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ORIGINAL REPORT

WITHIN-SUBJECT VARIATION IN THE COGNITIVE TIMED UP AND GO TEST AS AN EXPLANATORY VARIABLE IN FALL RISK IN PATIENTS WITH PARKINSON'S DISEASE

Sergio SEBASTIA-AMAT[1], MD, Juan TORTOSA-MARTÍNEZ[1]*, PhD, Miguel GARCÍA-JAÉN, PhD[1] and Basilio PUEO, PhD[1]
From the [1]Physical Education and Sport, University of Alicante, 03690 Alicante, Spain

Objective: **To explore the use of within-subject variation in the Cognitive Timed Up and Go test (Cognitive TUG_{wsv}) as an explanatory variable in fall risk in the Parkinson's disease population.**
Design: **Cross-sectional study.**
Methods: **Fifty-three patients with Parkinson's disease completed 3 trials of the Cognitive TUG_{wsv}. Within-subject variation was calculated using the standard deviation of an individual's repeated measurements, and compared on the basis of the fall history reported in the previous 6 months. Participants who reported < 2 falls were classified as "non-recurrent fallers" ($n = 31$) and those who reported ≥ 2 falls were classified as "recurrent fallers" ($n = 22$). Univariate and a multivariate logistic regression were used to investigate the statistical impact of the Cognitive TUG_{wsv} as an explanatory variable in fall risk. Discriminative ability and cut-off score were determined based on receiver operating characteristic analysis.**
Results: **There was a significant difference between groups in the Cognitive TUG_{wsv} ($p = 0.002$). Univariate logistic regression indicated a significant association between Cognitive TUG_{wsv} and fall risk ($\chi^2 = 12.365$, $p < 0.001$), with an odds ratio of 2.5 (95% confidence interval (95% CI) = 1.34–4.65). Multivariate logistic regression showed that body mass index (BMI), Falls Efficacy Scale-International (FES-I), Cognitive TUG_{wsv}, and the mean velocity of the centre of foot pressure under closed eyes condition (Velocity COP (CE)) were significant explanatory variables in fall risk. Cognitive TUG_{wsv} was the most important independent variable. Receiver operating characteristic analysis revealed an acceptable discriminative power (area under the curve (AUC) = 0.757, 95% CI = 0.619–0.864, $p < 0.001$) and a cut-off point of 1.53 s.**
Conclusion: **A higher Cognitive TUG_{wsv} correlated significantly with higher fall risk. Thus, diagnostic tests and exercise programmes could consider Cognitive TUG_{wsv} when assessing fall risk in the Parkinson's disease population.**

Key words: gait; risk of falling; variability; Parkinson's disease; dual task; postural balance; Timed Up and Go.

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Correspondence address: Juan Tortosa Martínez, University of Alicante. Faculty of Education. Area of Physical Education and Sport Campus de San Vicente del Raspeig s/n 03690 San Vicente del Raspeig, Alicante. E-mail: juan.tortosa@ua.es

LAY ABSTRACT

Motor deficits in patients with Parkinson's disease usually worsen when tasks are performed simultaneously or under maximal challenge conditions. Assessment of these motor complications has an important role in the prediction of fall risk. A range of parameters is used to assess motor alterations. Among them, within-subject variation is normally used as a parameter of reliability in validation studies. Nevertheless, the use of within-subject variation during a single session in the Timed Up and Go test with the addition of a cognitive dual task (Cognitive TUG_{wsv}) performed at maximum speed has not yet been studied as a predictor of fall risk in the Parkinson's disease population. The results of this study support the hypothesis that a higher Cognitive TUG_{wsv} is related to a higher risk of falling in patients with Parkinson's disease. Therefore, health professionals could consider this variable when assessing the risk of falling in this population.

Parkinson's disease (PD) is a progressive neurodegenerative disease that encompasses a wide range of motor and non-motor symptoms (1). Motor abnormalities include resting tremor, rigidity, bradykinesia, and disturbances in gait, balance and posture (2). Among them, postural instability and episodic gait disturbances are the most debilitating motor symptoms, which are associated with increased falls, dependence, morbidity and mortality (3). Patients with PD are at much higher risk of falling than those with other neurological diseases (4); hence, early detection of potential fallers is of clinical relevance in this population. Several risk factors for fall occurrence in patients with PD have been identified: gait disorders, increased disease severity, duration of PD, Fear of Falling (FoF), cognitive impairment, Freezing of Gait (FOG), impaired balance, impaired mobility, reduced muscle strength, and gait disorders (5). Specifically, gait disorders include reductions in speed, adaptability, step frequency, and step length, as well increased gait variability, which worsen with disease severity (6).

There are different types of instruments for assessing falls risk in patients with PD: questionnaires, rating scales, clinical tests, wearable and non-wearable devices. Within the clinical tests, the Timed Up and Go (TUG) test is a clinical timed tool that is used widely in the PD population to assess balance and walking ability, functional mobility and fall risk, using the time to complete the test as the main outcome analysis (7).

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In parallel, some studies have proposed the addition of a motor or cognitive task during the performance of the TUG test (8), since the ability to simultaneously perform multiple tasks is affected in patients with PD (9), which could lead to higher risk of falling. According to different studies (8, 10), a cognitive dual-task seems to be the best dual-task condition for detecting fall risk during TUG performance.

Nevertheless, the exact protocol and the use of cut-off times as a fall-risk parameter are still under debate, with inconsistencies in the literature (11). Technological advances have enabled TUG instrument devices, in addition to measuring the total time, to measure subcomponents of the test with greater accuracy and sensitivity. However, practical application of these instruments in clinical settings is limited, due to the cost of instruments and the excessive time necessary to treat and interpret the data (12). Thus, it is of interest to investigate other more practical solutions that could increase the limited data offered by the original TUG test.

In this sense, variability has normally been used to assess the reliability of an instrument (13). Moreover, in clinical testing variability has also been used as a parameter to assist in the diagnosis of PD (e.g. tapping test) (14) or to predict falls (e.g. variability of gait) (15). A simple statistic that reveals within-subject variation (WSV) on repeated testing is the within-subject standard deviation (SD) or the SD of an individual's repeated measurements (13). More precisely, in dependent older people, the WSV in the TUG test carried out on different days at a comfortable speed has shown correlation with the time to complete the test (16). However, to the authors' knowledge, the relationship between the WSV of the time taken to complete the cognitive TUG test (Cognitive TUG_{wsv}) at maximum speed in a single session and the risk of falling in the PD population has not yet been explored. The use of WSV could be an interesting parameter to introduce in the clinical evaluation because of simplicity and rapidity. In addition, this parameter could enable intra- and inter-subject performance to be merged, in a manner that reduces the effect of some non-controllable variables and measures the variability of motor performance between trials as a potential clinical parameter not previously considered in the TUG test score.

Thus, considering that alterations related to motor and non-motor symptoms could affect the time needed to perform the same action on different attempts, it was hypothesized that recurrent fallers should have a higher WSV compared with non-recurrent fallers. Moreover, these differences would probably be more noticeable if the TUG test is performed simultaneously with an added cognitive task. Therefore, the aim of this research was to explore the relationship between the Cognitive TUG_{wsv} and the risk of falling, and to investigate whether this parameter could be used as an explanatory parameter in fall risk in patients with PD.

METHODS

Participants

The study sample comprised 74 participants, age range 44–84 years (46 men and 28 women), with confirmed idiopathic PD, recruited between February 2018 and September 2019 from several PD associations of Alicante, Castellón and Elche, located in Comunidad Valenciana, Spain. The sample size was chosen based on previous similar research with PD (8), but not on statistical considerations. A total of 53 participants met the following inclusion criteria: subjects diagnosed with idiopathic PD according to the clinical diagnostic criteria of the United Kingdom Parkinson's Disease Society Brain Bank; diagnosed by a neurologist; over 18 years of age; Hoehn and Yahr stage (H&Y) 1–4; self-reported anti-parkinsonian drugs treatment with stable medication for at least 8 weeks before joining the study; capable of ambulating independently; able to give informed consent; and able to follow simple instructions. Exclusion criteria were: patients with a history of traumatic brain injury (TBI) or stroke, severe chronic obstructive pulmonary disease (COPD), a neurological disorder other than PD, myocardial infarction in the past 12 months, severe orthopaedic problems in the lower limbs, and a clinical diagnosis of dementia or severe cognitive impairment (Mini-Mental Status Examination Score ≤24). Selected participants were divided into 2 groups based on fall history (number of falls within the previous 6 months). Participants who reported fewer than 2 falls were classified as "non-recurrent fallers" whereas those who reported 2 or more falls were classified as "recurrent fallers".

Before starting the study, participants were fully informed of the aim, benefits and possible risks of participation. Participants provided written consent after receiving the project information, previously approved by the research ethics committee of the University of Alicante (approval number UA-2018-07-11) and conducted in accordance with the Declaration of Helsinki.

All testing procedures took place while participants were in the "ON" phase of the medication cycle (i.e. when the medication is working optimally, usually between 45–90 min after their morning dose of dopaminergic medication).

Procedures

Previous to collecting the data, eligible participants were evaluated by a neurologist and a psychologist to carry out the screening process. Participants were evaluated regarding several aspects related to PD, including motor and non-motor characteristics.

Potential covariates

Demographic characteristics were considered as potential covariates based on the possible impact on fall risk. Demographic characteristics that showed significant differences between non-recurrent and recurrent fallers were considered as covariates. Before carrying out the testing procedures, participants (with the help of their relatives) were asked to recall the number of falls they had had within the previous 6 months. A fall was defined as "an unexpected event, in which the participant comes to rest on the ground, floor, or lower level". The history of falls was used as a retrospective estimate of fall risk, as in previous studies (8).

This information was also used to group participants into non-recurrent fallers (0–1 fall) and recurrent fallers (>2 falls). The history of falls was therefore excluded as a potential covariate, since it was used as dependent variable.

Clinical visit

The Spanish version of the modified Unified Parkinson Disease Rating Scale motor section (MDS-UPDRS III) was used to assess motor symptoms and H&Y staging to assess disease severity (17). FoF, conceptualized as concerns about falling, was measured using the short version of the Falls Efficacy Scale-International (short FES-I) (18). FOG was also reported using the Spanish version of the Freezing of Gait Questionnaire (FOG-Q) in PD (19). All tests were carried out by a neurologist during the clinical visit, prior to the study.

Mental disorders assessment

Cognitive function was evaluated by a psychologist using the Mini-Mental Status Examination Score (MMSE) (20), since cognitive deficits can be detected even in the early stages of PD. Likewise, the MMSE was used to ensure that participants had sufficient cognitive function to understand the test procedures.

Motor execution assessment

The Trail Making Test (TMT) was carried out to assess executive function, cognitive flexibility, and working memory (21). Parts A and B of the TMT were evaluated individually, and the difference between parts (part B minus part A) determined.

Balance assessment

Posturographic analysis was carried out using a baropodometric platform (FreeMed, Rome, Italy) with an active surface of 400×400 mm, 8-mm thickness, and a sample frequency of 100 Hz. Postural sway was measured for 30 s while participants stood with open eyes (EO) and closed eyes (CE) conditions (quiet stance procedure) (22). The stabilometric parameter measured was the mean velocity (Velocity COP), calculated by dividing the COP excursion by the trial duration (the lower the velocity, the better the postural control). Also, the Functional Reach Test (FRT) was performed as a cheaper, easier and rapid test to assess dynamic balance (7).

Mobility assessment

The TUG test is the most frequently used tool to assess functional mobility in patients with PD. Moreover, it is widely used to assess fall risk in this population (23). According to the literature (8), the addition of a cognitive task improved the assessment of fall risk. Hence, it was decided to perform the TUG test under single and dual task condition (semantic verbal fluency task). Participants started sitting in a chair, with their back against the chair back and their arms resting on the armrests. From this position, they were required to get up from the chair, walk 3 m, turn around, walk back to the chair and sit down, as quickly as they could safely without running. Participants were also asked to complete the TUG test while enumerating animal names (24). Any repetition of the same animal with a different gender was not allowed within the same trial.

The whole procedure was timed, in s, from the initiation process of standing from the chair, after the word "Go", until the participants sat back down in the chair. After a practical trial, the mean time and SD of the 3 trials were recorded by 2 cameras (model RX100 IV, Sony, Tokyo, Japan). Participants rested for 1 min between trials and the use of assistant devices was not allowed. Time variables were obtained after the post-processing of videos (Kinovea 0.8.27 for Windows 10, Bordeaux, France).

Data analysis

Statistical analyses were conducted using the Statistical Package for Social Sciences (IBM, Armonk, NY, USA: IBM Corp). Mean and SD were used for descriptive analysis. The Kolmogorov–Smirnov test was performed to test for normal distribution. A χ^2 test, independent-samples *t*-test and Mann–Whitney *U* test were used to identify the variables presenting statistically significant differences between non-recurrent and recurrent fallers ($p<0.05$), and used as an inclusion criteria in the logistic regression analyses. A univariate logistic regression analysis was performed to determine the relationship between Cognitive TUG_{wsv} (independent variable) and history of falls (dependent variable). Moreover, a multivariate logistic regression analysis using a backward stepwise selection method (likelihood ratio, LR, $p<0.05$) was used to investigate the statistical impact of the Cognitive TUG_{wsv} combined with covariates in a model in which the retrospectively estimated fall risk was the dependent variable. Odds ratio (OR), 95% confidence intervals (95% CI) and significance were calculated for each variable.

A receiver operating characteristic (ROC) curve was constructed. The area under the ROC curve (AUC) was used to measure the accuracy of the Cognitive TUG_{wsv} to discriminate between non-recurrent and recurrent fallers. The optimum cut-off point was found according to maximum Youden index (sensitivity + specificity –1). An AUC >0.5 to <0.7 was considered poor discrimination, ≥0.7 to <0.8 acceptable discrimination, ≥0.8 to <0.9 excellent discrimination, and ≥0.9 outstanding discrimination (25).

RESULTS

A total of 53 participants with PD were enrolled in the study. Baseline characteristics of the entire cohort, non-recurrent and recurrent fallers, are shown in Table I. The entire cohort had a mean age of 68.9±8.4 years and a mean disease duration of 6.3±4.1 years (determined from the date of diagnosis of idiopathic PD until the date of the study evaluation session). The participants had a mean body mass index (BMI) of 26.4±3.6 kg/m^2.

Differences between non-recurrent and recurrent fallers

There were significant differences between non-recurrent and recurrent fallers for different demographic characteristics and clinical tests (see Table I). There were significant differences between groups in age and BMI. Surprisingly, the disease duration in recurrent fallers was shorter than in non-recurrent fallers, although the difference was not significant ($p=0.163$).

On the other hand, the H&Y scale, MDS-UPDRS III, short FES-I, FOG-Q, TUG, Cognitive TUG, Cognitive TUG_{wsv}, Velocity COP (OE) and Velocity COP (CE) showed significant differences between non-recurrent

Table I. Comparison of clinical, neuropsychological and functional characteristics of patients with Parkinson's disease

	All participants ($n=53$)	Non-recurrent fallers ($n=31$)	Recurrent fallers ($n=22$)	p-value (χ^2/U/t)
Demographic characteristics				
Sex, men/women	37/16	24/7	13/9	0.152
Age, years	68.9±8.4	67±9	71.4±6.7	0.035*
Disease duration, years	6.3±4.1	6.9±4.1	5.4±3.9	0.163
BMI, kg/m^2	26.4±3.6	25.4±3.3	27.9±3.5	0.012*
History of falls, number of events	2.2±2.7	0.5±0.5	4.6±2.7	0.001*
Clinical tests				
H&Y (1–5)	2.1±0.9	1.9±0.7	2.5±1	0.024*
MDS-UPDRS-III (0–132)	32.3±18	27±15.3	39.8±19.1	0.009*
Short FES-I (7–28)	13.1±4.8	11.2±3.5	15.8±5.3	0.001*
MMSE (0–30)	26.9±1.8	27.5±2.2	26.1±3.4	0.122
FOG-Q (0–24)	7.7±5.4	6.4±4.5	9.7±5.4	0.033*
TMT A, s	67.76±52.31	58.16±33.72	81.30±69.45	0.376
TMT B, s	171.45±122.48	149.52±99.26	202.36±146.16	0.220
TMT (B-A) , s	103.69±81.44	91.37±73.40	121.06±90.48	0.304
FRT, cm	20.53±6.02	21.06±6.62	19.79±5.11	0.594
TUG, s	11.67±4.60	9.90±2.28	14.17±5.82	0.004*
TUG$_{wsv}$	0.50±0.34	0.43±0.31	0.60±0.36	0.059
Cog TUG, s	16.83±9.18	13.31±4.79	21.79±11.47	0.002*
Cog TUG$_{wsv}$, s	1.46±1.32	0.94±0.80	2.15±1.56	0.002*
Velocity COP (OE), mm/s	15.92±5.68	14.18±3.90	18.38±6.88	0.011*
Velocity COP (CE), mm/s	17.86±7.72	16.02±6.92	20.45±8.19	0.017*

*Significant difference at $p<0.05$
U: Mann–Whitney *U* test; t: independent-samples *t*-test; BMI: body mass index; H&Y: Hoehn & Yahr scale; MDS-UPDRS (III): Modified Unified Parkinson Disease Rating Scale; Short FES-I: short version of Falls Efficacy Scale-International; MMSE: Mini-Mental Scale Examination; FOG-Q: Freezing of Gait Questionnaire; TMT A: Trail Making Test part A; TMT B: Trail Making Test part B; FRT: Functional Reach Test; TUG: Timed Up and Go test; TUG$_{wsv}$: Within-Subject Variation in the Timed Up and Go test; Cognitive TUG: time to complete the Time Up and Go test with an added cognitive task; Cognitive TUG$_{wsv}$: Within-Subject Variation in the Timed Up and Go test with an added cognitive task; Velocity COP (OE): mean velocity of the centre of foot pressure (Open Eyes); Velocity COP (CE): mean velocity of the centre of foot pressure (Closed Eyes).

and recurrent fallers. The TMT showed that recurrent fallers took more time to complete both sections of the test, although there were no significant differences between groups. In general, recurrent fallers performed significantly poorer than non-recurrent fallers on the majority of the motor tests.

As we hypothesized, the Cognitive TUG$_{wsv}$ showed a significant difference between groups ($p=0.002$). The participants who reported more than 1 fall in the previous 6 months showed significantly higher mean values in the Cognitive TUG$_{wsv}$. Otherwise, the TUG$_{wsv}$ did not show significant differences between groups ($p=0.059$).

Logistic regression analyses

Model 1: Univariate logistic regression. In order to analyse if the Cognitive TUG$_{wsv}$ was associated with fall risk, a univariate logistic regression was performed. The results showed a significant association between Cognitive TUG$_{wsv}$ and fall risk ($\chi^2=12.365$, $p<0.001$) with an OR of 2.50 (95% CI=1.34–4.65, $p=0.004$). The proposed model correctly classified 71.7% of the overall participants.

Model 2: Multivariate logistic regression. A multivariate logistic regression using backward stepwise selection method (LR) was performed adjusting for all study covariates that showed significant differences between groups (Table II).

BMI, Short FES-I, FOG-Q, Cognitive TUG$_{wsv}$ and Velocity COP (CE) were included in the last step of the logistic regression analysis. Of these, only the FOG-Q was excluded as significant explanatory variable in fall risk ($p>0.05$). In our model, the strongest variable was the Cognitive TUG$_{wsv}$, which means that if the Cognitive TUG$_{wsv}$ increased by 1 s, the odds of being a recurrent faller would be 2.47 times higher (95% CI 1.15–5.31, $p=0.021$).

Model 2 also indicated that the included variables significantly explained fall risk ($\chi^2=33.613$, df=5 and $p<0.001$). Our model correctly classified 83% of the overall participants.

Discriminative performance of the Cognitive TUG$_{wsv}$

ROC analysis was conducted to assess the accuracy of the Cognitive TUG$_{wsv}$ to discriminate between non-re-

Table II. Model 2: multivariate logistic regression analysis with fall risk as the dependent variable

	OR	95% CI	p-value
BMI	1.38	1.05–1.81	0.022*
Short FES-I	1.43	1.04–1.97	0.026*
FOG-Q	0.79	0.59–1.04	0.098
Cognitive TUG$_{wsv}$	2.47	1.15–5.31	0.021*
Velocity COP (CE)	1.28	1.05–1.55	0.013*

*p: significant difference at $p<0.05$. OR: odds ratio; CI: confidence interval; BMI: body mass index; Short FES-I: short version of Falls Efficacy Scale-International; FOG-Q: Freezing of Gait Questionnaire; Cognitive TUG$_{wsv}$: Within-Subject Variation in the Timed Up and Go test with an added cognitive task; Velocity COP (CE): mean velocity of the centre of foot pressure (Closed Eyes).

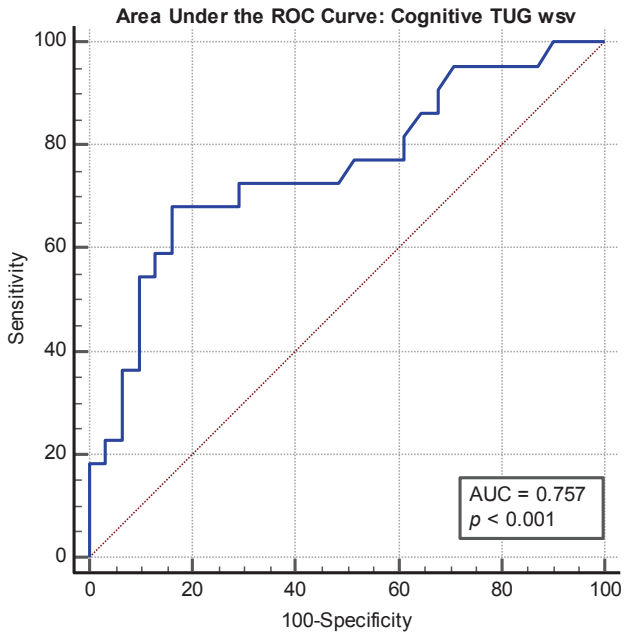

Fig. 1. Receiver operating characteristic (ROC) curve of the Cognitive TUG_{wsv}

current and recurrent fallers. The results showed an acceptable AUC value of 0.757 (95% CI=0.619–0.864, $p<0.001$) (Fig. 1). The highest Youden index was 0.52 with a cut-off point of 1.53 s (sensitivity=68.18%; specificity=83.87%).

DISCUSSION

The novel approach of this study was to analyse the relationship between fall risk and Cognitive TUG_{wsv} within the same session in a PD population. The results showed that Cognitive TUG_{wsv} was the strongest explanatory variable in fall risk, with acceptable accuracy in distinguishing between non-recurrent and recurrent fallers.

Previous to the logistic regression analyses, comparative statistics showed that there were significant differences between groups for different demographic characteristics and clinical tests. According to our hypothesis, the Cognitive TUG_{wsv} showed significant differences between non-recurrent and recurrent fallers. Conversely, the TUG_{wsv} did not show significant differences between groups, although the *p*-value was close to significance ($p=0.059$). The significant difference detected in the Cognitive TUG_{wsv} could be explained by attention deficits elicited by the dual-task performance of the test, which can lead to major changes in gait variability and stability (26) and the occurrence of more freezing episodes compared with single-task conditions (27).

The results of model 1 (univariate) showed a significant association between the Cognitive TUG_{wsv} and fall risk. For each 1-s increase in the Cognitive TUG_{wsv} the odds of being a recurrent-faller would be 2.5 times higher. Therefore, a multivariate logistic regression analysis was performed to confirm if the Cognitive TUG_{wsv} could be used as an explanatory variable in fall risk when other potential variables were taken into account. The variables that showed significant differences between groups ($p<0.05$) were entered into the regression analysis. However, some relevant tests, such as the TMT scores ($p=0.220$–0.376), MMSE ($p=0.122$) and the FRT ($p=0.594$), were excluded, despite being widely used tools (7, 28). Previous studies, such as that by Chen et al. (29), reported a significant association between cognitive tests and fall risk, but these measurements were not explanatory variables of prospective falls after considering other risk factors, specially psychomotor tests. The use of cognitive deterioration as an exclusion criteria in the majority of the studies, including in the current study (MMSE), could have influenced the relationship between cognitive impairment and fall risk (28). In the case of the FRT, the instrument fulfils the criteria of being recommended by the Movement Disorders Society Rating Scales Committee, although its relationship with fall occurrence in PD population is uncertain (7).

Model 2 (multivariate) showed that BMI, short FES-I, Cognitive TUG_{wsv} and Velocity COP (CE) were significant explanatory variables in fall risk. Specifically, Cognitive TUG_{wsv} was the most important independent variable (OR=2.47, 95% CI=1.15–5.31, $p=0.021$). ROC analysis indicated an acceptable discriminative power of the Cognitive TUG_{wsv} (AUC=0.757, 95% CI=0.619–0.864, $p<0.001$) and a cut-off point of 1.53 s. This means that a patient who reported a higher WSV than the cut-off point would have an increased risk of being a recurrent faller.

The TUG test, performed under single- and dual-task conditions, is used in the literature as a tool to assess functional mobility and to identify patients with PD who are at risk of falling (7, 23). However, no studies have reported information related to Cognitive TUG_{wsv} during a single session. Therefore, it is complex to compare the current results with those of other studies, because most of the studies compared trials between data groups, trials performed in different medication states (30), or trials performed in different days (31). Moreover, the WSV information provided in the studies are usually founded as a mean time of trials or, conversely, only a single trial was used to perform the TUG test.

It is usual to find variability in repeated measures, due to the participant, the evaluator, or the precision of the instrument (32). The main source of this variability is usually biological; for example, changes

in the mental or physical state of the participant (13) although mechanical variations, learning or fatigue effects should be also considered in patients with PD. Taking into account that PD is related to motor and non-motor symptoms, these alterations could explain the higher Cognitive TUG_{wsv} found in the recurrent faller group.

The relationship between Cognitive TUG_{wsv} and fall risk might be attributed to different factors. The most crucial could be the abnormal gait pattern found in patients with PD (33), characterized by small shuffling steps, hesitation, slowing of gait and reduced arm swing, sometimes combined with festination or FOG episodes. The difficulties of patients with PD in motor planning, particularly when they have to initiate locomotion or negotiate a turn, along with the impaired ability of dual tasking could influence gait performance and the appearance of FOG episodes and festination, which are strongly correlated with falls (27). Furthermore, the unexpected nature and duration of FOG episodes and festination could result in an increase in Cognitive TUG_{wsv}. In the case of Cognitive TUG, the influence of the different sub-tasks of which it is composed (sit, sit to stand, walk, turn, walk-back and sit-back) and the addition of the verbal fluency task should be taken into account to explain the WSV. The sub-task of getting up from the chair, including the stability during the lift-off phase as a consequence of the movement preparation to get up, requires sufficient muscle strength in the lower limbs especially at the hip, which could increase the Cognitive TUG_{wsv} (34). Consequently, different attempts or longer periods could be needed to get up from the chair. Another relevant point could be the maximum speed employed in the TUG test because of the impairment observed in patients with PD in automatic and rapid alternating movements (35) or when the tests were carried out at maximal challenge (36). Indeed, Van Uem et al. (37) observed that the TUG test performed at maximum speed differentiated mild to moderate patients better than when it was performed at a comfortable speed. Other disturbances related to motor performance, such as dysfunction of the internal clock rhythm observed in patients with PD, could also affect the Cognitive TUG_{wsv} and alter the results (38).

Various factors can also influence the displacement capability and, consequently, the Cognitive TUG_{wsv} including impaired balance, medication state, depression and stressful situations (2, 30).

All of the above can make it very challenging for a patient with PD to maintain a similar performance between trials. Consequently, it is reasonable that the most affected patients showed higher values of Cognitive TUG_{wsv} . Therefore, apart from using the time to complete the test, it would be necessary to consider WSV when assessing fall risk in a PD population.

On the other hand, BMI was reported in model 2 as a significant variable associated with risk of falling. Non-recurrent fallers showed a significantly lower BMI (25.4±3.3 kg/m^2) compared with recurrent-fallers (27.9±3.5 kg/m^2). It is well known that an increased BMI is correlated with poor health status, frailty, inactivity, fall risk and poor quality of life (39). Hence, it makes sense that the participants with the highest values of BMI reported a significant increase in fall risk. The short FES-I was also included in the final model as a significant explanatory variable in fall risk. Generally, FoF is associated with gait and balance problems, reduced mobility and poorer health and quality of life among others (40). This could result in a spiralling risk of increasing falls, FoF and functional decline (41). Therefore, the current results were in line with previous studies, which indicated that FoF was correlated with fall occurrence (42). Static posturography is a widely used technique to assess balance performance and fall risk in PD populations (22). Gervasoni et al. (43) identified body sway velocity as the best posturographic variable to predict recurrent falls in PD, although contradictory results have been reported in the literature in this regard (22).

Conversely, the FOG-Q was included in the final step of model 2, although it was not a significant explanatory variables of fall risk. Together with previous research (44), the current study showed the relevance of the presence of FOG as a potential variable in fall risk assessment, since significant differences between non-recurrent and recurrent fallers were found. Despite the well-known relationship between FOG and fall risk, the exclusion of this parameter as a significant explanatory variable ($p=0.069$) in the final step of model 2 could be due to the episodic nature of FOG, the "ON" medication state at testing, and the use of cognitive or compensatory mobility strategies to overcome freezing events (45).

Study limitations

This study has some limitations. First, it has a small sample size, which did not allow for generalization. Increasing the sample size in future studies would also enable the assessment and comparison of different PD phenotypes.

A second limitation was the disease severity in the sample. The majority of the sample were patients with mild to moderate PD. Future studies should examine the Cognitive TUG_{wsv} in patients with advanced PD, in whom this factor could be more relevant for the assessment of fall risk. Furthermore, it would be of interest

to explore whether the Cognitive TUG_{wsv} is sensitive to changes in medication states or changes due to physical therapy programmes. Thirdly, a methodological limitation was the use of the MMSE test to assess cognitive function instead of the MoCA test, which is more appropriate to this aim. Another methodological limitation was the retrospective classification of non-recurrent and recurrent fallers, since prospective recording is the reference standard for assessment of fall risk.

Finally, despite the use of a practical trial, a small learning effect could have occurred between trials 1 and 2, according to the literature (30). Alternatives, such as increasing the number of repetitions, were not considered, because they were not practical solutions, and would have resulted in more fatigue among participants.

Conclusion

Cognitive TUG_{wsv} was a significant explanatory variable in fall risk among patients with PD, with an acceptable accuracy in distinguishing between non-recurrent and recurrent fallers. The results of the current study also support the use of BMI, the short FES-I and velocity COP (CE) as significant explanatory variables in fall risk.

Overall, these results support the idea that a higher Cognitive TUG_{wsv} is related to a higher risk of falls in patients with PD. Thus, if the current results are confirmed in future studies, diagnostic tests and exercise programmes could consider this cheap, quick and simple parameter when assessing the risk of fall in patients with PD.

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The authors have no conflicts of interest to declare.

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