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Research Article

Does the fear of falls interfere with the task of boarding a bus in individuals with Parkinson's disease?

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HIGHLIGHTS
• Upper limb strength is a determinant of functional activities.
• Boarding a bus is difficult for individuals with handgrip strength decline.
• Fear of falling exerts an impact on the time required to board a bus.

ABBREVIATIONS

BMI	Body index mass
DT	Dual task
FES-I	Falls Efficacy Scale
HY	Hoehn & Yahr
MMSE	Mini Mental State Examination
MVC	Maximum voluntary contraction
PD	Parkinson's disease
ST	Single task
UEL	Universidade Estadual de Londrina
UPDRS	Unified Parkinson's Disease Rating Scale

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BACKGROUND: Individuals with Parkinson's disease (PD) have motor impairment that leads to the fear of falling, which limits functional independence.
AIM: To correlate the fear of falling with cognitive function, handgrip strength, upper limb pulling force and functional execution time on the task of boarding a bus in individuals with PD.
METHOD: A cross-sectional study involving 31 individuals with idiopathic PD. Assessments were performed with the Mini Mental State Examination (MMSE) and the Falls Efficacy Scale (FES-I). Handgrip strength and upper limb pulling force were measured using dynamometers installed on a bus prototype. Execution time was determined on the single task (ST), which consisted of climbing a bus, as well as a dual task (DT) (detecting specific letters from an audio recording during the task). Correlations between variables were determined using Pearson's correlation test, with the significance level set at 5% ($p < 0.05$).
RESULTS: Moderate correlations were found between the FES-I score and the following variables: MVC for right handgrip strength ($r = -0.491$), left handgrip strength ($r = -0.522$), right arm pulling force ($r = -0.522$) and left arm pulling force ($r = -0.563$) as well as execution time on the ST ($r = 0.514$) and DT ($r = 0.445$). Moreover, a weak correlation was found between the total FES-I score and MMSE ($r = -0.377$).
CONCLUSION: Greater concern with regards to falling was correlated with lower handgrip strength and upper limb pulling force, and a greater time spent boarding a bus under ST and DT conditions.

KEYWORDS: Neurodegenerative Disease | Hand strength | Locomotion | Falls

INTRODUCTION

Parkinson's disease (PD) is a chronic, progressive, neurodegenerative disease resulting mainly from the degradation of dopaminergic neurons of the compact substantia nigra of the mesencephalon [1]. Changes in posture, gait and balance in affected individuals are associated with postural instability, which can lead to functional disability, an increased risk of falls, immobility and the loss of independence. Fear of falling also intensifies concerns during the performance of activities of daily living, which limits the execution of such activities and diminishes quality of life [2].

A reduction in handgrip strength is among the determinants of physical frailty in older people and has repercussions for general functioning, leading to a reduction in autonomy and dependence with regards to basic and instrumental activities of daily living [3]. Reduced strength occurs in several muscle groups and is an important component of postural instability related to a reduction in walking speed and an increase in the incidence of falls in this population [4]. Thus, independent locomotion poses a challenge for individuals with PD, as physical changes caused by the aging process concomitant to motor symptoms (reduction in muscle strength and changes in postural control) as well as problems regarding family support (limited care capacity) and accessibility (architectonic aspects) restrict activities and participation in society [4,5].

The bus is form of public transportation used by the vast majority of older people in Brazil. However, its current structure, which exposes riders to physical barriers, results in difficulties in terms of accessibility, limiting the independence of older people and individuals with impaired mobility, such as those with PD [6].

The growing population of older people and the increase in the incidence of neurodegenerative diseases underscores the need for projects aimed at the maintenance of health and functioning [6]. Considering the negative association between the fear of falling and both participation and health-related quality of life in individuals with PD [7], a functional investigation applied to a commonplace activity, such as boarding a bus, is important.

The present study aimed to investigate associations between the fear of falling and cognitive status, handgrip strength, upper limb pulling force and execution time when boarding a prototype bus entrance during a single task and dual task in older people with Parkinson's disease. Taking context into consideration, we believe that individuals with PD would present a concern with falling during the performance of functional activities due to the reduction in strength and possible neuropsychiatric changes.

METHODS

Participants

A cross-sectional study was conducted involving 31 individuals with diagnosis of idiopathic PD according to the criteria of the London Brain Bank [8] recruited from the Specialized Neurofunctional Physical Therapy outpatient clinic of *Universidade Estadual de Londrina* (UEL). All participants received clarifications regarding the purpose of the study and assessment procedures and agreed to participate by signing a statement of informed consent. This study received approval from the UEL Human Research Ethics Committee (certificate number: 3.714.070).

Individuals with PD 60 years of age or older with independent gait without the use of a gait-assistance device, with a self-reported minimum of 120 minutes of any physical activity per week for at least the previous six months, disease stage between 1.0 and 3.0 according to the modified Hoehn & Yahr scale [9] and taking antiparkinsonian medication (levodopa) with stable doses for at least 3 months were included in the study. The exclusion criteria were other associated neurological diseases, musculoskeletal disorders, severe heart disease, associated disorders, cognitive impairment determined using the Mini Mental State Examination (MMSE) [10], comprehension difficulties that could interfere with the assessment process and inability to execute the tests.

Assessment procedures

The participants were assessed in two steps, both during "on" stage of dopaminergic medication by the same assessor. The first step consisted of tests related to the disease stage and progression of signs and symptoms, for which the modified Hoehn & Yahr (HY) scale, MMSE scale and Unified Parkinson's Disease Rating Scale (UPDRS) parts II and III of the Movement Disorder Society were used. In the second step, a questionnaire was administered addressing sociodemographic characteristics (sex and age), anthropometric characteristics (height, mass and body index mass [BMI]) were measured using an anthropometric mechanical scale Filizola® and the use of public transportation was investigated. The following tests and instruments were also administered:

Falls Efficacy Scale – International (FES-I) to assess the degree of concern with falls. The score ranges from 16 to 64 points, with a score ≥ 23 points suggesting an association with a history of sporadic falls and scores > 31 points suggestive of recurrent falls [11].

Bus entrance prototype with height, width and depth identical to that of the transportation most used in the city of Londrina, state of Paraná, Brazil. The participants performed the functional activity of climbing the stairs of the bus, simulating a commonplace situation. The first step was 40 cm above the ground and the second and third steps had a height of 30 cm each. Two handrails were fixed with lateral supports at a height of 116 cm from the first step and presented the same bar format as the handrail of a conventional bus. Two dynamometers were attached vertically to the handrails at 45º in relation to the ground, measuring 40 cm in length. The horizontal distance between the dynamometers was 70 cm, which is equivalent to the exact position of handrails that enable access to a conventional bus (Figure 1).

Figure 1. Prototype of bus entrance. Source: personal file.

Maximum upper limb muscle strength: Right handgrip strength, left handgrip strength, right upper limb pulling force and left upper limb pulling force were determined using two compression dynamometers (model EMG800C®, EMG System do Brasil Ltda®, São José dos Campos, São Paulo, Brazil). The system was calibrated for the measurement of strength (in kilogram-force [kgf]) in real time. The files were then saved for subsequent analysis. During the acquisition of the signals, time was normalized using a sampling frequency of 2 kHz per channel, an A/D converter with 16 bits of resolution, 600-fold dynamometer signal conditioner and Butterworth filter with a frequency band of 0-100 Hz. Handgrip strength was measured with the participant in the standing position in front of the prototype, feet apart (hip width) with the hand gripping the center of the force cell positioned on the handrail, shoulder in neutral position and elbow flexed. When necessary, wooden plates were used to correct the participant's height in relation to the bar and ensure the proper positioning of the upper limbs during the determination of maximum upper limb strength.

The participants were instructed to perform maximum voluntary contraction (MVC) sustained for five seconds after the verbal command "squeeze the bar" by the examiner. Three repetitions were performed with each hand (total of six readings), respecting a one-minute rest interval between trials. Upper limb pulling force was determined with the participant in the same position as that described above, but the foot contralateral to the hand being tested was positioned forward. The participant was instructed to perform MVC for five seconds during the pulling force task following the command of "pull the bar downward" by the examiner. Three repetitions were performed with each upper limb, respecting a one-minute rest interval between trials. The order of the MVC handgrip and pulling force tests was randomized by an independent researcher using the program available on the www.random.org site.

A previous study involving older people with the same equipment (dynamometer/bar) determined that this instrument is reliable for measuring handgrip strength and upper limb pulling force [12]. The data were processed using the software program provided by *EMG System™ do Brasil* considering the peak of the signal captured during MVC to be maximum strength. The best result of the three trials of each side (in kgf) for both handgrip strength and upper limb pulling force was used for the analyses, as suggested by Trampisch et al. [13].

Functional task on bus entrance prototype: The participants were first familiarized with the assessment and subsequently performed the functional task, which consisted of climbing the three steps of the prototype bus entrance starting on the ground and using the two lateral handrails (as they usually performed in daily living). The functional tasks were performed under the following conditions:

Single task (ST) – Climbing the stairs with the aid of the handrails beginning with the individual's foot of choice.

Dual task (DT) – combination of ST described above and a cognitive task, which consisted of hearing a sequence of letters on two audio recordings. The first was the sequence "A F E F C J F B C J" and the second was the sequence "F C F B F D T F R O" [14]. The participant was instructed to climb the steps and say how many times of the letter "F" was pronounced in the recordings. This task was chosen because it requires an attentional demand during the entire time of boarding the bus and enables standardized feedback.

Bilateral handgrip strength and pulling force were measured simultaneously under both conditions (ST and DT). Execution time on the ST and DT was measured (in seconds [s]) using a stopwatch beginning with the examiner's command and ending when the participant completely finished climbing all three steps. The order of the ST and DT was equally randomized. According to Miri et al. [14], each task was performed twice with a one-minute rest interval between trials.

Statistical analysis

The measures used in the analyses were mean MMSE, FES-I, handgrip strength, pulling force and execution time during the ST and DT. The Shapiro-Wilk test was used to determine the distribution (normal or non-normal) of the data. Continuous data were expressed as mean and standard deviation. Categorical data (use of public transportation, dominant side and upper limb of choice during the task) were expressed as absolute and relative frequency.

A sub-analysis was also performed considering the division of the sample into “use” or “nonuse” of public transportation. For such, Levene’s test was used to determine equality of variances and the t-test for independent samples was used for the comparisons of the groups.

Pearson’s correlation test was used to determine the strength of correlations between the FES-I score and MMSE, MVC for right handgrip, MVC for left handgrip, MVC for right pulling force, MVC for left pulling force, ST execution time and DT execution time. Correlation coefficients (r) were interpreted as weak ≤ 0.39, moderate (0.40 to 0.69) or strong (≥ 0.70) [15]. A p-value < 0.05 was considered indicative of statistical significance. All analyses were performed with the aid of the IBM SPSS Statistics program for Mac, version 27.0.

RESULTS

The sample was composed of 31 individuals with PD (23 men and eight women). The clinical characteristics, data for the characterization of the participants and information on the use of public buses are displayed in Table 1.

Moreover, a sub-analysis was performed between individuals who “used” and “did not use” the bus. The comparison of the variables is given in Table 2. No statistically significant differences were found for any of the outcomes analyzed.

The scatter plot diagrams display the data corresponding to the correlation analysis of the FES-I score with MVC for handgrip strength and upper limb pulling force (bilaterally) as well as ST and DT execution time of the participants upon climbing the bus entrance prototype and MMSE. Moderate statistically significant correlations were found between the FES-I score and maximum strength for right handgrip strength (Figure 2), left handgrip strength (Figure 3), right pulling force (Figure 4) and left pulling force (Figure 5), indicating that a greater concern about falling was correlated with lower maximum upper limb strength. Moderate correlations were also found with execution time on the ST (Figure 6) and DT (Figure 7), indicating that the greater the fear of falling, the longer the execution time in ST and DT). A weak statistically significant correlation was found between the total FES-I score and MMSE (Figure 8). No statistically significant correlations were found between the FES-I score and handgrip strength or pulling force during the ST or DT.

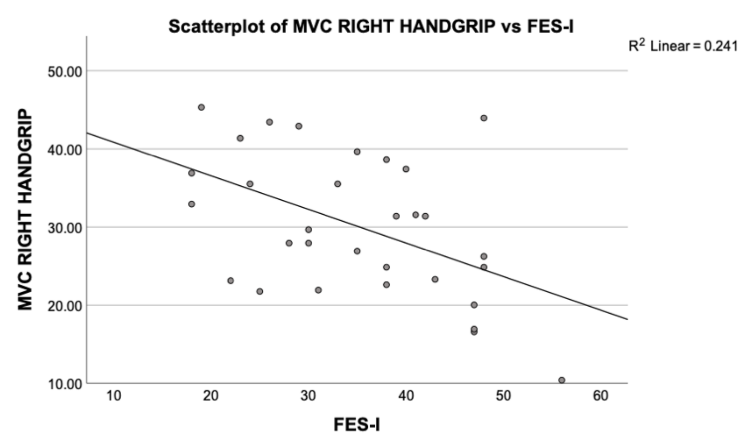

Figure 2. Person correlation between MVS right handgrip vs FES-I.

Table 1. Characteristics of participants and data on use of public bus transportation.

Variables	Use bus (N = 22)	Not use bus (N = 9)	p

Variables	**N = 31**
Sex (M/W)	23/8
Age (years)	70.85 ± 5.36
UPDRS part II	12 ± 5.87
UPDRS part III	33 ± 14.22
UPDRS Total	45 ± 17.51
HY - 1	1 (3.2%)
HY - 1.5	8 (25.8%)
HY - 2	15 (48.4%)
HY - 2.5	3 (9.8%)
HY - 3	4 (12.9%)
BMI (kg/m²)	28.26 ± 4.30
MMSE	26.22 ± 3.32
FES-I	34.74 ± 9.94
Years of schooling	9.13 ± 5.62
Maximum voluntary contraction (kgf)	
Right handgrip	30.43 ± 8.60
Left handgrip	30.77 ± 9.56
Right pulling force	10.77 ± 3.24
Left pulling force	6.77 ± 2.41
Strength during simple task (kgf)	
Right handgrip	13.35 ± 4.71
Left handgrip	12.37 ± 3.73
Right pulling force	9.34 ± 2.30
Left pulling force	6.35 ± 1.87
Strength during dual task (kgf)	
Right handgrip	12.70 ± 4.37
Left handgrip	11.18 ± 3.22
Right pulling force	9.14 ± 1.98
Left pulling force	6.32 ± 1.82
Time (s)	
Simple task	6.14 ± 2.22
Dual task	6.08 ± 2.12
Uses bus? (n/%)	
Yes (always/sometimes)	22 (71%)
No (has used/never used)	9 (29%)
Stopped using bus due to difficulty? (n/%)	
Yes	2 (6.5%)
No	28 (90.3%)
Uses bus alone? (n/%)	
Yes (always/sometimes)	22 (71%)
No	6 (19.4%)
Difficulty climbing stairs? (n/%)	
Yes (some/much difficulty)	22 (71%)
No	6 (19.4%)
Dominant upper limb (n/%)	
Right	29 (93.5%)
Left	2 (6.5%)
Preference for initiating task (n/%)	
Right lower limb	23 (74.2%)
Left lower limb	8 (25.8%)

Legend: M = Men; W = Women; UPDRS: Unified Parkinson's Disease Scale; HY = Modified Hoehn & Yahr Scale; BMI = Body mass index; MMSE = Mini-Mental State Examination; FES-I = Falls Efficacy Scale International; kgf: Kilogram-force; s = Seconds; (%): Percentage.

Table 2. Comparison of variables between groups that use and do not use bus.

MMSE	25.64 ± 3.23	27.56 ± 2.40	0.120
FES-I	33.73 ± 11.13	38.22 ± 7.64	0.279
Maximum voluntary contraction (kgf)			
Right handgrip	30.23 ± 9.80	29.74 ± 7.31	0.893
Left handgrip	29.99 ± 9.52	32.39 ± 9.83	0.534
Right pulling force	11.38 ± 3.41	9.64 ± 3.46	0.209
Left pulling force	7.06 ± 2.29	5.68 ± 2.40	0.140
Time (s)			
Simple task	6.21 ± 2.20	6.13 ± 2.18	0.925
Dual task	6.18 ± 2.20	5.87 ± 1.57	0.707

Legend: MMSE: Mini-mental Examination State; FES-I: Falls Efficacy Scale International; kgf: Kilogram-force; s = Seconds.

DISCUSSION

This is the first study conducted in Brazil to correlate the fear of falling with cognitive status, maximum voluntary contraction, upper limb pulling force and handgrip strength during the functional task of boarding a bus in individuals with Parkinson's disease. No differences were found in the variables studied between individuals who used and those who did not use public transportation. A greater degree of fear was correlated with less maximum handgrip strength and upper limb pulling force as well as a longer execution time on the single and dual tasks.

Studies in the literature have addressed postural instability in healthy older people and those with PD and the repercussions for dynamic tasks, such as walking and going up and down stairs, culminating in a greater risk of falls [16,17]. Due to its complexity, the task of going up and down stairs requires more of the neuromotor system in individuals with a certain degree of frailty, such as the older population and individuals with PD. This is due to deficient anticipatory postural adjustments at the onset of gait as well as the difficulty in maintaining one's balance during the transition between the static and dynamic states [18]. Moreover, deficits in sensory integration combined with poor motor planning due to changes in the basal ganglia increase the difficulty and affect the performance of complex activities, such as boarding a bus.

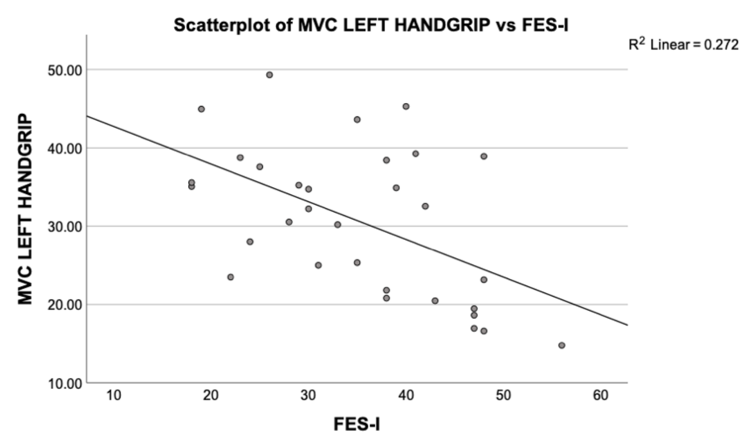

Figure 3. Person correlation between MVS left handgrip vs FES-I.

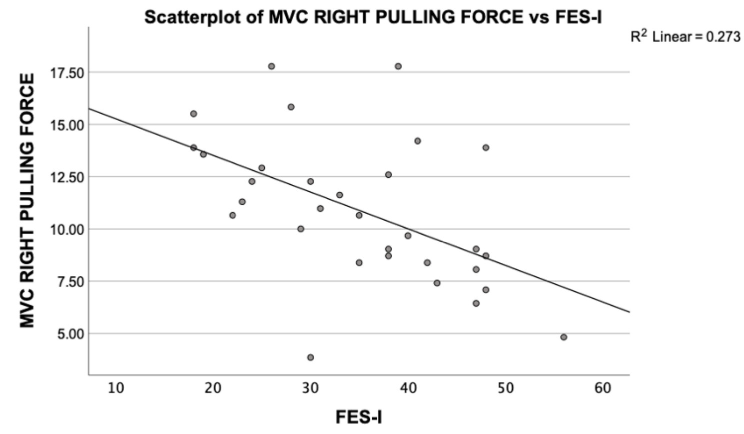

Figure 4. Person correlation between MVS right pulling force vs FES-I.

The increased risk of falls during the performance of activities of daily living (ADLs) due to balance deficit can lead to a greater incidence of injuries as well as the manifestation of the fear of falling, which contributes to the loss of independence and an increase in social isolation, exerting a negative impact on quality of life among individuals with PD [7,19]. Considering the importance of social participation as a strategy for active aging [20] and the vulnerability of older people to characteristics of the urban environment [21], the present study analyzed the correlation of the fear of falling with the task of climbing stairs in older people with PD in a real context – boarding public transportation (bus), which is widely used throughout the world, especially Brazil, due to the noteworthy social and economic differences in the country [5,22].

Weakness in different muscle groups has been investigated in individuals with PD, especially the lower limbs, due to associations with postural instability, the decline in physical functioning, gait performance and the risk of falls [4]. In a recent systematic review, however, Proud et al. [23] pointed out the scarcity of studies with high methodological quality that support the validity and response capacity of the numerous clinical tests currently used in the assessment of upper limb function in individuals with PD. Progressive upper limb impairment occurs throughout the course of the disease, with reductions in strength, fine manual dexterity and two-hand coordination, compromising the capacity to perform ADLs as well as restricting participation in work, recreational and social activities [24,25].

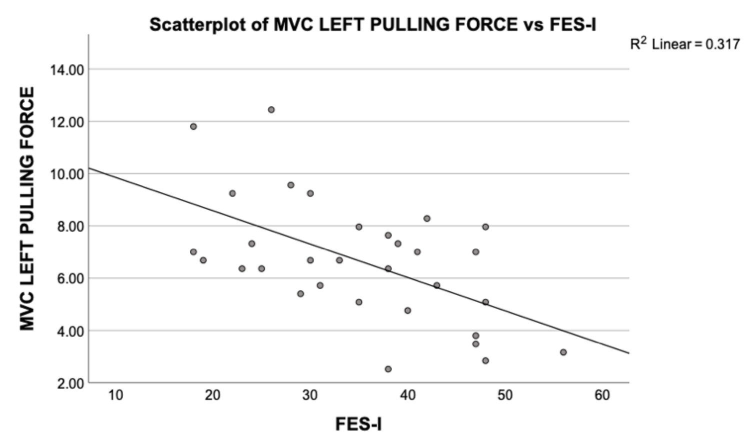

Figure 5. Person correlation between MVS left pulling force vs FES-I.

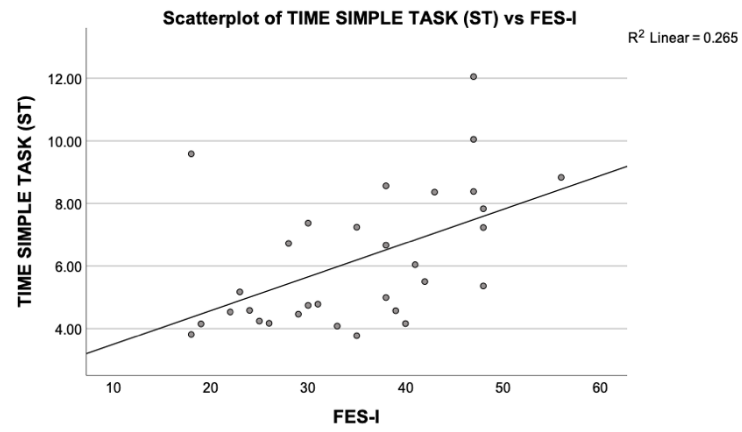

Figure 6. Person correlation between Time simple task vs FES-I.

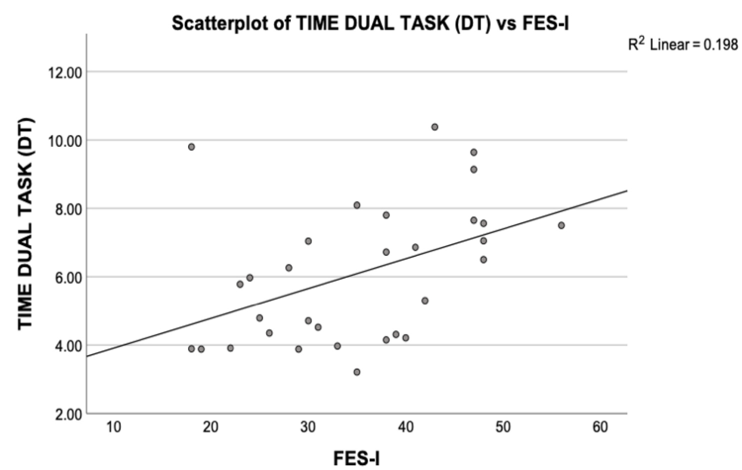

Figure 7. Person correlation between Time dual task vs FES-I.

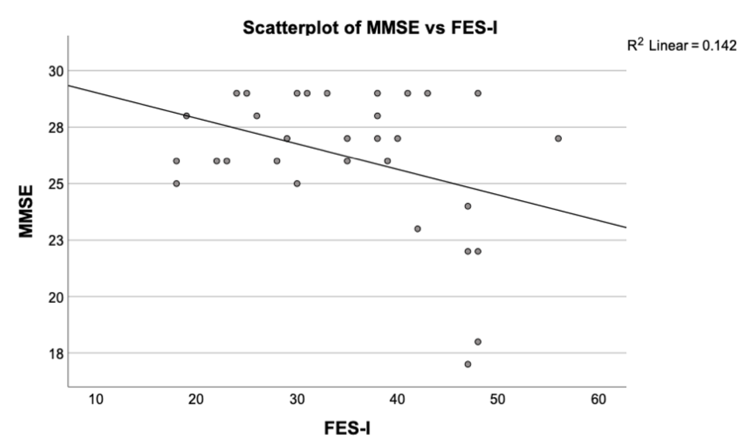

Figure 8. Person correlation between MMSE vs FES-I.

Studies have demonstrated the importance of the investigation of handgrip strength in older people as an indicator of overall muscle strength and due to its association with frailty and proneness to falls as well as the association between the decline in handgrip strength and the loss of functioning [3,25,26]. In the present study, significant moderate correlations were found between the fear of falling and both maximum handgrip strength and upper arm pulling force when boarding a bus, which is in agreement with data described in previous studies [27,28]. Fear of falling is closely related to the loss of functioning due to the greater social isolation and physical inactivity of individuals with PD, which, in turn, leads to a reduction in overall muscle strength (measured by handgrip strength) [2,3,19].

Cognitive impairment in PD is an important predictor of the increase in dependence on ADLs, with impacts on wellbeing and quality of life [29]. Mobility and cognition – specifically executive functions and attention – are closely interconnected and affect one another in PD [30]. This is due to the high level of information processing and attention allocation that occurs during the execution of two simultaneous tasks as a function of the involvement of basal ganglia, leading these individuals to present a loss of automaticity in daily activities, such as walking, when attention is directed toward balance control and gait, which results in the loss of functional mobility and predisposes these individuals to an increased risk of falls [30,31]. This explains the significant correlations between the FES-I score and both the MMSE score and execution time on the task of climbing the stairs of the bus during both the ST and DT, as the interference of cognition with mobility due to the loss of automaticity during activities that involve a dual task leads to an increased risk of falls and, consequently, a greater fear of falling. The weak correlation found between the FES-I and MMSE scores may be related to the sample of the present study, which was composed of individuals in the mild to moderate stages of the disease on the HY scale, as greater severity of the disease is related to greater cognitive impairment [32].

Thus, the present study reveals the importance of upper limb motor control and cognition in functioning and mobility during ADLs in individuals with PD. The literature offers evidence of the importance of the upper limbs and cognition to the quality of life this population. Acaröz, Candan & Özcan [31] found that the severity of the disease, the interference of a dual task on dexterity of the dominant hand and bradykinesia contributed to difficulties in performing ADLs. The authors also found that the interference of the dual task on dexterity of the dominant hand is a strong indicator of performance on ADLs in PD. Analyzing cognitive/motor performance during upper limb movements, Bank et al. [33] found that the degree of interference under the DT condition in individuals with PD seemed to be more related to cognitive rather than motor function, which demonstrates the impact of cognitive deficit on ADLs in individuals with PD, who depend on cortical executive control even for routine tasks due to the dysfunction of basal ganglia. Thus, there is a need to train upper limb motor skills during therapy as well as train single and dual tasks and include cognitive training in the rehabilitation process with the aim of improving performance of ADLs, increasing mobility and diminishing the fear of falling in this population.

The broad functional spectrum of the upper limbs in ADLs and its correlation with the fear of falling in the older population with PD reported in the present study can assist in understanding the repercussions of upper limb strength deficit during the task of boarding a bus. The findings underscore the need for future studies on the involvement of the upper limbs during ADLs in individuals with PD to assist in guiding clinical practice and policies directed at improving accessibility, as these individuals are submitted to numerous environments and activities that require dexterity and high cognitive processing.

The major strength of this study was the analysis of the correlation between fear of falling and performance when boarding a bus, which is a functional task that indicates independence and was assessed using equipment with dimensions identical to those found on a conventional bus, simulating the execution of a real-world activity. The limitation of this study was the absence of a control group for the comparison of individuals with and without PD, although the main objective was to correlate the fear of falling with the capacity to board a bus in the population with PD. Still, although less than 13% of the individuals (4 out of 31) were in stage 3 of HY, this may have been a limitation, which could influence when boarding a bus, as these individuals have more evident balance deficits. Future studies should broaden the investigation in individuals with cognitive decline and more advanced stages of the disease.

As implications for practice, the present findings underscore the need for functional training of the upper limbs as well as training of the cognitive system through the inclusion of dual-task activities – considering the important impact on functioning – to ensure safe, effective locomotion and minimize the risk of falls in older people with PD.

CONCLUSION

We conclude that boarding a bus is a difficult task for individuals with Parkinson's disease during both the single task and dual task, as this population presents a decline in the maximum muscle strength of handgrip and pulling force, and due to this physical alteration, the concern about falling becomes evident.

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