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ORIGINAL ARTICLE

The reliability and validity of the 3-m backward walk test in people with Parkinson's disease

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Abstract

Background People with Parkinson's disease (PwPD) lose the ability in backward walking which is an important part of mobility in daily life. The 3-m backward walk test (3MBWT) evaluates backward walking; however, its reliability and validity have not been examined in PwPD yet.

Aims To examine (1) the test–retest reliability of the 3MBWT in PwPD; (2) the minimum detectable change in the 3MBWT times; (3) the concurrent and known-groups validity of the 3MBWT; and (4) the optimum cutoff time which best discriminates fallers from non-fallers with Parkinson's disease (PD).

Methods This cross-sectional study included 36 PwPD and 33 healthy people. The 3MBWT was conducted with the 10-m walk test, timed up and go test, Berg Balance Scale, four square step test, activity-specific balance confidence scale, Movement Disorders Society Sponsored Unified Parkinson's Disease Rating Scale, and Hoehn and Yahr Scale.

Results The 3MBWT demonstrated excellent test–retest reliability (ICC = 0.965). The MDC of 2.13 s was determined. The 3MBWT had moderate to high correlations with the other outcome measures (correlation coefficient ranged from −0.592 to 0.858). On the 3MBWT times, there were significant differences between PwPD and healthy people, and between fallers and non-fallers with PD ($p < 0.001$ and $p < 0.001$, respectively). A 3MBWT time of 10.31 s was found to best discriminate fallers from non-fallers with PD.

Conclusions The 3MBWT is a reliable, valid, and easy to administer outcome measure to assess backward walking performance in PwPD, indicating it to be used in practice and research.

Keywords Outcome measures · Parkinson's disease · Rehabilitation · Reliability · Three-meter backward walk test · Validity

Introduction

Balance and gait impairments are particularly debilitating symptoms because they predispose people with Parkinson's disease (PwPD) to fall [1]. Between 35 and 90% of PwPD have experienced at least one fall per year and two-thirds of them are recurrent fallers [2]. The consequences of falls are devastating and lead to injuries, fractures, fear of falling, functional limitations, increased risk of home admission [3], hospitalization [4], increased

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caregiver burden [5], and health care costs [6]. The risk of falling increases for PwPD during transitional activities that require moving backward such as turning and stepping backwards to rise from chair or bed [7]. The use of backward walking, thus, has been proposed as a clinical measure in mobility and fall risk for PwPD [8].

Backward walking is similar to a simple time-reversed counterpart of forward walking [9, 10]. It also has the same rhythm circuitry of forward walking; however, backward walking requires specialized control circuits [11]. Individuals, even those with PD, may need backward walking in daily living activities such as opening the door and stepping back from a pavement while a rapidly moving bus passes [8, 12]. PwPD usually lose balance and fall as a consequence of moving in the backward direction during backward walking [13, 14]. Compared to healthy people, PwPD have worse performance in backward walking [8, 15]. Moreover, motor differences between PwPD and healthy people are greater during backward walking compared to forward walking [8]. The specific measurement tool in the assessment of backward walking, therefore, is of great importance in PD.

The 3-m backward walk test (3MBWT) was originally developed to assess backward walking and fall history. It is a standardized and timed test in which the individual is instructed to walk backward for 3 m [12]. Excellent test–retest reliability of the 3MBWT has been reported in stroke [16], community-dwelling older adults [17], and multiple sclerosis (MS) [18] (intraclass correlation coefficient (ICC) = 0.974, ICC = 0.940, and ICC = 0.854–0.889). The 3MBWT is correlated with functional mobility and balance in stroke [16] and MS [18]. For PwPD, fallers take a significantly longer duration to complete the 3MBWT than non-fallers, and the 3MBWT of 4.2 s has the highest overall accuracy to predict falls compared to other clinical outcome measures such as timed up and go test (TUG), 10-m walk test (10MWT), and 5 times sit-to-stand test [19]. However, the reliability and validity of the 3MBWT have not been comprehensively investigated for PD yet.

The aims of this study were therefore to examine (1) the test–retest reliability of the 3MBWT in PwPD; (2) the minimum detectable change (MDC) in the 3MBWT times; (3) the concurrent and known-groups validity of the 3MBWT; and (4) the optimum cutoff time which best discriminates fallers from non-fallers with PD.

Materials and methods

Study design

This cross-sectional study was carried out at Gazi University, Department of Neurology, between April and May 2022. The study was approved by the Gazi University Clinical Research Ethics Committee and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the study.

Participants

No study has investigated the reliability of the 3MBWT for PwPD. The sample size calculation, therefore, was based on previous studies that reported excellent test–retest reliability of the 3MBWT in other neurologic populations such as stroke [16] and MS [18] (ICC = 0.974 and ICC = 0.854–0.889, respectively). Assuming that ICC value for PwPD was about 0.90, a sample size of 30 would be required to obtain 90% power to detect an ICC of 0.90 with a confidence level of 0.05.

PwPD, who were diagnosed with idiopathic PD according to the UK Brain Bank-Criteria [20] by a neurologist specialized in movement disorders, were recruited. Inclusion criteria were 40 years or older age, and a score of 1 to 3 on the Hoehn and Yahr (H&Y) scale [21]. Exclusion criteria were neurologic disorders other than PD and any other problems that affect balance and gait. A group of age- and gender-matched healthy people, who met the same exclusion criteria, was recruited as a control group.

Procedures

Demographics and disease-specific variables were collected for each individual with PD. Fall history and freezing of gait were also recorded by self-report. Fall history was determined based on the response to this question: "Did you fall during the past year?" A fall was defined as an unexpected event in which the individual comes to rest on the ground, floor or lower level [22]. PwPD were classified as fallers if they reported one or more falls. Information about the freezing of gait is obtained via the freezing of gait questionnaire item 3: Do you feel that your feet get glued to the floor while walking, making a turn, or when trying to initiate walking? [23]. PwPD, who experienced freezing "about once a week" or more corresponding the score ≥ 2, were described as freezers [23]. For the test–retest reliability of the 3MBWT, PwPD were measured twice in two different sessions at the same time of the day, 7–10 days apart. All PwPD were also evaluated with the 10MWT, TUG, Berg Balance Scale (BBS), four square step test (FSST), activity-specific balance confidence scale (ABC), Movement Disorders Society Sponsored Unified Parkinson's Disease Rating Scale (MDS-UPDRS), and H&Y scale in session 1. A rest period of 2 min between tests and trials was given in order to avoid fatigue. All PwPD were tested in the ON state by the same physiotherapist. Additionally, demographics of healthy people were collected, and then, the 3MBWT with all 3 times was performed in one assessment session.

Outcome measures

The 3MBWT is a performance-based tool developed to evaluate backward walking. The 3-m course was determined and marked with black tape on the tile or wood surface. The test was started by asking participants to stand straight facing backward and to position their heels at the baseline level of the black tape. The examiner instructed the participants to walk backward rapidly, but as safely as possible. Participants were allowed to look back if they wanted and the examiner walked together with the participant to provide safety. The 3MBWT was performed with 3 trials, and the average time was expressed in seconds [12].

The 10-MWT is used to assess gait velocity. Participants are required to walk at their comfortable gait speed along a 10-m zone with an extra 2-m acceleration and deceleration zones. The 10MWT has excellent interrater (ICC = 0.87), and intrarater (ICC = 0.81) for PwPD [24].

The TUG is commonly used to measure functional mobility. It requires an individual to stand up from a chair, walk a distance of 3 m, turn around, walk back to the chair, and sit down [25]. For PwPD, acceptable test–retest reliability (ICC = 0.80) was found for the test [26].

The BBS evaluates functional balance performance related to 14 activities of daily living. It is scored on a 5-point scale (0–4), yielding a maximum score of 56. The higher scores reflect better balance ability [27]. The BBS demonstrated excellent test–retest reliability (ICC = 0.94) in PD [28].

The FSST is a clinical test evaluating dynamic balance. During the test, participants quickly step over obstacles the forward, backward, and sideways to the right and left [29]. The FSST has excellent interrater and good test–retest reliability (ICC = 0.99 and ICC = 0.78, respectively) [30].

The ABC is a self-report measure which evaluates balance confidence rated for 16-item related to mobility-based tasks. Each task is rated with a minimum score of 0% (no confidence) and a maximum score of 100% (completely confident). A total score is based on the average of 16 items, and higher scores reflect a higher level of balance confidence [31]. The Turkish version of the ABC has valid and excellent test–retest reliability (ICC = 0.95) [32].

The MDS-UPDRS is the most common scale to assess disease severity. It is composed of four parts: part I: non-motor experiences of daily living, part II: motor experiences of daily living, part III: motor symptoms, and part IV: complications. Higher scores indicate higher disease severity [33].

H&Y scale is a clinical rating scale that categorizes PD into five stages. Higher stages represent a greater level of functional disability [21].

Statistical analysis

The statistical package SPSS (version 17; SPSS Inc., Chicago, IL, USA) was used to perform the analyses. Descriptive statistics were used to summarize the characteristics of the sample. The normality of data was checked using the Shapiro–Wilk test, and the homogeneity of variances was tested using Levene's test. Normally distributed variables were presented as mean ± standard deviation; non-normally distributed variables were presented as median (interquartile range). Categorical variables were expressed as numbers and percentages. Continuous variables were compared between PwPD and healthy people using the independent *t* test for normally distributed data and the Mann–Whitney *U* test for non-normally distributed data. Categorical variables were compared using the chi-square test [34].

The test–retest reliability of the 3MBWT was assessed using ICC model 2 ($ICC_{2,1}$) with confidence intervals at the 95% level. The $ICC_{2,1}$ was calculated using a two-way random effect model with an absolute agreement for single measures because all assessments were performed by the same rater. The ICC was classified as follows: values above 0.90 indicated excellent reliability, values between 0.75 and 0.90 good reliability, values between 0.50 and 0.75 moderate reliability, and values below 0.5 low reliability [35]. Bland–Altman plots were constructed to examine the limits of agreement and to assess for any systematic bias between both sessions [36].

The MDC is defined as the minimal amount of change in a time that is required to distinguish a true performance change beyond measurement error. The MDC with a 95 confidence interval (MDC_{95}) was calculated based on the standard error of measurement (SEM) using the following formula [34]:

$$MDC_{95} = SEM \times 1.96 \times \sqrt{2}$$

The SEM was determined using the following formula [34]:

$$SEM = SD \times \sqrt{1 - r}$$

The SD is the pooled standard deviation of the 3MBWT times over both sessions and r is the calculated $ICC_{2,1}$ reliability coefficient [34].

Concurrent validity was evaluated by correlating the 3MBWT with the 10MWT, TUG, BBS, FSST, ABC, MDS-UPDRS III, MDS-UPDRS total, and H&Y scale by using Pearson's (r) or Spearman's correlation coefficients (ρ) as appropriate. Correlation coefficients were classified as negligible (0.0–0.30), low (0.31–0.50), moderate (0.51–0.70), high (0.71–0.90), or very high (0.91–1.0) [37].

Known-groups validity was determined by comparing times on the 3MBWT between PwPD and healthy people, and between fallers and non-fallers with PD, using the independent sample *t*-test and Mann–Whitney *U* test, respectively.

The optimal cutoff time of the 3MBWT was obtained through the receiver operating characteristics (ROC) curve. The highest value calculated as sensitivity + specificity − 1 was determined using the Youden index [38]. The ROC curve was used to describe the discriminative ability of the 3MBWT to classify PwPD as fallers or non-fallers. The area under the ROC curve (AUC) represented the probability of the 3MBWT time correctly discriminating between fallers and non-fallers with PD. An AUC of 1 indicates a perfect test while an AUC of 0.5 represents a completely worthless test. The AUC was interpreted as follows: 0.9–1.0 = excellent, 0.80–0.89 = good, 0.70–0.079 = fair, 0.60–0.69 = poor, and 0.50–0.59 = worthless test [39]. Additionally, the positive predictive value (PPV) and negative predictive value (NPV) were calculated to define the predictive ability of the 3MBWT. A PPV is the proportion of PwPD with test results below the cutoff time who were truly classified as fallers while a NPV is the proportion of PwPD with test results above the cutoff time who were truly classified as non-fallers [40]. The level of statistical significance was considered $p < 0.05$.

Results

Thirty-six PwPD, 25 men and 11 women, with a mean age of 63.19 ± 9.04 years, and 33 healthy people, 21 men and 12 women, with a mean age of 65.27 ± 6.89 years were included. The characteristics of the participants are presented in Table 1. There was no significant difference in age, gender, height, or weight PwPD and healthy people. For the PwPD, the mean H&Y stage and disease duration were 2.42 ± 0.69 and 8.79 ± 4.68 years, respectively. In the PD group, there were no significant differences between any demographic variables, and disease duration ($p > 0.05$ for all). However, fallers with PD had higher scores on the MDS-UPDRS III (34.08 ± 3.20 vs. 26.09 ± 8.51; $p = 0.004$), MDS-UPDRS total (63.54 ± 7.82 vs. 53.87 ± 13.61; $p = 0.032$), and H&Y scale (2.77 ± 0.60 vs. 2.22 ± 0.67; $p = 0.010$), as well as higher numbers of freezers ($n = 10$, 76.9% vs. $n = 5$, 21.7%; $p = 0.001$) compared to non-fallers with PD.

Test–retest reliability of the 3MBWT was excellent with an ICC of 0.965 (0.932–0.982). The MDC and MDC% for the 3MBWT were 2.13 s and 22.09%, respectively, representing acceptable measurement error. Bland–Altman plot showed minimal bias with the mean difference close to zero and the majority of data points were within 95% limits of agreement ranging from 2.82 to −3.10. Bland–Altman plot is seen in Fig. 1.

Table 1 Characteristics of participants

Characteristic	People with PD ($n = 36$)	Healthy people ($n = 33$)	p
Age, y			
Mean ± SD	63.19 ± 9.04	65.27 ± 6.89	0.290
Gender, *n* (%)			
Male	25 (69.4)	21 (63.6)	0.609
Female	11 (30.6)	12 (36.4)	
Height, cm			
Mean ± SD	170.69 ± 9.33	166.94 ± 7.73	0.075
Weight, kg			
Mean ± SD	77.44 ± 7.07	76.21 ± 10.22	0.633
Disease duration, y			
Mean ± SD	8.79 ± 4.68	NA	NA
H&Y stage, *n* (%)			
1	4 (11.1)		
2	13 (36.1)	NA	NA
3	19 (52.8)		
MDS-UPDRS-III			
Mean ± SD	28.97 ± 8.01	NA	NA
MDS-UPDRS total			
Mean ± SD	57.36 ± 12.63	NA	NA
Fall history, *n* (%)			
Fallers	13 (36.1)	NA	NA
Non-fallers	23 (63.9)		
Fall history, *n* (%)			
Freezers	15 (41.7)	NA	NA
Non-freezers	21 (58.3)		

H&Y Hoehn and Yahr, *NA* not applicable, *s* seconds, *SD* standard deviation, *MDS-UPDRS* Movement Disorders Society Unified Parkinson's Disease Rating Scale, *MDS-UPDRS-III* Movement Disorders Society Unified Parkinson's Disease Rating Scale-motor examination, *y* years

The completion times of the 3MBWT had high correlation with the TUG ($r = 0.858$, $p < 0.001$), BBS ($r = -0.816$, $p < 0.001$), FSST ($r = 0.774$, $p < 0.001$), and H&Y stage ($\rho = 0.714$, $p < 0.001$) while had moderate correlation with the 10MWT ($r = 0.674$, $p < 0.001$), ABC ($r = -0.592$, $p < 0.001$), MDS-UPDRS III ($r = 0.697$, $p < 0.001$), and MDS-UPDRS total ($r = 0.628$, $p < 0.001$). These correlation analysis results are presented in Table 2.

As shown in Table 3, PwPD had higher times on the 3MBWT than healthy people while fallers with PD had higher times on the 3MBWT than non-fallers with PD ($p < 0.001$ and $p < 0.001$, respectively).

ROC analysis showed an optimal cutoff time that best-discriminated fallers from non-fallers with a PD of 10.31 s, resulting in 82.6% sensitivity and 84.6% specificity with an AUC of 88.6%. Based on this cutoff time, the PPV was 84.6% while the NPD was 82.6%. The ROC analysis is presented in Fig. 2.

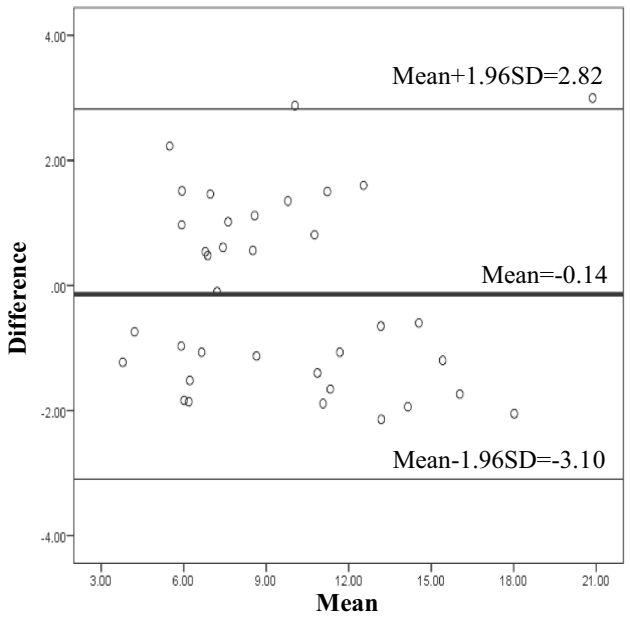

Fig. 1 Bland–Altman plot for the test–retest reliability of the 3-m backward walk test in people with Parkinson's Disease. The middle line represents the mean difference between the test–retest, and the upper and lower lines indicate the 95% limits of agreement

Discussion

To our knowledge, this is the first study designed to investigate the test–retest reliability of the 3MBWT for PwPD, MDC in the 3MBWT times, and both concurrent and known-groups validity of the 3MBWT. The cutoff times on the 3MBWT that best-discriminated fallers from non-fallers among the PD population was also determined. This study demonstrated that the 3MBWT is a reliable and valid measure of backward walking in PD, with acceptable sensitivity and specificity for discriminating fallers from non-fallers.

The 3MBWT showed an excellent test–retest reliability for PwPD, suggesting that the completion times of the test are consistent over time. Similar results were reported in reliability studies performed in other populations such as stroke [16], community-dwelling older adults [17] and MS [18]. The Bland–Altman plots also showed that overall there was a good test–retest agreement for the 3MBWT times.

Determined MDC value can help identify the smallest amount of change detected by a measured performance that is beyond random variations [41]. Our findings showed that the MDC_{95} was 2.13 s for the 3MBWT. This means the difference in time exceeds 2.13 s on the 3MBWT, so clinicians may be 95% confident in interpreting the difference as real in backward performance for PwPD. It should be also noted that the MDC% (22.09%) of the 3MBWT was below 30% of the mean of all times of the test–retest assessment, suggesting acceptable random measurement error [26]. Thus, the

Table 2 Correlations between the 3-m backward walk test and other outcome measures in people with Parkinson's disease

Measures	People with PD ($n=36$)	Correlation	p
10MWT, s			
Mean ± SD	11.49 ± 3.79	$r=0.674$	< 0.001
TUG, s			
Mean ± SD	13.90 ± 3.31	$r=0.858$	< 0.001
BBS			
Mean ± SD	51.08 ± 3.79	r = −0.816	< 0.001
FSST, s			
Mean ± SD	11.68 ± 4.46	$r=0.774$	< 0.001
ABC			
Mean ± SD	78.65 ± 11.87	r = −0.592	< 0.001
MDS-UPDRS-III			
Mean ± SD	28.97 ± 8.01	$r=0.697$	< 0.001
MDS-UPDRS total			
Mean ± SD	57.36 ± 12.63	$r=0.628$	< 0.001
H&Y stage			
Median (IQR)	3.0 (2.0–3.0)	$\rho=0.714$	< 0.001

10MWT 10-m walk test, *ABC* activity-specific balance confidence scale, *BBS* Berg Balance Scale, *FSST* four square step test, *H&Y* Hoehn and Yahr, *IQR* interquartile range, *PD* Parkinson's disease, *r* Pearson's correlation coefficient, *ρ* Spearman's correlation coefficient, *s* seconds, *SD* standard deviation, *TUG* timed up and go test, *MDS-UPDRS* Movement Disorders Society Unified Parkinson's Disease Rating Scale, *MDS-UPDRS-III* Movement Disorders Society Unified Parkinson's Disease Rating Scale-motor examination

3MBWT may be reliable for describing backward walking in PwPD. Moreover, the low MDC time could support the precision of the 3MBWT. For example, a low MDC value can reflect that either the evaluated performance is consistent from day after day, that the measurement tool itself has enough ability to specifically measure the real capacity it evaluates, or that the other factors do not impact the measured performance [42]. Clinically, the 2.13 s on the 3MBWT can help make evidence-based clinical decisions and adapt

Table 3 Known-groups validity of the 3-m backward walk test

Measure	People with PD ($n=36$)	Healthy people ($n=33$)	p
The 3MBWT times, s			
Mean ± SD	9.64 ± 4.06	3.97 ± 0.98	<0.001
	Fallers with PD ($n=13$)	Non-fallers with PD ($n=23$)	p
The 3MBWT times, s			
Mean ± SD	13.09 ± 3.85	7.69 ± 2.67	<0.001

3MBWT 3-m backward walk test, *IQR* interquartile range, *s* seconds, *PD* Parkinson's disease, *SD* standard deviation

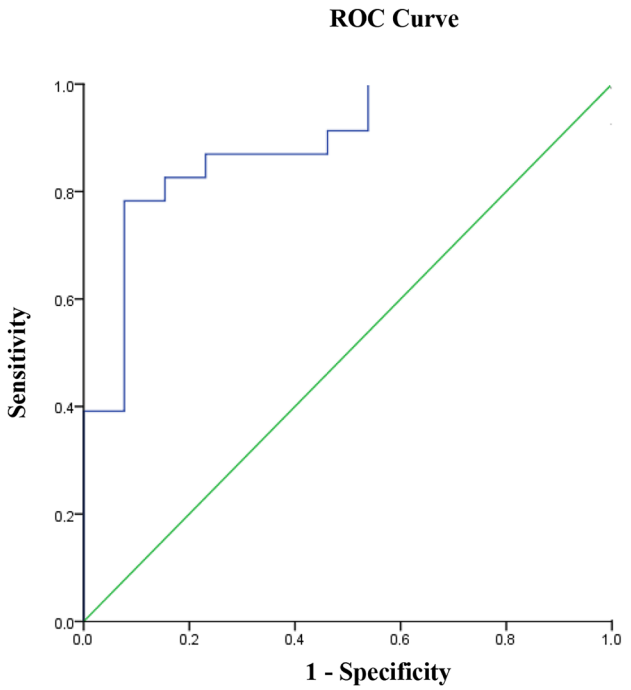

Fig. 2 Receiver operating characteristic curve analysis of the 3-m backward walk test time to discriminate fallers from non-fallers with Parkinson's disease. The optimum cutoff time was 10.31 s with 82.6% sensitivity and 84.6% specificity, with an AUC of 88.6%

intervention protocol at the right time to maximize the outcomes of the rehabilitation when clinicians can periodically use the 3MBWT to assess backward walking for PwPD.

A moderate correlation was found between the 3MBWT and 10MWT. PwPD had deficits in both backward and forward walking such as decreased gait speed, stride length, swing phase [15, 43], lower functional ambulation, and increased stance percents [8]. Moreover, both types of walking have some similar features; for example, they can have the same central pattern generator [10], control and adaptation mechanisms [44], use similar muscles to achieve horizontal and vertical acceleration of the center of mass [45], and show almost identical characteristics of angular displacement [46]. However, backward walking could be more provoked gait deficits for PwPD [8, 43]. Therefore, the 3MBWT could be more appropriate to detect gait deficits according to 10MWT and be separately used as a complementary tool for assessing walking speed.

There was a high correlation between the 3MBWT and TUG, which was in line with the previous studies conducted in healthy older adults [12], stroke [16], and MS [18] ($r=0.823$, $p<0.05$, $r=0.849$, $p<0.001$, and $r=0.814$, $p<0.001$, respectively). Individuals require to step backward while back up to a chair in the TUG [25]. Backward walking ability could give a piece of additive information related to mobility in PD [43] because individuals need backward walking for mobility in daily life such as moving away from a sink. This could indicate that the 3MBWT should be a useful tool as a clinical part of mobility for PwPD.

The 3MBWT was highly correlated with the BBS and FSST while moderately correlated with the ABC. As balance ability decreased, backward walking velocity decreased in PD [8]. Individuals stand with eyes closed in the BBS, and step backward direction in the FSST, which is required to have a good proprioceptive ability similar to the 3MBWT. Proprioceptive integration deficits could impact the postural control impairments in PD [47]. Backward walking has higher demands on postural control systems because of the lack of visual information and is unhabitually carried out [48]. PwPD did not receive visual information to anticipate the condition of the ground in the 3MBWT, they had to reorganize and adapt the altered information from visual, proprioceptive, and vestibular systems, and after that improve the movement control to provide dynamic balance [49]. In addition, the present study showed that the ability of backward walking performance is related to balance confidence in daily living activities. Thus, decreased backward walking performance may induce negative changes in the performance and perception of balance ability for PwPD.

The performance of 3MBWT times had moderate to high correlations with PD-specific impairments. Previous studies reported that the disabilities of backward walking were associated with MDS-UPDRS-II, MDS-UPDRS III [50], and UPDRS total [8]. Balance dysfunction, which adversely affected backward walking, is a significant marker differentiated between stage 2 and stage 3 that included nearly equal numbers of PwPD in this study. This could lead to a significant association between the H&Y stage and 3MBWT times. Taken together, increased motor symptoms, disease severity, and the stage could result in decreasing balance and mobility disorders that could result in the loss of backward walking performance. Thus, the rehabilitation program should focus more on improving the backward walking performance for PwPD, especially as the disease progresses.

On the 3MBWT, PwPD had worse performance than healthy people. In backward directions, PwPD walked more slowly with shorter stride length, lower swing phase [8, 15], higher double support phase, lesser functional ambulation performance [8], and impaired interlimb coordination [51] compared to healthy people. In addition, backward walking is more dependent on proprioception due to the lack of visual inputs [52]; however, PwPD showed proprioceptive deficits and had a visual dependency to provide postural control [47, 53]. Moreover, subclinical postural instabilities could be provoked by the visual deprivation task even at the early stages of the disease [53]. Decreased performance of the 3MBWT may have resulted from these problems, which indicates the importance of cueing strategies to improve walking performance in the rehabilitation of PD.

In the PD group, fallers took a longer time to complete the 3MBWT than non-fallers. This is consistent with a previous study reporting that fallers had worse performance on the 3MBWT than non-fallers in PD [19]. For PwPD, fallers had worse performance in terms of walking velocity [54], functional mobility, balance, balance confidence [55, 56], postural control in anterior–posterior and lateral directions [57], sensory organization, limits of stability [58] while higher disease-specific impairments including the freezing of gait, motor symptoms, disease severity, and disease stage [59, 60] according to the non-fallers. These impairments can lead to impaired backward walking ability for the fallers with PD; therefore, the 3MBWT may be used to identify PwPD with increased fall risk.

The optimal cutoff time of the 3MBWT to discriminate between fallers from non-fallers was 10.31 s with high sensitivity and specificity. The excellent AUC showed that the 3MBWT can correctly classify fallers and non-fallers with PD with a probability of 88.6%. Previously, the optimal cutoff time for performing the 3MBWT in identifying fallers was 4.2 s which was approximately 2.5 times that of the current study [19]. These differences could have resulted from a shorter time of fall history of 6 months, and a lower mean H&Y score of about 1.9 for the 3MBWT compared to our study. Based on the high PPV and NPV, a time $\geq$ 10.31 s is reassuring regarding the risk of falling inversely a time < 10.31 s should lead to addressing balance rehabilitation and fall prevention approach among PwPD who have this value. Additionally, fallers had higher motor symptoms, disease severity, and disease stage, and experienced more freezing than non-fallers, which could reflect the greater disability level of fallers. These clinical symptoms of the PD gradually compromised walking ability and can be likely to contribute to falls. Using the cutoff time of the 3MBWT in the clinic may help develop the design of rehabilitation programs that are tailored to the needs of PwPD with a better understanding of fall risk. However, PwPD reported falls in the past 1 year retrospectively in this study, possibly resulting in recall bias. Further studies, therefore, are required to examine the predictive ability to identify future falls.

Limitations

There were some limitations of the study. First, this study included only community-dwelling and mild- to moderate-stage PwPD, which may influence the generalizability of these findings. Further studies are needed to validate the 3MBWT in institutionalized and more severe PwPD. Second, several factors such as step length, step width, proprioception, muscle strength, and attention could affect the backward walking; however, they were not examined because this study mainly focused on the time required to complete the 3MBWT. Future studies should be performed to investigate these parameters. Third, the 3MBWT was performed while PwPD were ON state; thus, the performances of PwPD on the 3MBWT were not understood in the OFF state. Fourth, the responsiveness of the 3MBWT to detect changes in backward walking performance after intervention protocol was not explored in the current study and therefore needs investigation for PwPD.

Conclusions

The 3MBWT indicates excellent test–retest reliability for the assessment of backward walking in PD. A change in the 3MBWT time of at least 2.13 s may be used by rehabilitation professionals to interpret a real change in backward walking performance after an intervention protocol. The 3MBWT is associated with the gait speed, functional mobility, balance, balance confidence, motor symptoms, disease severity, and disease stage in PD. Significant differences in the 3MBWT performance were found between PwPD and healthy people, and between fallers and non-fallers with PD, which may help identify impaired backward ability. The cutoff time of 10.31 s was determined to best differentiate fallers from non-fallers, which can be used to help make decisions regarding fall prevention in the clinic of PD. Overall, the 3MBWT is a reliable, valid, and easy to administer clinical tool for assessing backward ability for PwPD.

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Data availability All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval The study was performed in line with the ethical principles and the Helsinki Declaration. Informed consent of the participants was obtained. The study protocol was approved by the Gazi University Clinical Research Ethics Committee on 27.12.2021. (Decision Number: 211).

Informed consent Written informed consent was obtained from all participants who participated in this study.

Conflict of interest The authors declare no competing interests.

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