\chi^2 = 9.01$ ;  $p < 0.006$ ), and the fallers consistently took several small steps immediately prior to the obstacle clearance ( $\chi^2 = 8.42$ ;  $p =$

0.007). **Conclusion:** There were significant differences in quantitative and qualitative walking characteristics differentiating fallers from nonfallers during over-ground walking at different velocities and during obstacle clearance.

**Key Words:** fallers, nonfallers, older adults, walking, obstacles, stride, single limb support, double limb support

## INTRODUCTION

Falls among older adults represent a serious problem with loss of quality of life.<sup>1</sup> Multidimensional system related problems such as diminished proximal muscular strength,<sup>2</sup> visual changes,<sup>3</sup> and dual cognitive processing,<sup>4-6</sup> have been studied to predict persons at greatest risk for falls. Degradation in skill performance has been demonstrated in studies of older adults during over-ground walking,<sup>7</sup> treadmill walking,<sup>8</sup> obstacle clearance,<sup>9</sup> or negotiation of stairs, curbs, crossing the street,<sup>10</sup> and turning.<sup>11</sup> Over-ground walking performance may degrade further especially after a fall.<sup>12</sup>

Approximately 30% of older adults over age 65 fall on one or more occasions every year.<sup>13</sup> About 6% of falls in older adults will result in a fracture,<sup>14-16</sup> and fall-related injuries are the main cause of death from injury in older adults.<sup>17</sup> In addition, falls can have other long lasting effects that include disability, fear of falling,<sup>18</sup> and reduced physical functioning.<sup>10</sup> Finally, falls are important from a financial perspective because of the increased frequency of hospitalization for persons over the age of 65 who are treated for injuries incurred from a fall, and many falls result in nursing home placement.<sup>20</sup> Differentiating between people who are at risk for falls and those who are not during walking tasks can help rehabilitation professionals perform interventions that may delay falls and loss of functional mobility.<sup>12</sup> Falls occur as a result of intrinsic and extrinsic factors; some intrinsic factors are impairment based and can be assessed using measures such as lower extremity strength and single limb stance,<sup>16,21-23</sup> while others are functionally based, assessed using measures such as timed chair rises, floor to stand, and preferred walking speed.<sup>7,24,25</sup> Extrinsic factors range from walking surfaces to doorways to other potential environmental hazards.<sup>26</sup> We need to turn our attention toward functional measures that challenge the dynamic balance of older adults during walking tasks.

Relationships between falls and functional activities that involve dynamic balance have been identified in older adults. Slipping and tripping during walking are major causes of falls, suggesting a near fall may be a precursor to an actual fall for many individuals.<sup>27</sup> Age-related walking differences have been

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identified between healthy young and older adults, such as decreased walking velocity, decreased cadence, changes in the base of support, and increased stride variability.<sup>7,28,29</sup> Fewer studies have described differences between fallers and nonfallers during performance of functional tasks such as over-ground walking,<sup>12,30</sup> treadmill walking at various speeds,<sup>8</sup> turning,<sup>11</sup> or during obstacle course negotiation.<sup>9</sup> Studies have explored obstacle clearance in older adults,<sup>9,31,32</sup> and yet none to our knowledge have compared the differences between fallers and nonfallers during obstacle clearance.

Since falls are a widespread problem that occurs frequently during walking in older adults, there is a need for a detailed comparison between the walking differences of fallers and nonfallers during over-ground walking and obstacle clearance. Our central question was: what differences exist between 2 groups of older adults, fallers and nonfallers, in relation to quantitative and qualitative measures during the task of over-ground walking at various speeds and obstacle clearance?

## METHODS

### Participants

Forty-eight participants (18 fallers and 30 nonfallers) were enrolled in the study (3 fallers and 6 nonfallers were men). The study was conducted at The University of Texas Health Science Center at San Antonio Gait Analysis and Innovative Technology Laboratory located at the South Texas Veterans Health Care System-Audie L. Murphy Division in San Antonio, Texas.

Participants were recruited by flyers and word of mouth from the local San Antonio community. To be eligible, potential participants had to be at least 60 years old, be able to walk 1 mile nonstop, and be free of neurological or orthopedic impairments that limited walking or stepping over an obstacle. A telephone screen was performed to rule out any neurological or orthopedic conditions. Two persons did not meet the selection criteria; 1 had a history of Gullian Barre' Syndrome and the other had Post Polio Syndrome. Upon arrival at the laboratory, investigators explained the study procedures, and the volunteers

signed an informed consent as approved by the Institutional Review Board. A brief examination, including participant self-report of history of falls, medications, and other pertinent medical information, was completed to determine the grouping of each participant. Fallers were defined as persons who had experienced at least 1 fall to the ground during the past year.<sup>16</sup>

### Equipment and Temporal-Spatial Measures

The results reported here are one component of a large study that used a variety of equipment, software, and processing procedures. The Oxford Metrics VICON 370 3-D Motion Analysis System (Vicon Peak, 14 Minns Business Park, West Way, Oxford OX2, 0JB, UK) hardware and software (version 2.5) was used for data collection of all quantitative walking parameters. The system consists of 6 synchronized infrared 60 Hz shuttered video cameras used for kinematic and temporal/spatial data collection and 4 fully insulated and grounded AMTI (AMTI, 176 Waltham Street, Watertown, Mass) wheatstone bridge force plates positioned tandem and flush with the laboratory flooring. The force plates provided magnitudes, directions, and positions of ground reaction forces as the participant walked along the calibrated walkway. The captured ground reaction forces were then used to calculate walking parameters. Subsequent displays of these ground reaction force vectors served as secondary confirmation of heel strike and toe-off, required for temporal-spatial measure calculations. Corresponding temporal data (normalized to 100% of the gait cycle) were extracted, averaged, and then interpreted for each task in both fallers and nonfallers. The quantitative dependent variables of interest in this report included walking velocity, cadence, step and stride length, single and double support times (Table 1).

Two super-VHS color camcorders, an S-VHS videotape recorder, and a video mixer provided split-screen (frontal and sagittal) views were synchronized with temporal-spatial data collection. These recordings were viewed for each individual's

**Table 1. Definition of Variables**

Gait Variables	Definition	Units
Velocity	Measured distance per unit time	Meters/second
Cadence	Number of steps per unit time	Steps/minute
Step Length	Distance from heel strike of the one limb to heel to heel strike of the opposite limb	Meters
Stride Length	Distance from heel strike one limb to heel strike of the same limb	Meters
Single Support	The time when one limb is the only point of contact with the floor	Percent of total normalized to the entire cycle
Double Support	The time when both limbs are in contact with the floor	Percent of total normalized to the entire cycle

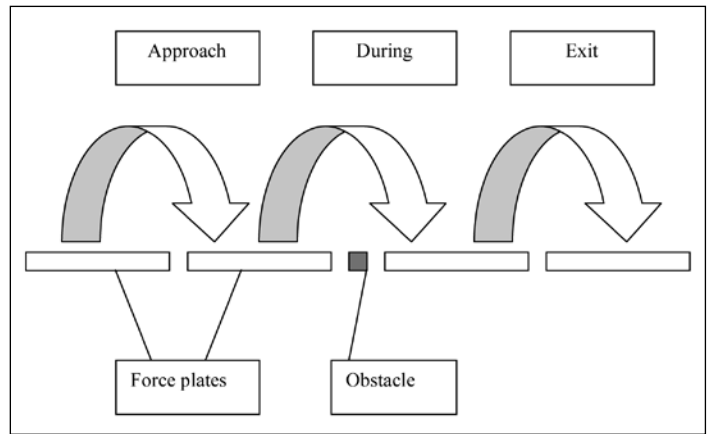
qualitative walking performance. Qualitative video analyses of walking at a self-selected velocity and during obstacle clearance were performed using the Rancho Los Amigos Observational Gait Analysis as a model.<sup>33</sup> Two physical therapists with over 30 years of clinical experience, blinded to subjects' fall status, separately viewed and scored the video recorded walking data. The aggregated data revealed an inter-rater agreement of greater than 60% (head and trunk > 90% agreement; limbs > 60% agreement). Special attention was given to the strategies used by each participant and then the strategies were compared between groups.

### Clinical Measures

Several functional tests were completed to more fully describe our participants including the Tinetti Performance Oriented Mobility Assessment,<sup>34</sup> Timed Up and Go,<sup>35,36</sup> Functional Reach,<sup>37,38</sup> and timed Single Limb Stance Test with eyes open.<sup>24,39</sup> High inter-rater reliability and validity have been reported for each of these measures.<sup>40,41</sup> The Tinetti consists of balance and gait components developed to determine who is at high risk for falls (< 19/28 total score indicates severe risk for falls;  $r = 0.71$ ).<sup>34</sup> The Timed Up and Go includes a 'go' command; the participant rises to stand, walks 10 feet, turns, and returns to sitting in the chair (ICC=0.916).<sup>35,36</sup> A Functional Reach was performed by asking the participants to reach as far as they could forward and the distance reached was measured from the 3<sup>rd</sup> metacarpal (ICC=0.81).<sup>37,38</sup> The Single Limb Stance Test is a timed test of balance performed while standing on 1 leg flexed along side the support limb with eyes open while the participants are not holding (ICC = 0.992; relative risk = 2.13).<sup>23,39,42</sup> Following a practice trial, 3 trials of each test were recorded, and the mean values were calculated. A physical therapist with over 25 years of clinical expertise administered the tests to all subjects.

### Quantitative Walking Measures

Participants wore short sleeve shirts, shorts, and comfortable laced walking shoes throughout the study. Reflective markers (2.5 mm in diameter) were placed on the participant at select bony landmarks (pelvis, hip, knee, ankle, and foot) to determine temporal-spatial measures. After the equipment was placed on the participants, at least a 2-minute walking acclimation period was allowed for the participants to accommodate to the laboratory environment and equipment. Participants were assigned a randomized sequence of locomotor tasks that addressed the multiple walking velocities and obstacle negotiation. Each task comprised a minimum of 5 to 7 trials, promoting a steady state walking velocity during the data collection period midway along the 10-meter walkway. The testing conditions included: (1) baseline over-ground walking—walking over a level surface at a normal comfortable, self-selected walk; (2) walking at a slow, leisurely pace; (3) walking as fast as possible while remaining confident; (4) obstacle clearance (5 cm width x 305 cm length x 5 cm height off the ground); bright blue; (Figure 1) walking at a self-selected pace, stepping over a 5 cm obstacle while in stride, and continuing to walk at a self-selected pace.



**Figure 1. Direction of walk through for the participants' trials for over-ground and 5 cm obstacle clearance. The arrow depicts the direction of the participant, the blocks of the force plates, and the bar the obstacle. The approach consisted of direct hit of the first force plate prior to the obstacle. The phase during the obstacle clearance was from heel strike prior to the obstacle to heel strike after the obstacle. The exit consisted of direct hit of the force plate after the obstacle. Only the left lower limb was studied.**

A repeated measures, cross sectional study design was used to control for potential order and fatigue effects. Baseline self-selected walking was performed at the beginning of data collection, in an effort to promote participants' confidence. All participants were supervised and guarded closely during the walking trials to insure safety. Subjects were allowed to rest in a seated position between trials as needed to minimize potential fatigue effects. Following performance of all walking tasks, the equipment was removed and the participants were offered basic education on prevention of falls and given a handout with Tips on How to Avoid Falls. Data was collected, for each subject, in a single 2 to 3 hour session.

### Qualitative Walking Measures

Videotaping of all participants allowed review of walking conditions, over-ground compared with obstacle clearance, at a time subsequent to the clinical examination. Slow motion and stop action assisted reviewers in the qualitative evaluation of gait trials. Evaluators independently reviewed videotaped trials, and, using a table of potential deviations modified from the Rancho model by body segment (eg, head, trunk, upper and lower extremities), determined whether a gait deviation was present (yes-no response). Particular attention was given to the similarities and differences between groups and within each condition. Although reliability has been reported to be low (< 52% agreement),<sup>43</sup> using the video analysis techniques from the sagittal and frontal planes contributed to consistency between reviewers in this study (> 60% agreement).<sup>44</sup> In the case there was a disagreement between the reviewers, we took a conservative approach to whether the deficit was demonstrated or not, by not counting this deficit as a deviation. If the deficit was slight, it was also not counted.

## Statistical Analyses

Statistical analyses of quantitative data were performed with SAS Statistical software (version 9.1). Initial differences in physical characteristics and performance on functional measures between the groups were evaluated using a t-test or Wilcoxon Rank Sum test as appropriate. A Chi-square fisher's exact test ( $\chi^2$ ) was applied to the frequencies of each qualitative walking characteristic (yes/no) for each group (fallers/nonfallers), for level walking and obstacle course conditions. A group (2) by walking condition (6) multifactorial ANOVA was applied to all 7 gait variables (adjusting for age, sex, height, and body mass index for all temporal-spatial walking measures) and was used to compare differences and relationships between groups for each task.<sup>45</sup> Least square means were used to test for the differences between groups for each walking condition. All test conditions were adjusted using Scheffe multiple testing procedure. Differences between fallers and nonfallers were analyzed for each clinical test, quantitative and qualitative measures, and for each walking condition at the 0.05 level of significance. A within group analysis was conducted for over-ground walk compared with during the obstacle clearance.

## RESULTS

Eighteen fallers and 30 nonfallers participated in the study. There were no initial differences in between groups with respect to age, height, weight, or performance on functional measures (Table 2). Inaccurate hits of the force plate that were needed for temporal-spatial quantitative data analyses contributed to incomplete for some participants.

### Qualitative Walking Characteristics

The results of qualitative evaluation of walking characteristics are summarized in Table 3. In overground walking at comfortable gait speeds, fallers demonstrated decreased trunk rotation ( $\chi^2 = 5.60$ ;  $p < 0.02$ ), and increased knee flexion as compared to nonfallers ( $\chi^2 = 9.01$ ;  $p < 0.006$ ). Both groups displayed a nonsignificant increased base of support along with

sustained upper extremity abduction, excessive medial-lateral trunk displacement, and decreased arm swing ( $p > 0.05$ ). During the obstacle clearance trials, the majority of the fallers took several small steps prior to obstacle clearance (approach phase;  $\chi^2 = 8.42$ ;  $p < 0.007$ ) and demonstrated decreased trunk rotation ( $\chi^2 = 9.23$ ;  $p < 0.004$ ). Both groups tended to keep their heads down (gazing at the ground) and/or forward, and both used a wider base of support during the approach and obstacle clearance ( $p > 0.05$ ).

### Quantitative Walking Characteristics

Evaluation of differences between fallers and nonfallers was based on analysis of left extremity gait performance. Two participants who were fallers were outliers for the gait variable step length under the fast walking condition; their step length values were replaced with half of their stride length for subsequent analysis.

Fallers were distinctly different from nonfallers for all gait conditions except for slow walk ( $p > 0.05$ ). As evidenced by main group effects for all 7 gait variables, fallers and nonfallers were most different during the comfortable walk condition ( $p < 0.001-0.05$ ) (Figure 2). During the other walking conditions, they differed, per main group effects, for select gait variables as follows: fast walk [stride length, cadence and velocity ( $p < 0.001-0.01$ )], approach to the obstacle [single support, cadence and velocity ( $p < 0.001-0.007$ )], obstacle clearance [step length, stride length and velocity ( $p < 0.001-0.004$ )], and exit from the obstacle [stride length, cadence and velocity ( $p < 0.009-0.04$ )].

There was a significant group by walking condition interaction for two gait variables; single support ( $F = 3.95$ ;  $p < 0.002$ ) and step length ( $F = 2.26$ ;  $p = 0.05$ ; Figure 2). First double support approached a significant group by walking condition interaction ( $F = 2.15$ ;  $p < 0.06$ ).

## DISCUSSION

The purpose of this study was to determine if older adults classified as fallers and nonfallers differed on selected temporal-

**Table 2. Characteristics of Older Adult Fallers Compared with Nonfallers**

Characteristics	N	Nonfallers		N	Fallers		p-value
		Mean	(S.D.)		Mean	(S.D.)	
Age (years)	30	75.8	(5.1)	18	78.1	(7.2)	0.21 <sup>1</sup>
Height (meters)	30	1.7	(0.1)	18	1.6	(0.1)	0.96 <sup>2</sup>
Weight (kilograms)	30	69.2	(16.9)	18	70.2	(0.1)	0.53 <sup>2</sup>
Tinetti POMA (# out of 28)	30	26.6	(2.2)	18	24.6	(2.5)	0.15 <sup>2</sup>
Timed Up and Go (seconds)	25	6.7	(2.5)	12	7.2	(2.2)	0.43 <sup>2</sup>
Single Limb Stance Left (sec.)	30	7.0	(2.9)	17	5.7	(3.4)	0.20 <sup>2</sup>
Single Limb Stance Right (sec.)	30	7.1	(2.8)	12	4.9	(3.7)	0.05 <sup>2</sup>
Functional Reach (inches)	25	11.3	(2.8)	12	11.8	(1.9)	0.61 <sup>1</sup>

<sup>1</sup> = t-Test

<sup>2</sup> = Wilcoxon Rank Sum Test

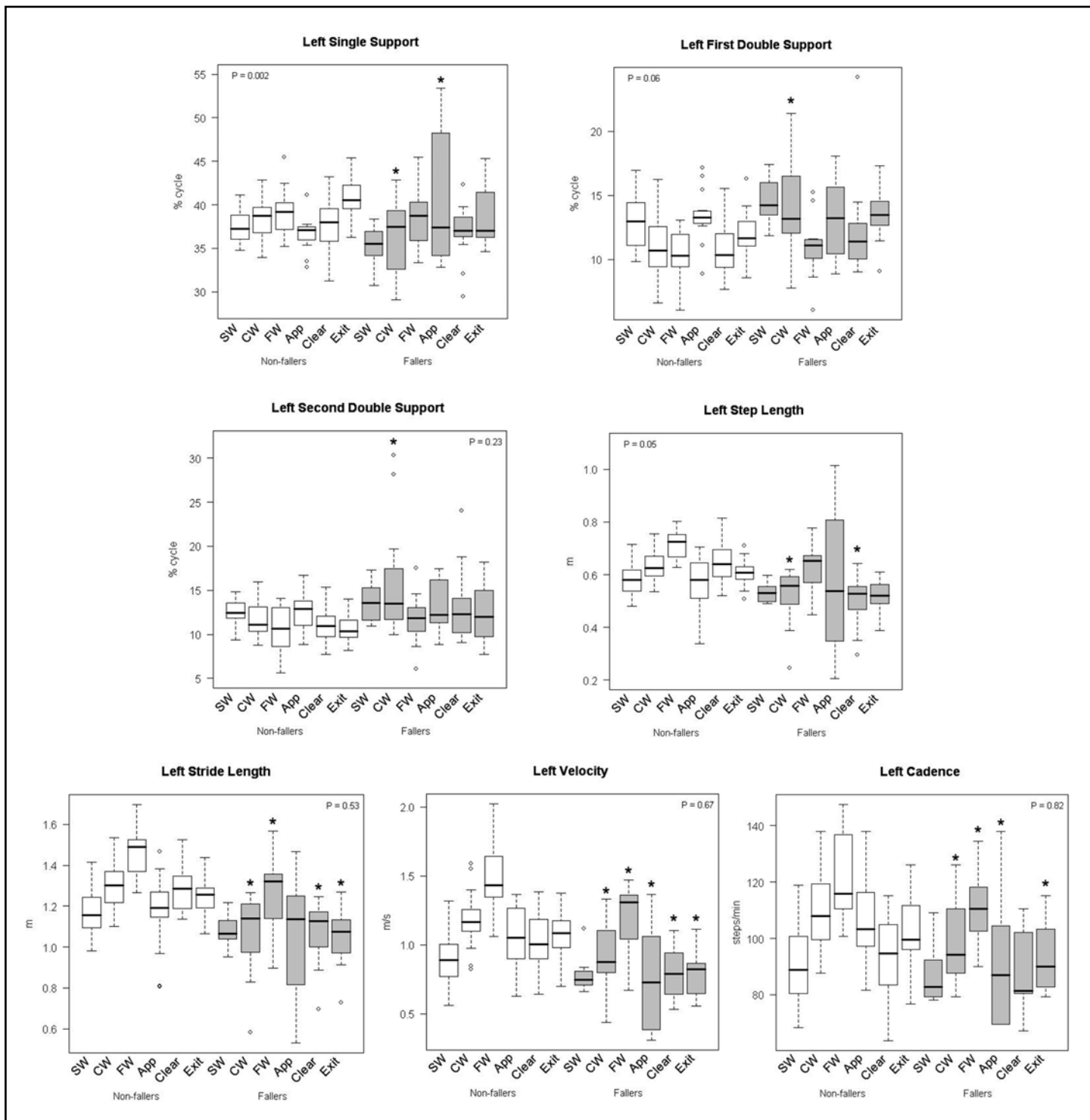
**Table 3. A Qualitative Comparison Between Fallers and Nonfallers During Over-ground Walking at a Comfortable, Self-Selected Velocity and During Clearance Over a 5-cm Obstacle**

			Group		Chi-Square	
			Number (percentage)			
Observed Behavior	Walking Condition		Faller	Non-faller	Statistic	P-Value <sup>1</sup>
Head Forward/Looks Down	Comfortable Walk	Yes	18 (40.0)	22 (81.5)	3.75	0.07
		No	0 (0)	5 (18.5)		
	Obstacle Clearance	Yes	15 (93.8)	23 (85.2)	0.72	0.64
		No	1 (6.3)	4 (14.8)		
Reduced Arm Swing	Comfortable Walk	Yes	11 (24.4)	11 (40.7)	1.79	0.23
		No	7 (15.6)	16 (59.3)		
	Obstacle Clearance	Yes	9 (56.3)	10 (37.0)	1.50	0.34
		No	7 (43.8)	17 (63.0)		
Increased Arm Swing	Comfortable Walk	Yes	4 (8.7)	14 (50.0)	3.55	0.07
		No	14 (30.4)	14 (50.0)		
	Obstacle Clearance	Yes	3 (18.8)	4 (14.8)	0.11	1.00
		No	13 (81.3)	23 (85.2)		
Upper Extremity Abduction	Comfortable Walk	Yes	3 (6.7)	5 (18.5)	0.03	1.00
		No	15 (33.3)	22 (81.5)		
	Obstacle Clearance	Yes	4 (25)	4 (14.8)	0.69	0.44
		No	12 (75)	23 (85.2)		
Decreased Trunk Rotation	Comfortable Walk	Yes	16 (35.6)	15 (55.6)	5.60	0.02
		No	2 (4.4)	12 (44.4)		
	Obstacle Clearance	Yes	13 (81.3)	9 (33.3)	9.23	0.004
		No	3 (18.8)	18 (66.7)		
Medial Lateral Trunk Sway	Comfortable Walk	Yes	8 (17.4)	11 (39.3)	0.12	0.77
		No	10 (21.7)	17 (60.7)		
	Obstacle Clearance	Yes	7 (43.8)	10 (37)	0.19	0.75
		No	9 (56.3)	17 (63)		
External Rotation/Wide Base Support	Comfortable Walk	Yes	9 (19.6)	9 (32.1)	1.47	0.35
		No	9 (19.6)	19 (67.9)		
	Obstacle Clearance	Yes	7 (43.8)	5 (19.2)	2.92	0.16
		No	9 (56.3)	21 (80.8)		
Knees flexed	Comfortable Walk	Yes	5 (10.6)	0 (0)	9.01	0.006
		No	13 (27.7)	29 (100)		
Small steps prior to obstacle	Obstacle Clearance	Yes	6 (14)	1 (3.7)	8.42	0.007
		No	10 (23.3)	26 (96.3)		

<sup>1</sup> Fisher's Exact test

spatial walking measures during over-ground walking and obstacle clearance. The findings in this study are comparable to those of other studies of quantitative walking measures over-ground walking. As previously reported, women demonstrated a mean comfortable walking speed of 1.2 m/s and a mean fast walk of 1.7 m/s.<sup>7</sup> In comparison, our nonfallers dem-

onstrated a slightly slower mean fast walk of  $1.49 \pm 0.23$  m/s, and the fallers adopted a fast walk of  $1.19 \pm 0.26$  m/s similar to the self-selected walk of the nonfallers. Determinants of faster walking capacity for the fallers<sup>8</sup> included step length and single support; these measures directly influenced walking velocity and successful obstacle clearance.



**Figure 2.** Temporal-spatial measures for fallers and nonfallers for slow walk (SW), comfortable walk (CW), fast walk (FW), upon approach to the obstacle (App), during the obstacle clearance (Clear) and exit from the obstacle clearance (Exit). The top and bottom of the box plots represent the first and third quartiles with a thick bar indicating the median. The whiskers extend to the minimum and maximum data values with outliers shown as circles. The asterisks indicate a significant difference between the faller and nonfaller groups for the walking condition specified. All tests were adjusted for multiple testing using Scheffe's multiple testing correction procedure.

Fallers exhibited a shortened step and stride length, slowed velocity for most conditions, but the nonfallers adjusted by using an increased step and stride length to clear the obstacle. Since the nonfallers were overall more adept at walking they

performed proportionately better for all conditions. Chen and associates<sup>9</sup> previously reported that older adults (mean age 71y) demonstrated slowed walking velocity ( $1.19 \pm 0.19$  m/s) and a shortened step ( $0.76 \pm 0.8$  m) to clear obstacles (2.5, 5.0,

or 15.2 cm) compared with young adults (age 21y; 1.3 m/s). Our study appears to be the first to compare fallers to nonfallers on approach, clearance, and exit from obstacles during walking. Fallers have a distinctly different strategy for management of obstacles (reduced stride 1.07 m [step length 0.50 m] and velocity 0.8 m/s [fallers]) in a controlled laboratory environment compared with nonfallers (stride = 1.18 m; step length = 0.64 m; velocity 1.02 m/s [nonfallers]). One explanation for this difference might be that nonfallers may be operating in a feed-forward or anticipatory mode compared with the fallers. Many older adults who fall demonstrate less effective anticipatory responses, ie, feed-forward control, and instead use feedback mechanisms to recover after the loss of balance; often leading to a fall despite their best efforts to remain upright.<sup>18,47</sup> Limited responses in the fallers may influence the ability to adapt to the more challenging task demands, especially under dual task conditions.<sup>5,6</sup> Theoretically, obstacle clearance is a dual-task for older adults, as it requires processing of environmental information while walking forward. Toulotte et al<sup>6</sup> found that over-ground walking velocity (1.08 m/s [fallers] vs. 1.12 m/s [non-fallers]), stride (1.13 m [fallers] vs. 1.09 m [nonfallers]) and single support measures were reduced significantly during dual-task conditions (carrying a glass of water) compared with single-task conditions ( $p = 0.04-0.007$ ) in fallers compared with nonfallers.

Closer examination of stride and step length along with velocity, cadence, single, and double support times indicates that nonfallers were more confident compared with the fallers because of their ability to adjust to the obstacle without significant changes in spatial-temporal measures in our study. Fear of falling has been described as a factor that has an effect upon walking confidence and velocity.<sup>18</sup> Our findings suggest that fallers are not simply nonfallers only moving more slowly. Fallers took a more conservative approach to the obstacle. A conservative approach by the fallers was exhibited by reduced stride length and slowed walking velocity for most walking conditions. It is possible that the fallers had a lesser ability to generate propulsive forces, especially during fast walking. Lee et al<sup>30</sup> proposed that muscle strength may not be the central factor that predicts fallers, instead suggesting that impaired muscular coordination and proximal hip power may be important contributors to risk of falling. Difficulty with single limb stance also plays a role in falls, and has been closely linked with temporal measures.<sup>23</sup> Fallers may have decreased single support time and increased second double support time. Alteration of these dimensions of gait (velocity, single support time, double support time, step length, and stride length) may lessen the disturbances to balance during walking, especially during obstacle clearance. Barak and associates<sup>8</sup> recently reported decreased stride length (0.9 m [fallers] vs. 1.1 m [non-fallers] at 1.3 m/s;  $p < 0.05$ ) and increased variability in the performance of fallers during walking at various speeds on a treadmill (0.18-1.52 m/s) especially at a faster velocity (1.3 m/s;  $p < 0.05$ ). In our study, fallers consistently took shorter steps/strides, decreased single support time, and increased double support time while

walking slower under all conditions and had a narrower range of walking velocity except under slow walk conditions.

Fallers displayed an overall more conservative over-ground walking and obstacle negotiation compared with the nonfallers. Fallers also demonstrated greater knee flexion during the comfortable walk, several small steps just prior to obstacle clearance, and decreased trunk rotation during both comfortable walk and obstacle clearance conditions. Both groups used vision as a strategy to closely monitor their performance prior to and during negotiation of the obstacle as demonstrated by looking down under most walking conditions.<sup>48</sup> Thigpen et al<sup>11</sup> reported that older adults were more cautious during turns, choosing to take several steps to complete the task compared with young adults. Visual reliance to negotiate the environment is a widely used strategy by many healthy young and older adults.<sup>31</sup> The need to rely on vision may be related to fear,<sup>18</sup> aging,<sup>7</sup> reduced peripheral vision,<sup>9</sup> and the need to scan the environment for on-line visual monitoring<sup>48</sup> of obstacles. We did not monitor eye glass wear, but a few participants complained of visual distortion secondary to new eyeglasses and trifocal lens during the obstacle clearance task. All of these factors need to be considered for optimal community functioning.<sup>19,49</sup>

There are several limitations in this study that must be acknowledged. Participants constituted a sample of convenience; many were active in the community as volunteers at a local hospital, and highly motivated to perform optimally. A single fall may not be the best criteria to differentiate nonfallers from those most at risk of falling: using markers of 2 or more falls per year, may better characterize fallers vs. nonfallers in future studies. In retrospect, asking participants about perceived fear of falling or level of confidence during the various walking conditions may help us better understand the differences between groups.<sup>18</sup> Although we lacked quantitative data on all participants for all conditions, we found that most completed the tasks except one who had difficulty negotiating the obstacle. Fatigue may have played a factor in some individuals who were frail because of repeated measurement, despite efforts to control the impact of fatigue by providing rest breaks as needed. Future study of typical performance for a larger sample of frail older adults would contribute to understanding of the challenges they encounter while attempting to negotiate obstacles. This study did not adjust the height of the obstacle to the height of the individual, and so may not be directly comparable to previous studies of healthy older adults for whom obstacle height was determined by overall height.<sup>9,50</sup> Fallers and nonfallers in this study were of similar height, so management of a single obstacle would likely be similar across groups.

Other variables that may affect balance and walking characteristics, such as visual acuity or contrast sensitivity, pain, and sensation were not considered in this study. We cannot conclude that fallers performed differently than nonfallers based on a previous fall event alone, or if their gait characteristics changed because of the fall that they experienced. Despite

these limitations, it appears that fallers and nonfallers may perform differently, qualitatively and quantitatively, in clinically measurable and meaningful ways.

## CONCLUSION

Differences in performance of fallers and nonfallers during over-ground walking at various speeds and during obstacle clearance has not been widely reported in the literature. In this study, there were significant differences in quantitative and qualitative walking characteristics when performance of fallers and nonfallers during over-ground walking at different velocities and during obstacle clearance was compared. The fallers demonstrated reduced walking velocity and cadence, shorter stride and step lengths, and reduced single support time during obstacle clearance when compared to nonfallers. These may prove to be important markers for older adults who are at risk of falling.

The results of this study suggest that, for older adults, the examination of temporal-spatial gait characteristics, eg, walking at various speeds (eg, slow to fast) and under differing task conditions (eg, obstacle clearance), may be useful in assessing an individual's ability to perform walking tasks when challenged. An examination of the ability to negotiate complex obstacles and change walking velocities, critical components of environmental demands, can be easily observed in clinical or home settings. Performance-based examinations may provide additional insight into an older person's strategies and ability to negotiate commonly encountered functional, meaningful tasks. Future work that quantifies differences in dynamic balance differences between persons who fall and those that do not fall during various walking conditions will assist physical therapists to interpret or predict an older adult's ability to accomplish functional tasks in real-world settings.

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