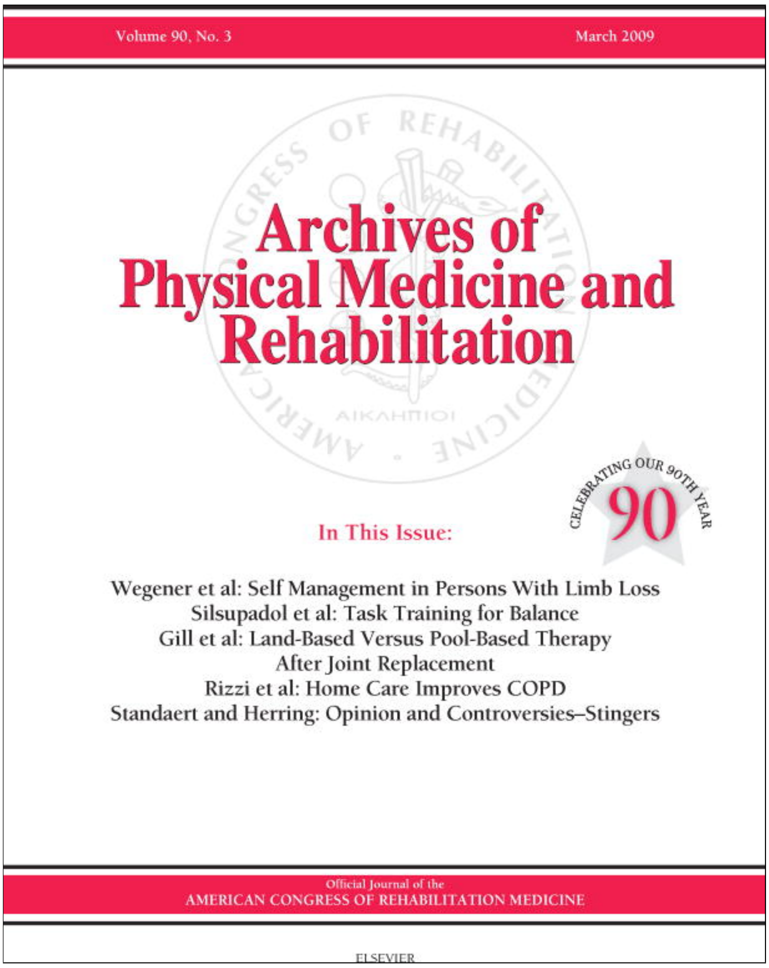
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ORIGINAL ARTICLE

Validity of a Functional Dynamic Walking Test for the Elderly

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ABSTRACT. Lark SD, Pasupuleti S. Validity of a functional dynamic walking test for the elderly. Arch Phys Med Rehabil 2009;90:470-4.

Objective: To determine the validity of a safe, quick, and simple method of measuring dynamic balance in the elderly during gait called the parallel walk test.

Design: Control study.

Setting: Outpatient clinic, community.

Participants: Twenty-seven elderly fallers (age 82±6y) registered at a falls clinic and 34 elderly nonfallers (age 76±7y) were recruited to this study based on Mini Mental State Examination and Barthel Index scores.

Interventions: Subjects were timed as they walked 6m between 2 parallel lines on the floor at 3 different widths (20, 30.5, 38cm) in their own footwear. They were scored for foot placement on the line (1 point) or outside the lines (2 points). Participants also performed a timed 6-m tandem walk test, a 30-second tandem stance, and a 30-second parallel stance.

Main Outcome Measures: Scores and time to complete the parallel walk test and tandem walk test along with the time of standing for tandem and parallel stance. Validity coefficients were calculated for the sensitivity and specificity of the parallel walk test.

Results: All subjects completed the parallel walk test, but few attempted and completed the tandem walk test. The fallers had significantly greater scores at 20 and 30.5cm and took significantly longer to complete the 6m at all widths. The 20-cm width was most discriminatory. The parallel walk test showed a significant correlation with the tandem stance.

Conclusions: All subjects attempted and completed the parallel walk test but not the tandem walk test. The time to completion and scoring accurately measures dynamic balance during gait in elderly fallers. The parallel walk test could be a useful tool in the clinical setting for assessing balance in gait pre- and postintervention.

Key Words: Balance; Elderly; Gait; Rehabilitation; Validity.

IN ASSESSING BALANCE during gait in elderly fallers, it became obvious that existing dynamic balance tests were either too time-consuming and/or did not specifically provide a quantitative measure of balance during gait to allow direct comparisons after an intervention.

Existing dynamic balance tests are primarily used as a discriminatory tool to determine a person at high risk of falling from those at low risk. These include several widely used dynamic balance tests such as the TUG test,[1] the Dynamic Gait Index[2] along with the modified version Functional Gait Assessment,[3] the Performance-Oriented Mobility Assessment,[4] and the Tinetti Balance Performance measure.[5]

The popular TUG test rates subjects on the time taken to complete the test, with those who take longer being classified as being at greater risk of falling.[6] Although this provides temporal data for comparative purposes, there is no objective description of the individual's balance throughout the movement. Other assessments that use a scoring method do attempt to address this. These include the Performance-Oriented Mobility Assessment and Tinetti Balance Performance, which are well documented as showing a high degree of discrimination between fallers and nonfallers[4,5,7-9] and being more responsive to changes in activities of daily living than the TUG test.[10] However, the Tinetti Balance Performance is a series of 13 different static and balance perturbation tests, with a further 9 components of gait that are graded on a subjective scale (0–2 for balance, and 0–1 for gait) that is descriptively classified.[5,7] Similarly, the Dynamic Gait Index depends on 8 different tests of gait,[2] and the Functional Gait Assessment depends on 10.[3] They all proved to be time-consuming in a clinical setting and were dependent on the cognitive ability and mobility of the patients. However, these longer-duration assessments do begin to address the etiology of the balance deficit so that appropriate interventions can be implemented.

A quick dynamic balance test that has been suggested for the clinical setting is the tandem walk test, yet studies using this test include only mild mobility-impaired subjects,[11,12] whereas fallers can be quite frail and suffer from postfall syndrome, which affects their confidence for such challenges. Potential subjects who use walking aids have been excluded,[11] and there is no alternative if the subject cannot start or complete the test so his/her result is recorded as a fail and they are simply categorized as being at a high risk of falling. This further highlights the need for a dynamic balance test of gait that even frail elderly and those suffering postfall syndrome can perform.

The following question remains: what parameter of gait can be easily measured that constitutes dynamic balance? Maki[11] found that stride-to-stride variability was important, whereas speed and other temporal measures were not. The variability from stride to stride can mean width as well as length. Indeed, an increased step width has previously been reported as an age-related phenomenon,[13-15] and, moreover, Moe-Nilssen and Helbostad[16] also found a significant difference in step width between the frail and fit elderly. Other studies[17-20] suggested that fallers have difficulty in controlling lateral stability, and,

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List of Abbreviations

SEM	standard error of the mean
TUG	Timed Up & Go

consequently, they adopt a wider stride for balance or often step laterally to recover balance. The greater step width has the obvious advantage of increasing the base of support to enhance stability. Furthermore, active lateral control within dynamic movements was found to be an important factor for stability.[21] Therefore, the measure of lateral movements during normal walking was thought to be an ideal indicator of dynamic balance.

The parallel walk test was devised to measure the lateral movement during gait. Important criteria for the test were ease of implementation and the provision of quantitative data for future comparison of consecutive assessments for individuals receiving an intervention. Therefore, the aim of this study was to examine the validity of the parallel walk test to estimate dynamic balance of a subject's own natural gait based on times achieved and a simple scoring method that took account of lateral movements. As a secondary aim, the study determined if the parallel walk test has sufficient sensitivity to discriminate the gait between elderly who have fallen and those who have not, which may then be used as a screening tool in a clinical setting.

METHODS

Subjects

Two groups of independently living elderly men and women were recruited for this study, which had been approved by the local National Health Service Ethics Committee. Twenty-seven elderly fallers (82±6y) who had suffered a recent fall and were referred to an outpatient falls clinic and 34 (76.2±7y) elderly with no history of falls (nonfallers) consented to take part. All subjects were mobile with or without the aid of a walking stick. Recruitment criteria were a score of greater than or equal to 23 on the Mini Mental State Examination[22] for mental cognitive ability and a score greater than 10 for the Barthel Index,[23] which assesses the performance of activities of daily living. Subjects were excluded if they had serious pathologies that may be exacerbated on exertion or may be deemed to make the participant unsafe. These included unstable cardiovascular disease (severe hypertension, unstable angina), stroke, severe breathing problems, Parkinson disease, diabetic peripheral neuropathy, or rheumatism/arthritis of the lower limbs that was painful on the day of examination.

Measurements

Two static balance tests and 2 walking dynamic stability tests were performed. The static balance tests have been prevalidated and were composed of the tandem stance and parallel stance.[24] The tandem stance consisted of standing with the heel of 1 foot placed in front touching the toes of the foot behind for a maximum of 30 seconds. For the parallel stance, participants were asked to stand with their feet 20cm apart for 30 seconds. In both tests, the time was recorded for their ability to maintain the stances.

Time was recorded for the tandem walk test, which required participants to place the foot heel to toe for 6m. Scoring of the test was based on the number of mistakes, which included staggering and misplacement of the foot. Scores were only considered for those who completed the test. Each mistake carried a score of 1; therefore, the larger the score the worse the participant did. It was noted if any participant did not perform the test or how many meters they covered if they did not complete the test.

For the parallel walk test, participants walked between 2 parallel lines using their normal gait and speed for 6m. The test was performed with 3 different randomized widths: 20cm, 30.5cm, 38cm (8, 12, and 15in). The scoring was based on +1 for foot placement on the line and +2 outside the line or grasping something to maintain balance (eg, wall or railing). A larger score denoted a worse performance. The time taken to complete the test was also recorded for comparison and to calculate velocity.

Each subject performed the tests in random order. Participants wore their own footwear, and they were allowed to use their walking stick if required. In each case, the subjects were asked to look directly ahead and not at their foot placement.

Statistical Analysis

An independent *t* test was used to compare means for the tandem stance and parallel stance static balance tests, with significance recorded at $P<.05$. Repeated-measures analysis of variance was used to determine statistical significance of the mean scores and completion time between the 2 groups for the 3 widths of the parallel walk test. Discrimination of the parallel walk test was evaluated by using an independent *t* test, effect size (Cohen's *d*),[25] and validity coefficients (ie, the percentage correctly classified as fallers). The tandem stance static balance test was correlated with the parallel walk test by using Spearman correlation. All data are presented as mean with SEM.

RESULTS

The fallers were on average slightly older than the nonfallers; however, the 2 groups of subjects were well matched for mass and Mini Mental State Examination scores (table 1). The activities of daily living scores from the Barthel Index were significantly different, but both groups were above the cutoff for independent living. The nonfallers had more people with mild heart disease and breathing difficulties, but in all cases (fallers and nonfallers) these were not severe conditions that exacerbated with exercise to cause exclusion from the trial.

All participants from both groups were able to perform the parallel stance test and were able to stand for 30 seconds (table 2). Only 7 subjects from the nonfallers group and 1 subject from the faller group maintained the tandem stance for the maximum 30 seconds (see table 2). Overall, the nonfallers maintained the tandem stance over 3 times longer compared with the fallers ($P<.05$).

For the tandem walk test, 16 nonfallers and 19 fallers did not attempt the test (see table 2). Fifteen nonfallers completed the test, whereas 3 managed to tandem walk only up to 4m. No faller subjects completed the test, but the 8 who attempted managed to complete between 1 and 6 steps only. All subjects completed the parallel walk test. Because of the high number of subjects unable to start or complete the tandem walk test, it was

Table 1: Subject Characteristics

Characteristics	Fallers (n=27)	Nonfallers (n=34)
Age mean (SEM)	82.1 (1.2)*	76.2 (1.3)
Mass (kg)	71.6 (2.2)	70.4 (1.5)
Barthel Index	17.9 (2.1)*	19.4 (0.4)
Mini Mental State Examination	27.6 (1.8)	27.2 (0.8)
Heart diseases (%)	22.6	26.5
Breathing difficulties (%)	18.5	20.6
Numbness (%)	0	0
Rheumatism/arthritis in lower limbs (%)	29.6	23.5

NOTE. Group mean (SEM) health and anthropometric measures.
*Significant difference between groups ($P<.05$).

Table 2: Timed Static Balance and Tandem Walk Test Scores

Test Scores/Time	Fallers (n=27)	Nonfallers (n=34)
Tandem stance (s)	3.6 (1.2)*	11.7 (1.8)
Parallel stance (s)	30.0 (0)	30.0 (0)
Tandem walk test (score)	NA	7.9 (1.7) n=15
DNP	n=19	n=16
0–2m	n=8	n=0
2–4m	n=0	n=1
4–6m	n=0	n=2

NOTE. Group mean (SEM) for tandem stance and parallel stance shown in seconds.
Abbreviations: NA, not available; DNP, did not perform.
*A significant difference ($P<.05$) between elderly groups.

not possible to perform any comparative statistical analysis between the groups for this test. However, the tandem stance mean time and the scores for the parallel walk test were significantly ($P<.001$) correlated for all widths. The correlation values ranged from r equals 0.28 at 38cm to 0.49 at 20cm.

A repeated-measures analysis of variance showed a significant main effect for both balance score and score by group. Further comparison of the parallel walk test scores between the 2 groups showed a significant difference ($P<.05$) for 2 of the 3 widths (20 and 30.5cm) but not for 38cm (fig 1). Analysis performed on the nonfallers for differences between the 3 widths showed that 20cm was significantly different from both 30.5 and 38cm, but scores at 30.5cm were not statistically different from 38cm (see fig 1). Calculated effect sizes were very large (1.27) at 20cm, moderate (0.98) at 30.5cm, and small (0.38) at 38cm for the group differences.

The fallers took significantly longer to complete the parallel walk test at each width (fig 2) compared with the nonfallers, which is supported by the slower velocities calculated at all 3 widths calculated. Furthermore, the fallers took increasingly longer with the narrower widths, whereas the nonfallers completed the test in ~10 seconds for each width (see fig 2). The effect sizes for the group differences were all very large ranging from 1.52 to 1.94. Validity coefficients were generally higher for time (.82–.87) than balance score (.70–.84).

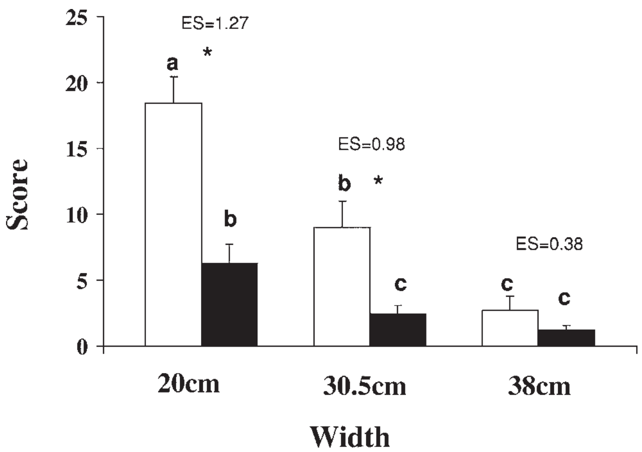

Fig 1. Group mean (SEM) for balance scores of the faller (unblocked) and nonfaller groups (blocked). Cohen's *d* effect sizes (ES) are shown for comparisons between groups. A significant difference ($P<.05$) between faller and nonfaller groups is denoted by *, whereas a, b, and c show significant differences where the letters are different and no differences when they are the same.

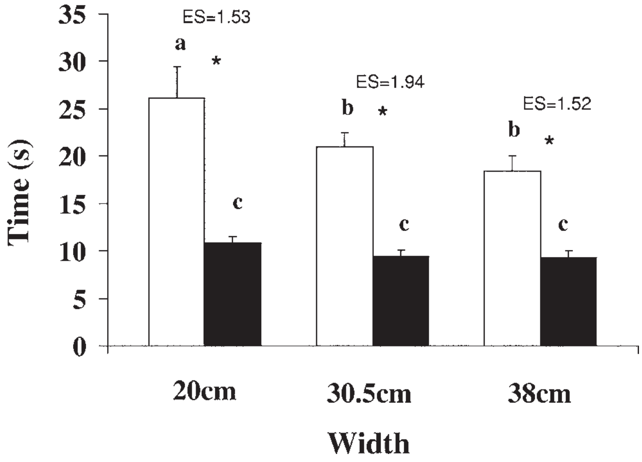

Fig 2. Group means (SEM) for the time taken to walk 6m between different widths for fallers (unblocked) and nonfallers (blocked). Cohen's *d* effect sizes (ES) are shown for comparisons between groups. A significant difference ($P<.05$) between faller and nonfaller groups is denoted by.* The letters a, b, and c denote significant differences where the letters are different; where the letters are the same, there were no differences.

DISCUSSION

The parallel walk test can distinguish a lack of dynamic balance during gait. The elderly fallers had significantly worse walking dynamic balance in the parallel walk test compared with the group who had not fallen, particularly at the narrow widths. Furthermore, the fallers took progressively longer with the narrower widths to complete the test, whereas the nonfallers completed all 3 widths in similar times.

The scoring method used in the parallel walk test provided the quantitative data that described the level of dynamic balance during gait but not the etiology of the balance disorder. To determine if the parallel walk test scoring could distinguish those with poor dynamic balance, it was tested with both elderly patients who had suffered a fall(s) and those who had not, although the objective was not to develop a discriminatory tool. A higher score signified greater lateral stepping, a wider stance for stability, and/or possible bias to one side causing the individual to step outside the parallel lines. The fallers exhibited significantly more lateral stepping at the narrower widths of 20 and 30.5cm compared with the nonfallers (see fig 1). The largest difference between group scores was reported at the narrowest width of 20cm, which had a very large effect size of 1.27 (see fig 1). The 38-cm width was not sensitive enough to distinguish between the 2 groups and had a small effect size of 0.38. The significant lateral movement of the fallers determined by the balance scores compares with a greater step width and medial-lateral acceleration in the frail elderly reported by Moe-Nilssen and Helbostad.[16]

Several factors were considered that could affect the balance scores other than compromised balance. These included cognitive ability because reduced cognition has been linked to declining gait speed.[26] However, in this study, both elderly groups had similar Mini Mental State Examination scores and the cutoff was above the widely accepted value of diminished cognitive ability. It is also reasonable to assume body mass would affect lateral movement because control of the trunk roll motion as the body's center of mass shifts from the left to right foot is important for coordination.[27] However, the body mass of both groups in this study was similar (see table 1).

The time to complete the 6-m test for both groups reinforces the balance differences. The fallers completed the test in significantly greater times (26, 21, and 18s for the 20-, 30.5-, and 38-cm widths, respectively) all with very large effect sizes compared with approximately 10 seconds at each width for the nonfallers (see fig 2). This result is comparable to Krebs et al[28] who found a slower gait in the preferred walking speed of those with unsteady gait.

It was not known in advance which width would be best at capturing the lack of balance in those with unsteady gait without capturing large numbers of those with adequate balance. Therefore, 3 different widths were chosen (20cm [8in], 30.5cm [12in], and 38cm [15in]) and were based on average width with feet together, average width with feet slightly apart, and a midpoint. Analysis of how each separate group behaved with the range of widths showed fallers had progressive and significantly higher scores the narrower the width (see fig 1). In contrast, the score of the nonfallers at the 20-cm width was significantly higher compared with both 30.5cm and 38cm, but the scores of the wider widths are not significantly different from each other. The parallel walk test at 20cm appears to have the greatest difference between fallers and nonfallers but also captures a significantly greater number of nonfallers. However, at 30.5cm, the parallel walk test identifies significantly less fallers, which is much less desirable. Validity coefficients (percent correctly classified as fallers) were 0.70 to .84 (0.75 at 20cm with a score cutoff point of 12) and higher for time 0.82 to 0.87. It would appear that the optimum width may lie between 20cm and 30cm, and further study is needed to determine this. However, if the decision of width was based on time and scores alone, then the narrower width of 20cm was best for capturing poor dynamic balance and distinguishing between fallers and nonfallers.

Initially, the authors set out to compare the parallel walk test with the existing dynamic gait stability test (ie, the tandem walk test) because both systems use scoring and time as a measure of dynamic balance. It was expected that some of the fallers and all of the nonfallers would be able to complete the tandem walk test to allow initial comparisons. However, many of the fallers (n=19) and nonfallers (n=16) did not feel confident enough to even attempt the tandem walk test. Furthermore, only 15 nonfallers (44%) completed the tandem walk test so comparison was not possible even for the nonfallers (see table 2). The tandem walk test imposes such an unnatural gait that even the well-balanced elderly individual felt inherently unstable. In contrast, all subjects attempted and completed the parallel walk test.

The tandem walk test does not take into account a lack of confidence being the cause for the lack of attempts.[11,12] However, it has been previously reported that subjects fearful of falling have a slower stride and greater stride width,[29] which would be discernible with the parallel walk test. Many of the subjects in this study lacked the confidence to even attempt the tandem walk test so their dynamic balance ability remained unknown, and no conclusions could be drawn. There are further psychologic consequences in failing to undertake or complete such a test (ie, the patient may feel they have failed), which could further decrease an already low confidence level in the short and possibly long-term. A questionnaire of each subject's confidence about his/her ability to perform both the tandem walk test and the parallel walk test would have been advantageous here. The concept of the parallel walk test allowing subjects to walk in their normal gait did not appear to induce a sense of failure, and subjects frequently asked if they "did ok."

It was thought that existing static balance tests might mirror those of the tandem walk test and parallel walk test and help provide further understanding of a person's ability in upright balance. Static balance was measured by using the tandem stance and parallel stance tests. The results of the tandem stance showed that nonfallers stood more than 3 times longer compared with fallers (see table 2). Furthermore, the tandem stance correlated significantly to the dynamic balance parallel walk test scores. This suggests that the tandem stance test and the parallel walk test could be used in conjunction with one another to assess the 2 elements of balance (static and dynamic) simply and effectively. The multitask assessments such as the Tinnetti Balance Performance, Dynamic Gait Index, Functional Gait Assessment, and the Performance-Oriented Mobility Assessment also contain elements of static balance with the advantage of perturbations and/or unstable surfaces.

Study Limitations

No comparison was made with the TUG test, which is also quick and easy to administer, with quantitative data. It is used successfully as a discriminative tool for the risk of falls.[1] However, as a simple tool to estimate walking ability, it is limited to temporal measurements only. The original TUG test did attempt to describe dynamic balance, but it was only moderately reliable between testers[1] because it was open to subjective interpretation within a 5-point scale of normal to abnormal responses. Perhaps further research comparing or correlating the TUG test and parallel walk test is warranted because the TUG test is a very popular test performed in falls clinics.

The walking speed was not controlled, and specific gait parameters such as stride length and cadence were not measured. Some may criticize that you cannot measure dynamic balance without recording gait parameters such as stride length; however, it is known that the elderly do not walk faster by increasing stride length but increase their cadence instead. In a study in which the frail elderly increased their cadence to achieve a regulated speed of 0.9m/s, they still had significantly greater step widths than the fit elderly.[16] The walking velocities achieved in this study ranged from 0.29 m/s at 20cm to 0.4m/s 38cm for the fallers and twice that for the nonfallers (ie, 0.65 m/s at 20 cm to 0.78 m/s at 38 cm). Although the velocities were 2 times faster in the nonfallers, the parallel walk test was sensitive enough to identify poor balance of some nonfallers even when walking at preferred gait speeds. Therefore, it was considered that the parallel walk test measurement of lateral movement was more indicative of gait dynamic balance and relatively independent of walking speed.

It has been suggested that the performance of timed tests is dependent on footwear and floor surfaces. Notably, those in walking shoes achieved faster walking speeds than bare feet or dress shoes in women.[30] However, the parallel walk test was performed at the participant's normal gait to measure lateral movements independent of speed. Furthermore, it was decided to let participants wear their own footwear because Grabiner et al[15] found that stride width was not influenced by the wearing of shoes. Although there was no strict uniformity of footwear in this study, nearly all participants in both groups wore low-heeled shoes. Furthermore, all patients from the falls clinic had been instructed on the safety of flat rubber-soled walking shoes versus dress shoes by the clinic.

A prospective trial was not performed as such a large number of subjects would have been required because the number of falls were low. Although risk could be assessed, it is not always possible to know when a person may fall or when his/her confidence in mobility would be affected. A comparative study between elderly participants with known balance problems versus those who do not have obvious problems was considered adequate to show the validity of the parallel walk test. It is the intention to do a more longitudinal study to show how the parallel walk test score changes with intervention or over time with no intervention.

One of the main differences between the fallers and nonfallers was perhaps psychological. As mentioned previously, confidence and postfall syndrome can inhibit the performance in some tests; however, all subjects managed to attempt and complete the parallel walk test.

CONCLUSIONS

In conclusion, the parallel walk test can identify a lack of dynamic balance. It was specifically developed to take into account lateral movements for stability during walking based on the suggestion that the elderly often step laterally to recover balance and need a wider base of support. The parallel walk test is performed at the participant's own speed, which is a truer reflection of balance during walking even when using walking aids. The test was attempted and completed by all participants so there were no issues of postfall syndrome or other fear factors compared with the tandem walk test. The narrower widths of 20cm and 30.5cm were most significant in discriminating people who had balance problems, and time is a further discriminate measure because all nonfallers achieved a time of ~10 seconds regardless of width. Above all, the parallel walk test was quick and simple to conduct and provided quantitative data, which has advantages for use in a clinical setting for the comparison of consecutive assessments before and after an intervention.

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