HHS Public Access
Author manuscript
Exp Gerontol. Author manuscript; available in PMC 2019 October 01.

Published in final edited form as:
Exp Gerontol. 2019 July 15; 122: 60–66. doi:10.1016/j.exger.2019.04.011.

Older Women Take Shorter Steps During Backwards Walking and Obstacle Crossing

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Abstract

Background: Community ambulation requires the ability to adapt walking patterns to task demands. For example, complex walking tasks, such as obstacle crossing (OBS) and backwards walking (BW), require modification of gait kinematics to complete the task, maintain stability and prevent falling. More women than men fall each year, but few studies have investigated gender differences in performance of adaptive walking tasks.

Objective: The purpose of this study was to determine gender differences in two common adaptive tasks.

Methods: Walking performance was assessed from 54 age and gender matched participants (72 ± 5 yrs.) while they completed forward walking (FW), OBS and BW. Gait outcomes and the distance of the lead foot and the trail foot from the obstacle were normalized by leg length and assessed using multivariate analysis of variance. Additionally, performance in a battery of clinical physical and cognitive measures as well as self-reported activity levels were associated with adaptive gait behavior.

Results: Gait speed and step width were not different between genders in any walking task. Compared to FW and OBS, women only decreased step length in BW, resulting in significantly shorter step lengths than men in OBS ($p = 0.02$) and BW ($p = 0.04$), a conservative walking strategy. Women crossed the obstacle in a manner that may limit recovery steps in case of a trip: stepping closer to the obstacle during approach without increasing trail toe-clearance. The Timed Up and Go mobility test, Short Physical Performance Battery, and Trail Making Test of processing speed and executive function were associated with gender differences in adaptive gait patterns.

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Conflict of Interest
The authors confirm no conflict of interest exists

Conclusion: The findings revealed that older adult women adapt walking in a way that might predispose them to tripping or falling (i.e. shorter steps and closer obstacle approach). Gender differences in adaptive walking are related to functional test performance and processing speed. Clinicians should consider targeting step length during adaptive walking tasks in women that may be at risk of mobility impairments.

Keywords

Mobility; cognition; aging; adapting; gait

1 Introduction

Everyday we adjust walking patterns to negotiate uneven surfaces, step over curbs, or maneuver backwards in a tight space. Adapting walking patterns in order to maintain balance and prevent slipping or tripping is more neurologically demanding than usual forward walking (FW).[1,2] Many injurious falls occur in older adults because of difficulty adapting steps when backing up to a chair, walking on uneven surfaces, or stepping over or around obstacles.[3,4] Such falls lead to devastating mobility impairments and reduced quality of life in older adults.[5]

A greater number of older women suffer injurious falls than men,[3,6] motivating a better understanding of gender differences in walking behaviors. Existing reports typically control for gender effects,[7,8] whereas gender-dimorphism studies typically evaluate only FW [9] or gait speed, [10] do not correct for morphological differences,[11] or report gross measures of functional performance.[12,13] Thus, previous findings neglect potentially important gender differences in adaptive walking that underlie real-world fall events. Moreover, adaptive walking ability is associated with cognitive acumen in older adults,[14] but cognitive assessments are inconsistently included in previous studies. Despite the relevance of adaptive gait performance in detecting the risk of mobility-disability,[15] fall-risk,[16] and cognitive status,[14] the question remains if performance during adaptive walking behaviors, such as backwards walking (BW) and obstacle crossing (OBS), differs between genders in older age.

Gender may influence adaptive walking across locomotor tasks and could manifest in a greater risk of mobility impairment. In usual FW, there are no gender differences in gait parameters after accounting for body size.[17] However, women demonstrate worse performance than men on clinical balance assessments including more complex locomotion.[12,13] For instance, women exhibit difficulty performing gait adaptations such as stair ascent [13] or standing from a chair, walking three meters, then turning and returning to one's seat.[12] Evidence of gender differences could be related to reduced strength or smaller statures in women,[18,19] but older women also perform locomotor tasks that are not as physiologically demanding, such as BW at self-selected speeds, more slowly than men.[11] Slower BW speeds in women have been attributed to shorter stride lengths and wider steps,[11] but emerging evidence suggests slower speed in BW may reflect a higher risk of falling.[16,20] Gender differences are also noted in OBS where women cross obstacles more quickly, earlier in the stride cycle, at shorter distances, and with lower limb clearances.[21] This adaptive strategy may limit the ability for older women to recover balance in case of tripping over an obstacle.[21,22] Additionally, gender differences in older adults are present in some cognitive functions [23] that are associated with mobility impairment and difficulty crossing obstacles.[19,24,25]

Research suggests there may be a link between gender and aspects of locomotor adaptation, but it remains unclear if older women are susceptible to difficulty adapting walking that could negatively impact daily mobility. Therefore, the purpose of this study was to examine gender differences in the performance of adaptive locomotor tasks in older adults and evaluate potential contributing factors. We quantified spatial and temporal features of locomotion during FW, BW, and OBS in an age-matched sample of older men and women. We also obtained several measures of physical function and cognitive status related to adaptive gait in older adults to contextualize the results.[19,20,25] We hypothesized that after normalizing for leg length, there would be no differences between genders during FW, but women would have a slower gait speed, shorter step length, and wider step width than men during BW. In OBS, we predicted women would show slower gait, shorter and wider steps, and cross the obstacle from closer distances with lower foot clearance than men. Finally, we predicted that associations between cognitive and clinical balance assessments would reveal clinically relevant factors related to gender differences in adaptive gait performance.

2 Methods

2.1 Participants

Fifty-four older adults (27 women) participated as part of a larger intervention (NIH R21 AG048133) approved by the Institutional Review Board at the University of Florida. Primary inclusion criteria were: 1) aged ≥ 65 years, 2) and the ability to walk comfortably without assistance. Activity levels were determined by the Community Healthy Activities Model Program for Seniors (CHAMPS) survey [26] in which individuals report their time spent performing leisure and exercise activities. Participants were excluded if they exercised > 150 minutes weekly, if they reported their vision and hearing were not corrected to normal, or if they were diagnosed with a neurological condition, cardiac or pulmonary disease, insulin-dependent diabetes, or another condition affecting ambulation. We did not exclude participants based on clinical and cognitive assessments to capture a greater range of scores.

2.2 Procedures

Participants self-reported gender and completed several validated clinical measures of cognition and physical function. We focused on three validated tests of cognition that are associated with functional walking behavior:[19,24,25] the Montreal Cognitive Assessment (MoCA), Trail Making Test (TMT), and Stroop test. The MoCA screens for mild cognitive impairment and assesses orientation, memory, executive function, and language. [27] The TMT is a two-part cognitive assessment which measures processing speed and set-switching aspects of executive function. The score quantifies the time to connect circles on paper, first using numbers (Trails A) and then alternating from numbers to letters (Trails B). The difference (delta TMT a.k.a. dTMT) quantifies the performance costs from Trails A to Trails B and detects cognitive impairment.[28] The Stroop test measures processing speed and executive functions, primarily inhibition. The first half (Stroop Congruent) requires the test-taker to recite the color of printed X's on the page in 45 seconds, challenging processing speed. The second portion (Stroop Incongruent) involves naming the color of the font that is mismatched with another color-word (i.e., the word 'blue' printed in red font), requiring the inhibition of prepotent responses.[29]

Participants completed two common clinical tests to characterize functional ability. First, they completed the Short Performance Physical Battery (SPPB) to test lower body strength, static balance, and gait speed.[30] Participants performed functional tasks in the following order: 1) sit-to-stand: time taken to stand from a chair five times at a maximal speed, 2) standing balance: balancing for 10 seconds with feet side-by-side, in a semi-tandem stance, then a full tandem stance, and 3) walking speed: usual gait speed along a three meter path.[30] Scores were assigned by the researcher as per traditional methods using a 0–4 scale; participants earned a 0 if they could not perform the task, and 4 points if they successfully completed the task below specific time thresholds. After all walking protocol were complete, participants then performed the Timed Up and Go (TUG) test, a measure of functional mobility in older adults.[31] The TUG measures the time people take to stand from a chair and walk three meters at their usual pace, turn around, and walk back to sit in the chair.

We used motion capture technology to measure walking patterns. Thirty-nine reflective markers were placed on the participant's body according to the Vicon (version 2.3) Plug-in-Gait model. Movement was recorded at 120 Hz with a 10-camera system as participants walked barefoot at a self-selected pace across an eight-meter walkway. Participants did not complete any practice trials. In a fixed order, participants performed FW, BW, and OBS five times. The participant was told to walk at a normal, comfortable pace and verbally cued to begin walking by a researcher. In BW, participants were instructed to walk backwards at a constant comfortable speed and were encouraged to keep their eyes up. A research assistant walked slightly behind them, and the participant stopped walking backwards when they felt the assistant touch their low back and say, "Stop". In OBS the participant was told to walk at a comfortable speed and to try not to hit the obstacle in their path. The obstacle was non-threatening: a wooden dowel fixed at 10 cm to simulate curb height. The participant was made aware that, to ensure participant safety, the dowel was placed such that the dowel would fall if contacted lightly. Participants crossed the obstacle in the middle of the walkway with their preferred crossing limb.

2.3 Data Analysis

Gait performance was examined when participants reached a constant speed in the center of the walkway using the middle two strides per walking trial. Measures of FW, OBS, and step width in the mediolateral direction were determined using markers on the heels that were placed on the posterior aspect of the foot, just above the prominence of the calcaneus. Speed and step length during BW in the anterior-posterior direction were calculated using a marker on the toe that was placed on the base of the second metatarsal. Gait speed was quantified as the linear velocity of the heel marker for FW and OBS, and the toe marker in BW. Step length was the horizontal distance between the heel markers in the sagittal plane at the time of heel strike for FW and OBS, and was the distance between the toe markers at toe contact for BW. Step width was the horizontal distance between the heel markers in the frontal plane at the instant of heel strike for FW and OBS, and at toe contact for BW. Gait parameters for left and right steps were averaged across both feet. Gait parameters (gait speed, step length, step width) were then normalized by average leg length; measured as the distance from the anterior superior iliac spine to the medial malleolus via the knee joint.

In OBS, the lead limb is defined as the first limb to cross the obstacle, and the trail limb is the second limb to cross the obstacle (Figure 1). Three OBS foot placement outcomes were calculated as the distance from the obstacle to each foot for the lead and trail limb: 1) approach distance: the distance between the toe marker and obstacle in the step before the obstacle, 2) toe-clearance: the distance between the toe marker and obstacle during the crossing step over the obstacle, and 3) landing distance: the distance between the heel marker and obstacle in the step after the obstacle (Figure 1). Foot placement parameters during OBS were normalized by average leg length.

2.4 Statistical Analysis

Participant characteristics were compared with two-tailed independent t-tests. A 2 (Gender: Men vs Women) × 3 (Task: FW, OBS, BW) mixed MANOVA was conducted to evaluate gender differences in spatiotemporal variables (gait speed, step length, step width). Another MANOVA evaluated differences in OBS foot placement measures (approach distance, toe-clearance, and landing distance). Post-hoc comparisons used Bonferroni corrections for multiple comparisons. Gait parameters that exhibited significant gender effects were first analyzed in a one-tailed bivariate correlation with cognitive and functional assessments. The variables demonstrating significant associations with gait were included into a forward block regression using the stepwise method to determine if gender and clinical assessments can predict adaptive gait parameters. Significance was set a priori at $p < 0.05$.

3 Results

3.1 Gait performance in FW, OBS, and BW

The MANOVA detected a main effect of Gender ($F(3, 50) = 6.43$, $p = 0.001$), Task ($F(6, 47) = 390.00$, $p < 0.001$), and Gender × Task ($F(6, 47) = 3.59$, $p < 0.01$). Follow up univariate tests indicated that speed ($F(2, 104)= 132.23$, $p <0.001$), step length ($F(2, 104) = 342.80$, $p < 0.001$), and step width ($F(2, 104) = 1260.02$, $p < 0.001$) were significantly different between FW, BW, and OBS (Table 2). The Gender × Task interaction remained significant for gait speed ($F(2, 104) = 9.63$, $p = 0.001$) and step length ($F(2, 104) = 5.38$ $p = < 0.01$), but not step width ($F(2, 104) = 1.36$, $p = 0.26$). The interaction supported that gender influences adaptive walking behavior.

Exploring the interaction revealed gait speed was not different between genders in FW ($p = 0.87$), OBS ($p = 0.34$), or BW ($p = 0.99$). Women walked faster in FW than BW and OBS, slowing gait the most during BW (all $p < 0.001$). Men demonstrated similar declines in gait speed in BW and OBS and slowed gait the most in BW (all $p < 0.001$). The analyses revealed no difference in step length between genders in FW ($p = 0.54$), but normalized step lengths were significantly shorter in women compared to men during BW ($p = 0.04$) and

OBS ($p = 0.02$). Women had longer steps in FW compared to BW ($p < 0.001$) but did not change step length in OBS ($p = 0.17$). Men executed longer steps in FW than BW ($p < 0.001$) and longer steps in OBS than FW ($p = 0.02$). No gender differences were found in step width in any condition. Relative to FW, both groups increased their step width in BW and OBS (all $p < 0.001$), with the widest steps in BW. Comparing adaptive walking behaviors between genders showed that women adopt shorter steps to walk backwards and cross obstacles.

3.2 Obstacle crossing foot placement

No obstacle contacts were observed in this study sample. The MANOVA analyses of foot placement failed to detect a significant main effect of gender after controlling for leg length ($F(6, 47) = 2.13$, $p = 0.07$) (Figure 2). However, univariate tests assessing individual metrics showed that, even when accounting for differences in leg length, women showed a significantly shorter approach distance for the lead foot ($F(1, 52) = 5.47$, $p = 0.02$) and a significantly lower toe-clearance for the trail limb ($F(1, 52) = 4.12$, $p = 0.048$). These findings illustrate that women take shorter steps than men in OBS to approach the obstacle more closely, but do not increase toe-clearance to avoid obstacle contact.

3.3 Associations with measures of cognition and physical function

Bivariate correlations revealed associations between several cognitive and functional tests and gait parameters that were identified as being significantly affected by gender: Step length in BW and OBS, lead approach distance, and trail toe clearance. The TUG was significantly associated with lead approach distance ($r = -0.51$, $p = <0.001$) and step length in BW ($r = -0.46$, $p = 0.001$), while OBS ($r = -0.57$, $p = <0.001$) showed a moderate to large association of longer TUG times (worse physical function) with closer obstacle approach and shorter adaptive step lengths. The SPPB was significantly associated with step length in BW ($r = 0.42$, $p = 0.002$) and OBS ($r = 0.32$, $p = <0.02$), revealing that lower scores (worse physical function) on the SPPB were associated with shorter adaptive step lengths. Finally, the Trails A test was weakly associated with OBS step length ($r = -0.24$, $p = 0.04$), revealing that slower visual processing speed was related to shorter steps during OBS.

3.4 Predicting adaptive gait performance with gender, cognition, and physical function

Hierarchical regression analyses included Trails A time, the SPPB, and TUG test with gender group to predict adaptive gait parameters (Table 3). First, a 'Group' predictor was entered into the model represented by Gender where women were coded as 0 and men were coded as 1. Subsequently, a 'Cognition' predictor including the Trails A test was added to reveal unique variance in gait performance from cognitive processes. Finally, a 'Function' predictor block including both the SPPB and TUG test were included into the model to reveal the role of physical function in adaptive gait performance.

The regression model predicting BW step length revealed significant effects of Group ($p = 0.007$) and Function ($p < 0.001$), but the effects of Cognition did not reach significance ($p = 0.056$) (Table 3). Inspecting the variable coefficients showed that shorter BW step lengths are significantly and strongly associated with being a woman (Gender $\beta = 0.446$, $p < 0.001$), moderately associated with worse strength, balance, and gait (SPPB $\beta = 0.269$, $p = 0.046$) and poor overall physical function, represented by the TUG test ($\beta = -0.336$, $p = 0.015$). Only the analysis of BW step length showed that the SPPB explained unique variance aside from the TUG test, suggesting lower limb strength and static balance are important for BW step lengths. The finding supports that women took shorter steps during BW, and individuals with worse physical function took the shortest BW steps.

Regression analysis of OBS step length showed significant effects of Group ($p = 0.006$), Cognition, ($p = 0.015$), and Function ($p < 0.001$) (Table 3). Examining the coefficients for each variable showed that shorter OBS step lengths are significantly and strongly associated with being a woman ($\beta = 0.464$, $p < 0.001$) and longer TUG times ($\beta = -0.519$, $p < 0.001$), but not Trails A time ($\beta = -0.166$, $p = 0.154$), or SPPB score ($\beta = 0.063$, $p = 0.607$). Including Trails A time with Gender improved the model, but variability in OBS step length associated with Trails A time appears to be shared with variance from the SPPB or TUG, and the unique variance from Trails A time and the SPPB seems to be represented by TUG performance. The result suggests that OBS step lengths are not strongly related to basic lower limb strength and balance measured by the SPPB, but may be better explained by clinical tests including more complex locomotor tasks such as the TUG. The results support that women take shorter steps in OBS and those with worse locomotor function, represented by TUG performance, exhibited the shortest steps.

Analysis of lead approach distance showed significant effects of Group ($p = 0.027$), Cognition, ($p = 0.035$), and Function ($p = 0.002$) (Table 3). The variable coefficients showed significant moderate to strong associations between shorter lead approach distances with being a woman (Gender $\beta = 0.385$, $p = 0.003$), and worse TUG performance ($\beta = -0.500$, $p = 0.001$), but not Trails A time ($\beta = -0.161$, $p = 0.219$) or SPPB score ($\beta = -0.027$, $p = 0.847$). Similar to OBS step length, variability in lead approach distance appears to be explained by gender, and TUG performance encompasses any unique variance from the Trails A or SPPB tests. The findings support that women approach the obstacle at shorter distances and individuals with poor locomotor function (i.e. TUG performance) came closer to obstacle.

The analysis of trail toe clearance showed only the model including Group as a predictor was significantly associated with trail toe clearance ($p = 0.048$) and no added predictors improved the model (Table 3). The results confirmed that women exhibit lower trail toe clearances, but variance in this measure of adaptive gait performance was not explained by our measures of cognition or function.

4. Discussion:

The aim of this study was to determine if men and women perform adaptive walking tasks differently. Our hypotheses were partially substantiated by the results. Gait speed was not different between genders in FW when morphology was considered. Contrary to our expectations, gait speed and step width were not statistically different between men and women in BW or OBS. Men increased their step length from FW to OBS. Women maintained their step length from FW to OBS but had shorter steps than men in BW. Further examination of the differences in step length during OBS showed that women approached the obstacle more closely with a lower trail-toe clearance than men. Cumulatively, the results showed that women shorten step length to accomplish adaptive walking, suggesting a conservative walking strategy.[32,33]

Contrary to previous reports,[11] our findings revealed that gait speed and step width were not different between men and women in any walking task. We speculate this discrepancy may be because gait outcomes in previous findings were not normalized to leg length [11] which eliminates gender differences during FW.[17] We only found longer steps in men during BW, whereas previous reports show that men walk faster and take longer steps than women during both FW and BW.[11] Others suggest that older women increase their step length from FW to cross obstacles,[34] but after normalizing by leg length, we found that only men increase their step length and approach the obstacle from a greater distance. Accounting for body size confirmed that despite similar FW patterns, men and women demonstrate differences in step length during adaptive walking.

Women performed both BW and OBS with shorter step lengths than men. A shorter step length suggests that women adapt walking patterns in a manner that promotes recovery from external perturbations.[32] Independent of gait speed, a shorter step length in FW brings the center of mass closer to the lead foot and promotes recovery from a slip.[32,35] A tendency to adopt shorter steps could relate to slower walking speed during BW in those at increased fall-risk,[16] which may be a compensatory strategy to enhance stability.[32,35] Shorter steps in OBS led women to step more closely to the obstacle, but they did not correspondingly increase toe-clearance to ensure obstacle clearance. Shorter steps during OBS increases hip flexion, which is associated with postural destabilization.[1] Shorter approach distance and lower toe-clearances for the trail limb may increase the likelihood of contacting the obstacle with the trail foot.[22,36] Note, the women in our sample were approximately 15 centimeters shorter than the men (Table 1). Safely crossing an obstacle would thus require greater hip flexion and lead to greater destabilization for women. Consequently, smaller stature may exaggerate imbalances during obstacle crossing in women as they navigate a fixed environment in daily life. Compensating for imbalances with a closer approach prevents slipping after the obstacle, but correspondingly increases the trail limb trajectory required for a recovery step and limits fall-prevention if an obstacle is contacted [36] Women may avoid slipping by approaching obstacles more closely, but consequently increase the risk of obstacle contact without adjusting the trail toe trajectory. The findings suggest the conservative adaptive walking patterns in women may relate to increased risk of mobility-disability.[3,33]

Contrary to our hypotheses, our results did not support a relationship between many cognitive processes and adaptive gait performance. However, correlation and regression revealed that the Trails A test of visuospatial processing speed and executive function may be an important factor in adaptive gait, particularly during OBS. Our findings suggest that speed of processing and the ability to shift attention between stimuli plays a role in adaptive walking tasks such as OBS that necessitate unique sensorimotor processes. In OBS, crossing limb control depends on visual and visuospatial feedback in the approach step to remember the characteristics of the obstacle.[37] This result aligns with previous studies showing significant associations between the Trail Making Test and obstacle avoidance [19,25] in older adults. However, this study was not designed to examine the interplay between complex visual processes and adaptive gait and was unable to detect gender differences in performance due to such cognitive processing. Considering evidence of gender influences on the relationship between vision and functional mobility, [7] and limb control during OBS [38] in older adults, our results suggest that aspects of higher-order visual processes could relate to gender differences adaptive performance and warrants further investigation. Future studies should more closely examine gender effects in visual processes involving executive function for adaptive walking.

In this study, associations between adaptive walking performance and clinical measures of physical function did confirm that walking ability improves with better strength and balance. Interestingly, only BW performance was uniquely associated with SPPB, which measures lower-limb strength, static balance, and usual gait. The findings suggest that physiological demands affect BW step lengths and may contribute to the gender differences observed here. However, the SPPB was not uniquely associated to measures of OBS performance, which contradicts studies reporting significant associations between quadriceps strength and obstacle avoidance.[19] After controlling for gender effects and cognitive performance, the TUG showed the strongest unique associations with each measure of adaptive gait performance, highlighting its value in measuring adaptive mobility. Although the TUG measures similar aspects of physical function as the SPPB, the TUG includes a 360° turn. Effectively coordinating turns is more difficult for those with mobility impairments.[39,40] Therefore, the unique turning component of the TUG test may better capture mobility behaviors related to adaptive gait. Our results support previous studies that report worse TUG performance in older women,[12] which may reflect gender differences in adaptive walking behaviors. Previous evidence has shown older women exhibit slower response times to sudden turns,[41] which was attributed to longer deceleration phases to arrest forward velocity.[42] Although the TUG test requires a pre-planned turn, gender differences in sudden turning performance may extend to pre-planned turns and warrant further investigation. Future studies should determine if kinematics during pre-planned turning performance are different between older men and women.

5. Conclusion

Older men and women demonstrate different stepping strategies during adaptive walking. When walking backwards women shorten their steps and seem to over-correct with a closer approach to crossing obstructions in the walkway. Shorter step lengths indicate women may adopt a more conservative walking strategy in adaptive tasks than men. Future research should investigate gender differences in adaptive walking patterns and related physical and cognitive factors to better understand mobility impairments in older adults. Clinicians should consider targeting step length during adaptive gait in older women that may be at risk of mobility impairments.

6. Strengths and Limitations

The strengths of this study add novel information to the literature about gender differences in adaptive walking in older adults. As opposed to many existing aging studies, we included a balanced sample of age-matched older men and women with a relatively large sample size. Our gender groups engaged in similar low-levels of physical activity, and we included several measures of physical function to support that gender differences are prominent in, and specific to, adaptive gait strategies. Additionally, our participants had slower walking speeds than those of a normative healthy community-dwelling older adult sample,[17] but did not yet utilize assistive walking devices, improving generalizability of our results to the older population.

Several limitations should be considered when interpreting the findings from this study. One limitation is that we did not assess fall history and are unable to definitively classify participants as fallers and non-fallers. We used self-report to verify visual function and did not measure levels of visual acuity or contrast sensitivity, thus we could not adjust our measures for a potential range of visual function. However, all participants performed the experiment with the same lighting conditions and walkway characteristics to keep visual input constant. Both groups engaged in similar levels of physical activity and exhibited similar levels of physical function, but we did not include muscle-specific measures of strength that could have affected our results.[19] Additionally, we administered the chair stand portion of the SPPB before the balance component, which could have worsened balance performance during the SPPB. Another limitation is that the walking conditions were performed in a fixed order that may have affected behavior or anxiety levels by gradually increasing task difficulty. Although fear of falling is related to poor adaptive gait in older adults,[19,43,44] we did not measure dispositional characteristics in our participants. However, the participants were aware that the obstacle was non-threatening and would not have caused a trip if contacted. Future studies of adaptive walking should include additional contextual variables that could capture gender differences. Our ability to generalize the findings to more impaired older adults is limited because we excluded older adults that used a walking aid. Generalizability may also be limited because our tests took place in a laboratory and the participants may have performed differently because they were being observed or in an effort to impress younger research assistants.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements:

We would like to thank the undergraduate volunteers in the Applied Neuromechanics Laboratory and the Language Over the Lifespan Laboratory for their assistance. Additionally, we thank LB Hannahs for sharing their expertise regarding gender terminology. Importantly, we thank the participants that contributed to this project for their time and effort. Finally, we thank the reviewers for their helpful feedback.

Funding sources:

This work was supported by the National Institute of Health (1 R21 AG048133–01A1), National Institute of Aging (NIH-NIA T32: AG-020499), and the University of Florida.

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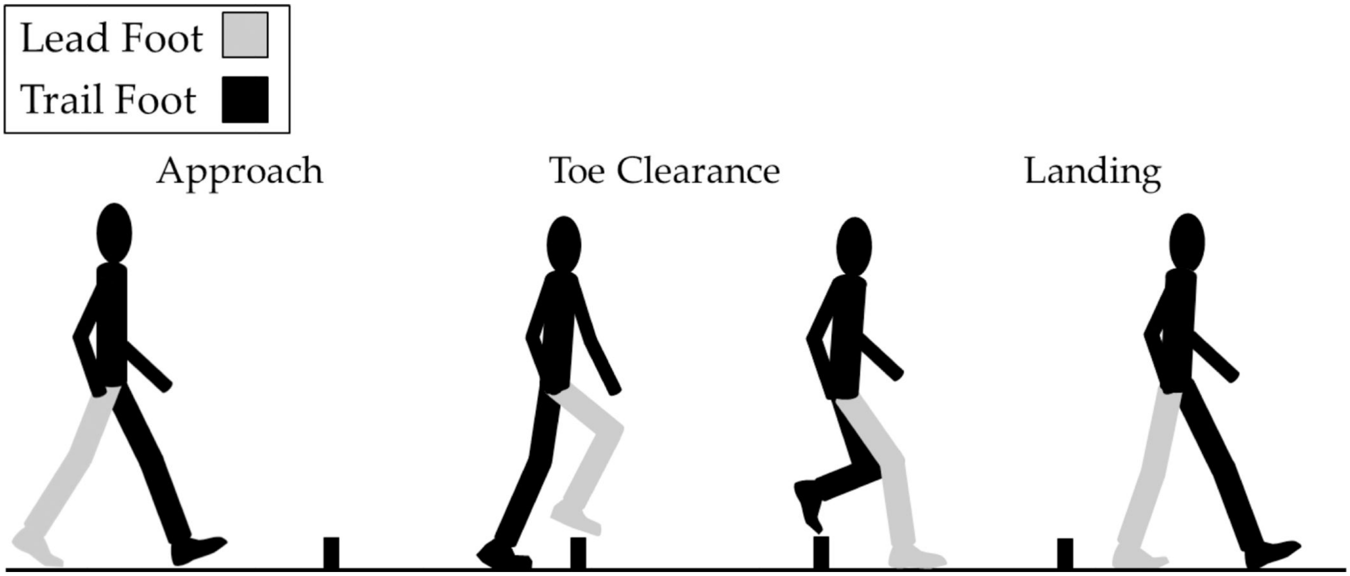

Figure 1.
Depiction of lead and trail foot placement outcomes for obstacle crossing (OBS) conditions. The lead foot is the first to cross the obstacle, represented in grey. The trail foot is the second limb to cross the obstacle, represented in black. The foot placement outcomes for obstacle crossing were based on distance from the obstacle and defined as lead foot approach and trail foot approach, lead toe clearance and trail toe clearance, and lead foot landing and trail foot landing.

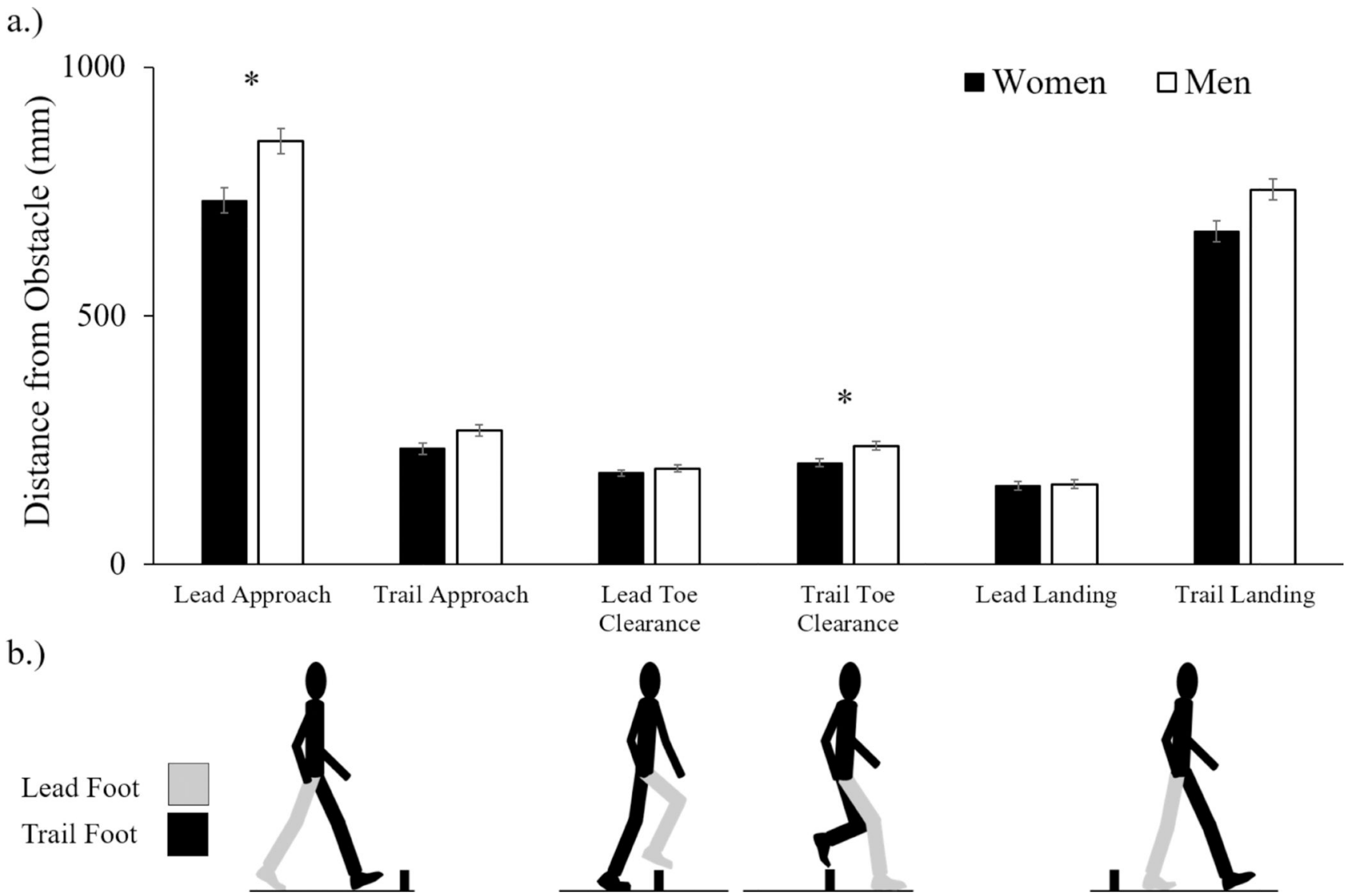

Figure 2.

Women step closer to obstacles than men. 2a) Obstacle crossing foot placement results for men and women showing women approached the obstacle more closely. Presented as non-normalized mean values for distance from obstacle (mm) and standard error. See supplemental data for corrections by leg length. 2b) Icons represent step outcomes: approach distance for lead and trail foot, crossing toe-clearance for lead and trail foot, and landing distance for lead and trail foot; lead foot=grey, trail foot=black. Asterisk indicates significant group differences $p < 0.05$.

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Table 1.

Demographics, Cognitive, and Physical Function Test Scores for Men and Women, Mean (SD)

	Women	**Men**
Sample size	27	27
Age (years)	72.0 (5.0)	72.0 (5.0)
CHAMPS (h/wk)	0.4 (0.7)	0.4 (0.7)
MoCA	25.0 (2.8)	24.5 (3.3)
Trails A (s)	103.1 (23.2)	115.9 (35.3)
Trails B (s)	150.3 (79.1)	157.8 (65.9)
dTMT (s)	47.2 (68.1)	41.9 (46.7)
TUG (s)	10.0 (2.3)	10.3 (2.5)
Stroop Congruent	62.8 (11.5)	60.2 (16.1)
Stroop Incongruent	36.5 (9.7)	33.9 (10.4)
SPPB	9.2 (1.8)	9.1 (1.6)
Body Mass (kg) *	77.9 (17.1)	95.1 (18.8)
Height (m) *	1.6 (0.1)	1.8 (0.1)

(*) Note: Asterisk represents significant differences between genders (p <0.001). CHAMPS: Community Healthy Activities Model Program for Seniors, presented as hours of activity per week (h/wk). MoCA: Montreal Cognitive Assessment, dTMT: delta TMT (Trails A-Trails B), TUG: Timed-Up-and-Go, SPPB: Short Physical Performance Battery, (s) = seconds, (kg) = kilograms, (m) = meters.

Table 2.

Gait Speed, Step Length, and Step Width during SS, OBS, and BW for Men and Women

	FW		OBS		BW	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**
Speed (m/s)	1.10 (0.04)	1.16 (0.04)	1.01 (0.04)	1.01 (0.04)	0.85 (0.05)	0.72 (0.05)
Step L (m)	0.61 (0.02)	0.60 (0.02)	0.63 (0.02)	0.58 (0.02) *	0.45 (0.02)	0.39 (0.02) *
Step Width (m)	0.07 (0.01)	0.07 (0.01)	0.12 (0.01)	0.11 (0.01)	0.16 (0.01)	0.15 (0.01)

(*) Note. Results presented as mean (standard error), normalized by leg length. Asterisk represents group level differences. FW= Forward Walking, OBS = Obstacle Crossing, BW= Backwards Walking, Step L= Step Length, Step W = Step Width.

Table 3.

Hierarchical Regression Models Predicting Gait Outcomes

Model	Variable	R^2 Change	Model *p*-value	Standardized β
BW Step Length				
Predictor 1: Group	Gender	0.152	0.007 *	0.446 *
Predictor 2: Cognition	Trails A	0.070	0.056	−0.098
Predictor 3: Function	SPPB + TUG	0.239	< 0.001 *	0.269 * −0.336 *
OBS Step Length				
Predictor 1: Group	Gender	0.158	0.006 *	0.464 *
Predictor 2: Cognition	Trails A	0.070	0.015 *	−0.166
Predictor 3: Function	SPPB + TUG	0.239	< 0.001 *	0.063 −0.519 *
Lead Approach Distance				
Predictor 1: Group	Gender	0.106	0.027 *	0.385 *
Predictor 2: Cognition	Trails A	0.088	0.035 *	−0.161
Predictor 3: Function	SPPB + TUG	0.219	0.002 *	−0.027 −0.500 *
Trail Toe Clearance				
Predictor 1: Group	Gender	0.086	0.048 *	0.302 *
Predictor 2: Cognition	Trails A	0.003	0.706	−0.096
Predictor 3: Function	SPPB + TUG	0.028	0.525	−0.185 −0.033

(*) Note: Asterisk represents significant effects $p < 0.05$