Mobility disorders in Stroke, Parkinson disease, and multiple sclerosis: A multicenter cross-sectional study

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MOBILITY DISORDERS IN STROKE, PARKINSON'S DISEASE AND MULTIPLE SCLEROSIS:

A MULTICENTER CROSS-SECTIONAL STUDY

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Conflict of interest

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Drs. Cattaneo, Gervasoni, Bianchi, Aprile, Imbimbo, Russo, Cruciani, Jonsdottir and Agostini declares that there is no conflict of interest.

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ABSTRACT

Objective: To compare mobility in multiple sclerosis (MS), Parkinson's disease (PD) and stroke, and quantify the relationship between mobility and participation restrictions. **Design**: Multicenter cross-sectional study. Included were compliant subjects with PD, MS and stroke seen for rehabilitation, with no comorbidities interfering with mobility. Functional scales were applied to each subject to investigate gait speed (10-meters walking test), balance while maintaining body position (Berg Balance Scale), dynamic balance and mobility (Timed-Up-&-Go and Dynamic Gait Index) and participation (Community Integration Questionnaire). **Results**: 299 patients (111 MS, PD and stroke 94 each) were enrolled. Stroke had the slowest gait speed (mean gait speed 0.9 m/s) compared to PD (1.1 m/s) and MS (1.2 m/s); P <0.001). Multiple Sclerosis was more limited than PD and stroke in dynamic balance both in the Timed-Up-&-Go Test (MS 16.7s, PD 11.4s, stroke 14.0s; P<0.001) and Dynamic Gait Index (MS 11.6 points, PD 12.9 points, stroke 13.6 points, P=0.03); ability to maintain balance and body position (Berg Balance Scale) was more affected in stroke and PD than MS (MS 42.6 points, PD 39.4 points, stroke 39.7 points; P=0.03). Balance disorders were associated with participation restrictions but not gait speed. **Conclusion:** Neurological conditions have differing impacts on gait and balance, leading to different levels of participation restriction.

Keywords: Parkinson disease; multiple sclerosis; stroke; falls; mobility.

List of abbreviations

BBS = Berg Balance Scale

CIQ = Community Integration Questionnaire

DGI = Dynamic Gait Index

IADL = Instrumental Activities of Daily Living

IQR = Interquartile range

MMSE = Mini-mental State Examination

MS = Multiple sclerosis

ND = Neurological disorders

PD = Parkinson's disease

TUG = Timed-Up-&-Go

10MWT= 10 meters walking test

Introduction

Mobility and balance disorders are frequently reported in subjects with neurological disorders (ND) in view of their impact on participation in social activities.[1] Deficits in post-stroke mobility include impaired standing balance on the paretic leg and reduced propulsion at paretic push-off, leading to slow gait and an increased risk of falls.[2] Mobility disturbances are almost universal in people with Parkinson's disease (PD) and involve balance deficits, freezing of gait, and bradykinesia, leading to a slowing of gait speed and a high fall risk.[3] People with multiple sclerosis (MS) have a range of gait abnormalities, including shorter step length, increased variability of gait parameters, and balance disorders[4] that have been identified as fall risk factors.[5]

Given the above, mobility and balance disorders are frequently assessed and treated in subjects with stroke, PD and MS in a clinical setting. However, it is difficult to compare the mobility deficits in different ND because of different methodological approaches.

The assessment of different conditions using common tools could provide fuller understanding of the different effects of a given pathology and individual functional problems on mobility and balance, facilitating the development of tailored assessment. The assessment of different pathological conditions could reveal that certain balance and mobility disorders are more prevalent in certain diseases and could serve to orient clinicians toward a disease-specific assessment leading to more tailored interventions.[6] Moreover, although it is known that mobility and balance impairments can cause participation restrictions[7,8] the impact of these impairments on participation has not been quantified and no comparison of neurological conditions has been reported. Consequently, the use of the same assessment methods might be indicated in identifying and comparing common balance and mobility factors associated with participation restrictions. The identification of these factors is important because they are mostly modifiable and may respond to rehabilitation. Further, investigation of the magnitude of these

relationships with tools commonly used in rehabilitation could give indications to clinicians, prompting them to undertake a more thorough analysis of pathology-specific balance impairments and their impact on daily living activities.

The aims of the present study were to compare balance and mobility in MS, PD, and stroke and quantify the relationship between disease-specific mobility limitations and participation restrictions.

Material and Methods

This study stems from a large multicenter prospective cohort study conducted from 27 February 2013 to 7 September 2015, to compare the risk of falls and identify fall predictors in patients with PD, MS, and stroke.[9] In the present cross-sectional study we focused on baseline data. Eligible patients were subjects with PD, MS or stroke in need of rehabilitation, in three Italian rehabilitation centers. Written informed consent was obtained from each patient. We excluded people having at least one among: 1. Cognitive impairment (Mini-Mental State Examination score <21); [10] 2. Major depression (Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition); [11] 3. Severe joint/bone disorder defined as impairments interfering with balance and gait (based on clinical judgment); 4. Aphasia if interfering with understanding the aims of the study and self-administered tests; 5. Relapses in the previous three months (MS); 6. Stroke occurred less than four weeks before study entry. Information on the presence of major depression, aphasia and time from relapses and stroke was retrieved from clinical charts and medical history.

Examinations carried out were all done by experienced clinicians in each center trained for the assessment. Information on clinical variables, disease type, duration, and use of walking aids was collected and all participants were assessed with investigating scales: 1. Balance and maintenance of

body position, Berg Balance Scale (BBS), ranging from 0 (poor balance) to 56 (good balance)[12]; 2. Dynamic balance and mobility: Dynamic Gait Index (DGI), ranging from 0 (poor performance) to 24 (good performance)[12] and Timed-Up-&-Go (TUG) test[13]; 3. Walking speed, 10 meters walk test (10MWT) as a proxy of walking ability[14]; 4. Instrumental Activities of Daily Living (IADL), ranging from 0 (completely dependent) to 8 (independence) for both sexes[15]; 5. Social integration, Community Integration Questionnaire (CIQ), ranging from 0 (no integration) to 29 (excellent integration).[16]

The operational definition of the scale domains was based on International Classification of Functioning, Disability and Health[17]. In the balance and mobility outcome, the total value of the BBS refers to maintaining and changing body position (d410, d415) while the DGI and the TUG test refer to dynamic balance and functional mobility since they include aspects such as, turning during gait and performing head movements during gait (d450). The use of the 10MWT as a measure of walking ability refers to gait speed as an important measure of community walking and participation.[18,19]

The use of a walking aid was allowed during testing, if needed. All participants using a wheelchair could walk at least 10 meters using a walking aid according to inclusion criteria. In line with the literature, participants using a rollator or a wheelchair received a score of 0 at the DGI.[20]

The study was approved by the local ethics committees.

Berg Balance Scale (BBS), DGI, TUG scores and the 10MWT score were compared between conditions using multivariable linear models, adjusting for IADL score and use of a walking aid. We did not find any significant effect of age and disease duration on the selected scales, so these variables were not entered in the models.

To ensure standardization between centers, an instruction booklet was used and two practice sessions were held to minimize the differences between the three assessors.

We checked for homogeneity of variances, relationship between the response and predictor, distribution of the residuals, and influential points. The TUG scores did not meet the assumptions of data normality, so Box-Cox transformation (λ-0.06) was applied.[21] We used least square means to represent adjusted values and contrast analysis to compare conditions. Since MS causes specific walking difficulties when turning the head,[20, 22] we compared conditions during the execution of the third item of the DGI (walking while turning the head). Finally, we used a multivariable linear model to quantify the impact of balance and mobility disorders on social integration (CIQ score). The model was adjusted for IADL, and for balance and walking speed scales.

This study conforms to all STROBE guidelines and reports the required information accordingly (see Supplemental Checklist, Supplemental Digital Content 1, http://links.lww.com/PHM/A840).

Results

The study sample comprised 299 patients with PD (94), MS (111) and stroke (94) with a median age of 63.7 years (IQR, 52.5-72.0y). Men (median age 62.9 years, IQR, 53.9-70.9) and women (median age 64.5 years, IQR, 51.5-72.7) were equally represented.

At baseline, all three patient groups presented with moderate to severe mobility impairment (Table 1). Fifty-six percent did not reach the cut-off of 45 points at the BBS and 67% did not reach the cut-off of 19 points at the DGI, indicating they had balance disorders while maintaining body position and in dynamic balance as well as an increased risk of falls.[23, 24] Also on the TUG test (14.8s, IQR:9.1-21.1)

people with PD (11.5s)[25] and people with stroke (14s) [26] exceeded the cut-off scores for risk of falls while the cut-off score has not been established for MS.

People with MS were younger (PD = 70.4 (9.8), MS = 54.3 (11.1), stroke = 64.1 (12.3)), with higher education and longer disease duration than the other two conditions (Table 2). Stroke and PD predominated in men and MS in women. People with PD used walking aids less than those with MS and stroke.

The model for the **10MWT** (Table 3) fitted the data (overall P<0.001) and indicated significant associations between this test, IADL and walking aids, with subjects with a lower level of independence and using an assistance device having worse performances. We also found statistically and clinically significant differences across conditions (Figure 1). Contrast analysis showed MS performed better than stroke with a mean difference of 0.31m/s (P<0.001); PD also performed consistently better than stroke, with a mean difference of 0.17m/s (P=0.05). People with MS were faster than PD although the difference of 0.13 m/s was not statistically different (P=0.18).

Dynamic Gait Index (DGI) total scores (Table 3) showed the same significant association between dynamic balance and IADL and walking aid, with worse scores for people who used a walking aid and were less independent (P=0.03). The MS had the lowest total scores (Figure 1). Contrast analysis gave 2.1 points difference between stroke and MS (P=0.02), 1.2 points between PD and MS (P=0.28), and only 0.8 points difference between stroke and PD (P=0.60).
We investigated differences across conditions during the execution of Item 3 of the DGI to assess the specific impact of head rotations on dynamic balance. Figure 2 depicts more difficulties for MS and

stroke compared with PD when walking while turning the head left and right; however, the differences were not significant after controlling for IADL score and the use of walking aids.

The **TUG test** showed significant differences across conditions, with associations between TUG and IADL and walking aid (P<0.001, Table 3). The analysis (Figure 1) confirmed MS-related disorders in dynamic balance with MS taking 5.3s (back-transformed values) longer than PD to complete the TUG (P<0.001) and 2.7s longer than stroke (P=0.04), while PD took 2.5s longer than stroke (P=0.02).

The model for **BBS** is reported in Table 3. We found the same significant associations with IADL and walking aid (p=0.03). Least squared means (Figure 1) showed worse performance for stroke and PD than MS. Contrast analysis gave a 3.1-point difference between PD and MS (P=0.05), 2.9 points between stroke and MS (P=0.07) and no difference (0.27 points) between PD and stroke (P=0.98).

Subjects with PD and stroke had a significantly lower **CIQ** rating than MS (Figure 3). Contrast analysis indicated -3.00 points difference between PD and MS (P<0.001), -2.73 points between stroke and MS (P<0.001) and only 0.25 points between stroke and PD (P=0.92).

Table 4 reports the results of multivariate analysis, with CIQ as dependent variable. The first model included all dependent variables listed in Table 3. In this model, 10m Walking Test, walking aid and TUG were not associated with the CIQ. After removing these variables, the overall P value was <0.001. Similarly to the first model, we found a significant association between CIQ and IADL and balance scales (BBS and DGI).

Discussion

The aims of this study were to compare mobility and balance disorders in three of the most disabling neurological conditions[27] and to study the relationship between mobility and balance tests and social participation restrictions. The results indicated that dynamic balance and mobility were impaired in all three diseases, although people with stroke and PD had worse balance during maintenance of body position, and people with stroke also had the slowest gait speed. Regarding participation, deterioration in balance during walking and the maintenance of body position were better independent predictors of participation restrictions than gait speed.

Measures of gait speed are frequently used to provide an indication of patients' abilities in daily life.[28,29] We found gait speed to be greatly reduced in all conditions, with a median of 1.0 m/s for males (1.04m/s) and females (0.90m/s), which is below normal for age-matched healthy females (1.3m/s) and males (1.4m/s). [30] Reduced gait speed is very likely due to a range of factors present in all these conditions such as age, muscle weakness, and use of walking aids. The co-presence of these factors makes it hard to understand the pathology specific effects on mobility. However, while we did not have measures of muscle strength, the present study adds important information to previous reports.

People with stroke walk more slowly than those with MS or PD, with a mean gait speed of 0.9 m/s (SD: 0.51), and almost 30% of our sample had a gait speed below 0.8 m/s, which is the cut-off classifying people as having difficulties in activities such as shopping and social outings.[18] This agrees with previous reports that walking speed is frequently reduced in persons with stroke, with changes in the stance/swing phase and lack of propulsive force.[31]

While all conditions have deficits in dynamic balance and mobility, people with MS appear to have even more impairment in their ability to modify gait in response to tasks with different demands for balance,

as indicated by lower scores on the DGI. This may contribute to their increased probability of falling: in fact lower DGI scores have been found to be related to an increased risk of falls.[20] In particular, they had difficulties in tasks requiring turning and head rotations that challenge visuo-vestibular information gathering, in line with other reports of sensory abnormalities in up to 80% of people with MS.[32,33,34] It has been speculated that visuo-vestibular disorders and somatosensory loss in MS may limit the accurate perception of physical input from the visual, somatosensory, and vestibular systems, and their integration, leading to inadequate motor responses affecting balance. People with PD had balance disorders as shown by low static and dynamic balance scores, giving support to findings of others that have referred impairment in postural adjustments[35], sensory disorders[36] and increased axial rigidity[37] in persons with PD. However, no specific differences emerged with MS and stroke when comparing the item requiring head movements on the DGI, and there were indications that head rotations were less disturbing for PD than for MS and stroke. We can speculate that reliable somatosensory information from the lower limbs in PD leads to better performance compared to MS and stroke.

Deficits in balance while maintaining body position were more pronounced in people with stroke and PD than in MS subjects. These differences could be also related to the subjects with stroke and PD being older than MS. However, data reported by others[38] indicates that this difference cannot be attributed solely to differences in age since the expected score of 51 points on the BBS for healthy 75-year-old people is well above the mean scores we recorded here (38 points for stroke, and 42 for PD). In addition, mean scores for stroke and PD were below the cut-off of 45 points, suggesting that both had clinically relevant deficits in maintaining body position. Although less pronounced compared to PD and Stroke, also MS had a BBS mean score (43 points) that was below the cut-off of 44 points established for this pathology.[39]

This overall difficulty in balance, highlighted by the low BBS scores, is a concern since maintaining and changing body position is important during home activities and impairments in these domains can lead to falls.[40] The study suggests the need for closer analysis of balance disorders in the domestic environment for people with neurological disorders.

Regarding participation, people with MS appeared to have fewer restrictions than PD and stroke. The results of the regression model, inquiring on the relationship between mobility and social participation, indicate that participation restrictions are mostly explained by IADL. The addition of static and dynamic balance added some explanation while gait speed was excluded from the model, suggesting balance is more associated with participation restrictions than gait speed. This agrees with previous studies showing relations between balance disorders and participation restrictions in MS[7] and in subjects with brain injury.[41]

The present study underlines the importance of assessing participation restrictions in people with low IADL scores. The results also show that poor performance on balance scales is of concern since it can increase the person's fear of falling, and consequently interfere with the basic activities of daily living and curtail overall activity.

Our findings suggest that the impact of different neurological conditions on balance should be addressed using scales measuring different aspects of balance and mobility. The use of common assessment tools revealed pathology-specific static or dynamic balance disorders interfering with the ability to maintain body position and gait adaptability. This suggests the need for pathology-specific in-depth assessment and tailored interventions.

Overall, the results also suggest that a multivariate assessment of mobility and balance could be useful to promote tailored interventions in the three neurological disorders studied with potential impact on level of participation.

The study has a number of limitations. First of all, apart from the extent of functional disability at the time of enrolment, data is not available on the specific phenotypes and the severity of each disease. Second, the previous rehabilitation programs (if any) and their effects on functional disability are not known. Third, we recruited a sample of subjects in need of rehabilitation, potentially reducing the external validity of the study results.

Conclusion

The present study illustrates the different effects of neurological conditions on functional ability, with people with all three conditions demonstrating dynamic balance disorders and people with stroke having slower gait speed. There were indications that the outcomes captured small but pathology specific and clinically relevant differences supporting recommendations[42] that clinicians carry out tailored pathology-specific assessments. Further, the results suggest that rehabilitation approaches should aim to reduce balance and mobility disorders in order to facilitate social participation.

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Figure 1. Least-squares means of clinical scales (Timed up and Go, Dynamic Gait index, Berg Balance Scale and Ten Meter walking Test) across the three conditions

TUG: Timed up and Go test, seconds (Transformed Data); DGI: Dynamic Gait Index; BBS: Berg Balance Scale; Ten_m: Ten meter walking test, m/s; ST: Stroke; PD: Parkinson Disease; MS: multiple Sclerosis.

Figure 2. Means and standard errors of DGI Item 3 (turning the head). The three box plots represent the three conditions (Multiple Sclerosis, Parkinson's Disease and Stroke).

Cond: Condition, MS: multiple sclerosis, PD: Parkinson disease, ST: Stroke

Figure 3. Least-squares means of Community Integration Questionnaire (CIQ) scores across the three conditions

CIQ:Community Integration Questionnaire; ST: Stroke, PD: Parkinson Disease, MS: multiple Sclerosis.

Figure 1

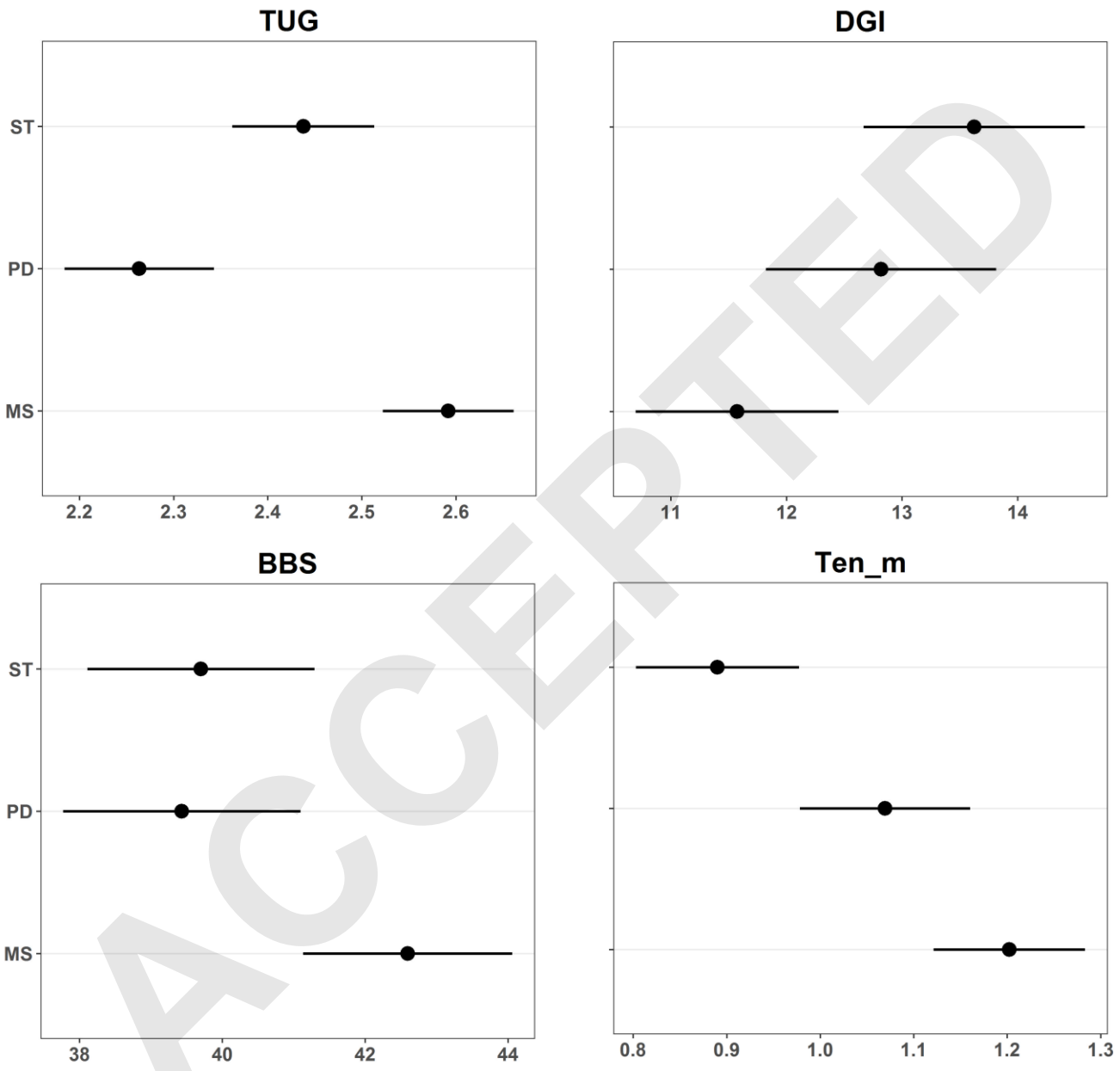

Figure 2

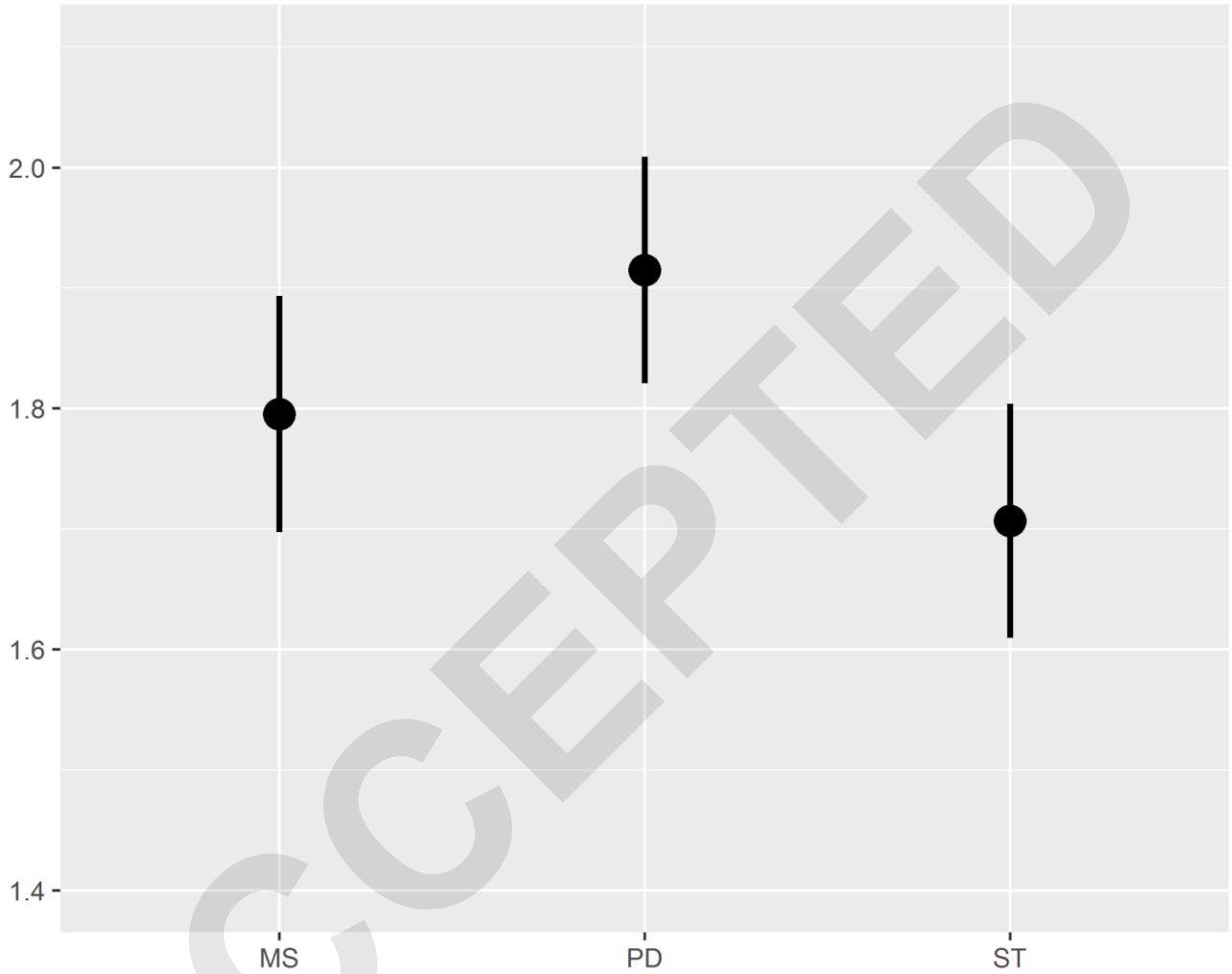

Figure 3

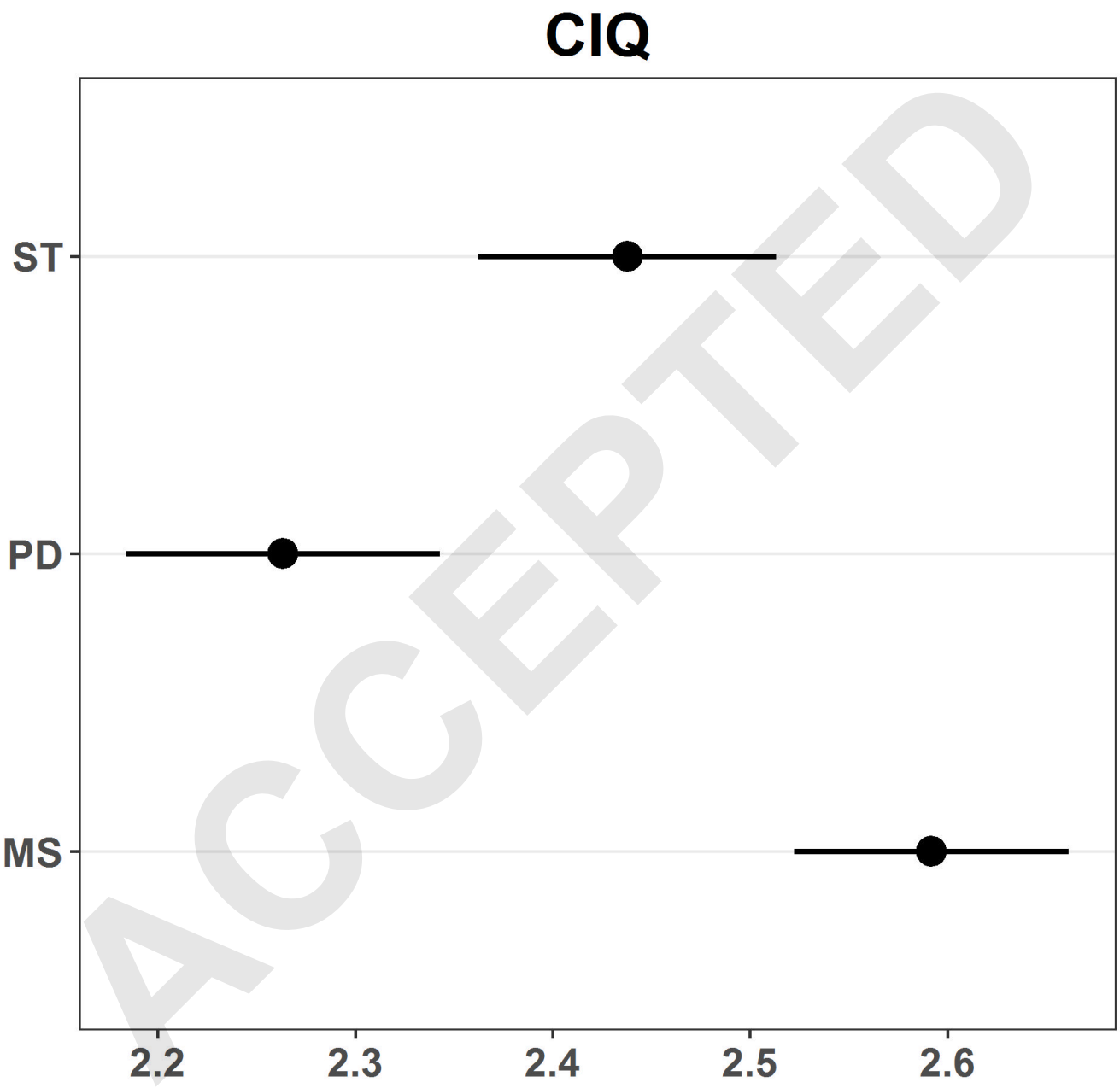

Table 1. General characteristics of the sample

	Total sample (N=299)	
	n	%
Age (years)		
<55	81	27.2
55-64	75	25.3
65-74	89	30.0
75+	52	17.5
Missing	2	
Sex		
Female	147	49.2
Male	152	50.8
Disease		
Multiple sclerosis	111	37.1
Parkinson	94	31.4
Stroke	94	31.4
Occupation		
Unemployed/Retired	202	68.5
Employed	93	31.5
Missing	4	
Education (years)		
0-8	91	30.9
9-13	114	38.8
14+	89	30.3
Missing	5	
MMSE		
>24	277	95.9
21-23	5	1.8
NA (patients with aphasia)	7	2.4
Missing	10	
Living alone		
No	258	87.2
Yes	38	12.8
Missing	3	
Walking aids		
None	141	47.2
Unilateral	64	21.4
Bilateral	49	16.4
Wheelchair	45	15.0

	N	Median score	IQR
Disease duration (years)	286	6.9	2.0 - 14.9
IADL	287	6.0	4.0 - 7.0

Timed up & go (s)	299	14.8	9.1 - 21.1
10 meters walking test (m/s)	296	1.0	0.5 - 1.4
Berg Balance Scale (BBS)	299	43.0	35.0 - 50.0
Dynamic Gait Index (DGI)	298	15.0	9.0 - 20.0
Community Integration Questionnaire (CIQ)	298	12.4	9.0 - 15.8

IADL: Instrumental activities of daily living. IQR: Interquartile range

Table 2. General characteristics of the sample at baseline for each disease separately

	Multiple sclerosis (N=111)		Parkinson (N=94)		Stroke (N=94)		p-value
	n	%	n	%	n	%	
Age (years)							
<55	58	52.3	7	7.5	16	17.2	<0.0001
55-64	33	29.7	13	14.0	29	31.2	
65-74	19	17.1	43	46.2	27	29.0	
75+	1	0.9	30	32.3	21	22.6	
Missing	0		1		1		
Sex							<0.0001
Female	74	66.7	33	35.1	40	42.5	
Male	37	33.3	61	64.9	54	57.5	
Occupation							<0.0001
Unemployed/Retired	59	53.6	76	81.7	67	72.8	
Employed	51	46.4	17	18.3	25	27.2	
Missing	1		1		2		
Education (years)							<0.0001
0-8	18	16.4	35	38.0	38	41.3	
9-13	39	35.4	35	38.0	40	43.5	
14+	53	48.2	22	24.0	14	15.2	
Missing	1		1		2		
Living alone							0.7664
No	95	86.4	83	89.3	80	86.0	
Yes	15	13.6	10	10.7	13	14.0	
Missing	1		1		1		
Walking aids							<0.0001
None	37	33.3	62	65.9	42	44.7	
Unilateral	28	25.2	15	16.0	21	22.3	
Bilateral	35	31.5	11	11.7	3	3.2	
Wheelchair	11	9.9	6	6.4	28	29.8	
	Median	**IQR**	**Median**	**IQR**	**Median**	**IQR**	
Disease duration (years)	15.5	9.9 - 22.8	6.9	4.4 - 11.3	1.0	0.4 - 2.3	<0.0001
IADL	7.0	5.0 - 8.0	6.0	4.0 - 8.0	4.0	3.0 - 7.0	0.0001
Timed up & go (s)	16.3	11.1 - 25.0	10.5	7.4 - 15.9	17.1	10.8 - 21.4	<0.0001
10 meters walking test (m/s)	1.1	0.6 - 1.6	1.1	0.8 - 1.5	0.7	0.5 - 1.1	<0.0001
Berg Balance Scale (BBS)	44.0	38.0 - 50.0	44.0	35.0 - 50.0	40.5	29.0 - 48.0	0.0749
Dynamic Gait Index (DGI)	14.0	0.0 - 19.0	17.0	12.0 - 21.0	13.0	9.0 - 20.0	0.0027
Community Integration Questionnaire (CIQ)	14.4	11.0 - 19.0	12.0	8.0 - 14.5	10.5	8.0 - 14.8	<0.0001

IADL: Instrumental activities of daily living.

IQR: Interquartile range

Table 3. Multivariables models for clinical variables

Variable	Predictor	Estimate	Std. Error	t	P value	Pr(>|t|)
Ten_M [m/s]	(Intercept)	1.15	0.10	11.06	P< 0.001	***
	Walking aid	-0.16	0.02	-6.89	P< 0.001	***
	IADL	0.04	0.01	3.90	P< 0.001	***
	CondPD [Ref: MS]	-0.13	0.08	-1.77	0.078	.
	CondST [Ref: MS]	-0.31	0.07	-4.30	P< 0.001	***
DGI	(Intercept)	13.86	1.13	12.22	P< 0.001	***
	Walking aid	-3.87	0.25	-15.28	P< 0.001	***
	IADL	0.48	0.13	3.80	P< 0.001	***
	CondPD [Ref: MS]	1.24	0.82	1.52	0.135	
	CondST [Ref: MS]	2.05	0.79	2.59	0.009	**
TUG [s]	(Intercept)	2.58	0.09	28.67	P< 0.001	***
	Walking aid	0.17	0.02	8.71	P< 0.001	***
	IADL	-0.04	0.01	-3.71	P< 0.001	***
	CondPD [Ref: MS]	-0.33	0.07	-5.04	P< 0.001	***
	CondST [Ref: MS]	-0.15	0.06	-2.47	0.014	*
BBS	(Intercept)	41.57	1.89	21.96	P< 0.001	***
	Walking aid	-3.62	0.42	-8.58	P< 0.001	***
	IADL	1.00	0.21	4.76	P< 0.001	***
	CondPD [Ref: MS]	-3.16	1.37	-2.31	0.021	*
	CondST [Ref: MS]	-2.90	1.32	-2.20	0.028	*

Ten_M: Ten metre walking test; DGI: Dynamic Gait Index; TUG:Timed up and Go test, seconds (Transformed Data); BBS: Berg Balance Scale; IADL: Instrumental Activities Of Daily Living. ; Cond: Condition, PD: Parkinson Disease, ST: Stroke, MS: Multiple Sclerosis.

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1

Table 4. Multivariables model for participation restrictions.

Variable	Predictor	Estimate	Std. Error	t	P value	Pr(>|t|)
CIQ	(Intercept)	6.76	1.16	5.85	<0.001	***
	IADL	0.55	0.10	5.56	<0.001	***
	BBS	0.08	0.03	2.36	0.02	*
	DGI	0.10	0.05	2.10	0.04	*
	CondPD [Ref: MS]	-2.98	0.64	-4.65	<0.001	***
	CondST [Ref: MS]	-2.73	0.63	-4.32	<0.001	***

CIQ: Community Integration Questionnaire; IADL: Independence in Activity of Daily Living, DGI: Dynamic Gait Index, BBS: Berg Balance Scale; Cond: Condition, PD: Parkinson Disease, ST: Stroke, MS: Multiple Sclerosis.

Signif. codes: '***' 0.001; '**' 0.01; '*' 0.05; '.' 0.1