The combination of short-step and wide-based gait is a gait characteristic in progressive supranuclear palsy: A retrospective, cross-sectional study

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Key summary points

Aim:

To investigated the gait characteristics in patients with progressive supranuclear palsy compared with healthy older persons and patients with Parkinson's disease.

Findings:

Progressive supranuclear palsy shows Parkinsonian gait—slower walking speed and shorter step length.

Step width and foot angle are larger ("wide-based-gait") in progressive supranuclear palsy than older persons and Parkinson's disease patients.

Message:

Gait characteristics in progressive supranuclear palsy are combined with Parkinsonism and cerebellar involvement.

Abstract

Purpose: Like Parkinson's disease (PD), gait disturbance is a major problem in progressive supranuclear palsy (PSP). Despite limited studies investigating the gait characteristics, we hypothesize that they differ from PD owing to the involvement of different brain lesions. Hence, this study aims to investigate the gait characteristics in patients with PSP by comparing with healthy older adults and patients with PD.

Methods: We identified 27 PSP patients, 25 PD patients, and 25 neurologically healthy older persons. Using a device that detected the distribution of foot pressure during walking, we analyzed gait variables and measured the walking speed (cm/s), cadence (steps/min), step length (cm), step width (cm), foot angle (°), and gait cycle time (s). Additionally, we calculated the coefficient of variation (CV, %) on walking speed and cadence and analyzed the gait characteristics by the PSP subtypes.

Results: In PSP and PD, the walking speed was slower and the step length was shorter than healthy controls. The CV of cadence in PSP was higher than healthy controls and PD. In PSP, the step width and foot angle were higher than healthy controls and PD. The gait cycle time was longer in PSP and PD than healthy controls. PSP with progressive freezing gait tended to display a faster walking speed. Furthermore, PSP with parkinsonism-resembling idiopathic PD tended to exhibit the larger step width and foot angle compared with PSP–Richardson's syndrome.

Conclusion: This study suggests that the gait of PSP was unstable with parkinsonism and wide-based, which might be similar to combining features of PD and cerebellar disorders.

Keywords:

Progressive supranuclear palsy;

Parkinson-related diseases;

Gait disturbance;

Parkinsonian gait;

Wide-based gait

1. Introduction

Progressive supranuclear palsy (PSP) is one of the progressive neurodegenerative disorders with cardinal characteristics as ocular motor dysfunction, postural instability, akinesia, and cognitive dysfunction [1,2]. In addition, gait disturbance is one of the major problems in PSP, which accounts for frequent falls [3].

Regarding gait characteristics, parkinsonism and gait freezing are common features both in PSP and Parkinson's disease (PD) [2,4], making the differential diagnosis challenging, especially in their early stage. As different brain lesions are involved in these diseases [5–7], we hypothesize that PSP develops some gait characteristics different from PD. However, to date, limited studies have explored the gait characteristics in PSP. Perhaps, the identification of some different characteristics could be useful for the differential diagnosis between PSP and PD. Recently, various clinical phenotypes of PSP have been reported; however, their gait characteristics remain unexplored. Thus, comprehending the characteristics of each phenotype is imperative for differential diagnosis in PSP.

Reportedly, gait disturbance is one of the crucial targets for rehabilitation in patients with PSP [8]. Although recent research has reported the impact of exercise, the evidence is inadequate [9,10]. Hence, elucidating the gait characteristics of PSP and their subtypes could lead to the establishment of optimal rehabilitation for patients with gait disturbance.

To elucidate the gait characteristics of patients with PSP, this study analyzes their walking using by gait analyzer and compares the finding with healthy older persons and patients with PD. Furthermore, this study aims to evaluate the gait characteristics by each PSP subtype of patients included in this study.

2. Materials and methods

2.1 Participants

All participants were 65 years of age or older. We identified 27 patients with PSP at Higashinagoya National Hospital, between 2014 and 2018, who were diagnosed probable or possible PSP by the Movement Disorder Society Criteria (MDS-PSP criteria) [2,11]. As comparative groups, we enrolled 25 neurologically healthy older persons (CON) in the community-dwelling and 25 patients with PD at Higashinagoya National Hospital who were diagnosed by the United Kingdom Brain Bank criteria [12]. We enrolled patients with PSP and PD who could spend their daily living with, at least, light aid and whose modified Rankin scale (mRS) [13] scores were ≤4.

2.2 Assessments

We assessed all participants' age, sex, body height, weight, and body mass index (BMI), as well as disease duration and mRS in patients with PD and PSP. The severity of motor

dysfunction in patients with PD and PSP was determined using the Unified Parkinson's Disease Rating Scale part III (UPDRS-III) [14] and Progressive Supranuclear Palsy Rating Scale part V and VI (PSPRS-V, VI) [15], respectively.

Gait variables were measured using a device that detected the distribution of foot pressure during walking (WalkWay MW-1000; Anima, Tokyo, Japan) [16]. Participants walked 6.4 m at their comfortable speed, which was distance adding the additional path of 2-m anterior and posterior of the whole length of the 2.4-m device. We obtained three measurements and calculated the average. The measured parameters were as follows: walking speed (cm/s), cadence (steps/min), stride length (cm), step width (cm), foot angle (°), and gait cycle time (s) in the stance, swing, and double supporting phase; these parameters were corrected by the body height. Furthermore, we evaluated the coefficient of variation (CV, %) on the walking speed and cadence.

2.3 Statistical analysis

We tested the normal distribution using the Kolmogorov–Smirnov test; based on the test results, we analyzed the parametric data by one-way ANOVA or Student's *t*-test and the nonparametric data by the Kruskal–Wallis test or the Mann–Whitney *U*-test for between-group comparisons. In addition, a post-hoc Bonferroni test was used for multiple comparisons if a significant difference was observed. Using the chi-square test, nominal scale (sex) was tested.

In this study, all statistical analyzes were performed using statistical software (IBM SPSS Statistics ver. 22; IBM Inc., Armonk, NY, USA), and we set the criterion for significance at 0.05.

3. Results

Table 1 summarizes the demographic data of all participants. we observed no significant differences in age, sex, body height and body weight. However, significant differences were noted in BMI ($F_{2,74}$ = 6.265, P = 0.003). In the post-hoc test, the BMI was significantly lower in patients with PD than CON (P = 0.029) and patients with PSP (P = 0.004). The disease duration exhibited no significant differences between patients with PD and PSP; however, the mRS was severer in patients with PSP than those with PD (P = 0.025).

Table 2 summarizes the results of gait analysis, and Figure 1 represents the footprint picture. We noted significant differences in the walking speed ($F_{2,74}$ = 30.116, P < 0.001), CV of cadence (Kruskal–Wallis, P = 0.001), step length (Kruskal–Wallis, P < 0.001), step width ($F_{2,74}$ = 5.283, P = 0.007), foot angle ($F_{2,74}$ = 4.886, P = 0.010), time of stance phase (Kruskal–Wallis, P = 0.031), and double supporting phase ($F_{2,74}$ = 12.569, P < 0.001). The post-hoc test revealed that the waking speed was significantly lower in patients with PSP (P < 0.001) and PD (P < 0.001) than CON. The step length was significantly lower in patients with PSP (P < 0.001) and PD (P < 0.001) than CON. In addition, the time of the double supporting phase was

significantly longer in patients with PSP ($P < 0.001$) and PD ($P < 0.001$) than CON. In these parameters, we observed no significant difference between patients with PSP and PD. The step width was significantly larger ($P = 0.007$) in patients with PSP than CON, although no difference was noted between patients with PD and CON. In patients with PSP, the foot angle was significantly larger than CON ($P = 0.047$) and patients with PD ($P = 0.016$), although no difference was noted between PD and CON.

Table 3 presents demographic data and gait parameters for each subtype in PSP; we only present the results without statistical analysis because each sample size was small. The number of PSP– Richardson syndrome (PSP–RS) was highest in this study, compared with fewer numbers in other subtypes. Patients with PSP–progressive gait freezing (PSP–PGF) tended to exhibit a faster walking speed, and patients with PSP–predominant parkinsonism (PSP–P) tended to exhibit a lower walking speed, larger step width and foot angle than patients with PSP–RS.

4. Discussion

PSP is classified as atypical parkinsonism, and akinesia is included in the diagnostic criteria [2]. In this study, patients with PSP exhibited slower walking speed and shorter step length similar to patients with PD; it was a telltale symptom of parkinsonism. The walking cycle time in the stance and double supporting phase was increased in patients with PSP and

PD, developing remarkably slower walking speed, which could be attributed to the impact of parkinsonism. Reportedly, a difficulty in activating the motor control system correlates with gait hypokinesia in patients with PD by basal ganglia dysfunction [17–19]. In this study, patients with PSP exhibited parkinsonian gait because nigra is involved in PSP like PD [1].

A systematic review reported that the gait characteristic in patients with PD is parkinsonian gait—a slower walking speed and shorter step length [20]; in this study, patients with PSP also exhibited similar features. In addition, the step width, foot angle, and cadence variation were larger in patients with PSP than CON and patients with PD, which differed from that of patients with PD described in a review [20]. Reportedly, the characteristics were similar to patients with cerebellar disorders, such as spinocerebellar degeneration, which shows swaying and wide-based walking [21,22]. The cerebellum also degenerates in patients with PSP unlike those with PD [1]. Notably, dentate nucleus as efferents, inferior olivary nucleus, pontine nucleus as afferents, and cerebellar white matter are involved in PSP [1]. Thus, patients with PSP might display unstable and wide-based gait similar to patients with cerebellar disorders. Reportedly, the walking speed was slower with the wider step width in patients with PSP than healthy subjects and PD [23–25], corroborating the gait performance of patients with PSP in this study. Hence, we might have to check whether their gait is wide-based or not to determine the differential diagnosis between PSP and PD.

Recently, various clinical phenotypes of PSP have been reported [2]. PSP–RS is a typical phenotype, which was reported highest in this study. Freezing of gait is a typical symptom in patients with PSP–PGF, and we measured their walking ability when they did not freeze. In addition, the walking speed of patients with PSP–PGF tended to be faster than that of PSP–RS. In their daily living, patients with PSP–PGF tend to start walking faster after freezing, explaining their faster walking speed in this study. Patients with PSP–P displayed the lower walking speed, shorter step length, and walking cycle time, namely shuffling gait due to parkinsonism; moreover, their step width and foot angle were the largest in three subtypes. Reportedly, the differentiation of patients with PSP–P from those with PD is challenging[26]. Hence, the wider step width and foot angle could be useful characteristics in the differential diagnosis between PSP–P and PD.

This study has some limitations. First, we lacked the data on the dosages of levodopa and other Parkinson's drugs in patients in this study. Levodopa effects reflected the performance in PD because we assessed their waling ability on “ON” condition and did not investigate their levodopa dose; it effectively improves the motor function of PD [27,28]. Some parameters of gait did not exhibit a marked difference between patients with PD and healthy subjects; however, it must be kept in mind that it was the effect of the medicine. Second, the sample size of each clinical subtype was small, and the number did not match between groups. Thus, an investigation with a large sample size is warranted in the future study. Finally, we only

investigated simple gait parameters, necessitating the analysis of additional parameters of gait by using another device.

However, our findings offer valuable data that analyzed the gait characteristics of patients with PSP comprehensively. Patients with PSP exhibited the gait characteristics that combined features of PD and cerebellar disorders. Perhaps, the findings might be useful for the differential diagnosis between PSP and PD. Furthermore, regarding the rehabilitation that has not been established for patients with PSP, this study might facilitate the selection of approaches for PD or cerebellar disorders [29–31].

Conclusions

This study suggests that the gait of patients with PSP was unstable with parkinsonism and wide-based, which might be similar to combining features of PD and cerebellar disorders.

Notes

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Declaration of interest

Dr. Aiba serves as a consultant for Biogen MA Inc. and AbbVie GK. The other authors had no declaration of interest.

Ethical approval

This study was conducted in accordance with the Declaration of Helsinki. This retrospective, cross-sectional study protocol was approved by the Ethics Committee of Higashinagoya National Hospital (approval number: 28-13, 30-11. Nagoya, Japan).

Informed consent

Healthy older persons provided written informed consent after receiving a verbal

explanation of the study. Informed consent for patients was obtained in the form of opt-out on the web-site, and those who rejected were excluded in this study.

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Table 1
Demographic data of all subjects in each group

	CON	PD	PSP	*P* (ANOVA/Kruskal–Wallis)	*P* (post-hoc test)		
					CON vs. PD	CON vs. PSP	PD vs. PSP
Numbers[#]	25	25	27				
Age (y)*	73.1 ± 5.3	74.2 ± 5.3	73.4 ± 5.3	0.764	–	–	–
Sex (M/F)[#]	11/14	14/11	19/8	0.157	–	–	–
Body height (cm)*	158.7 ± 8.7	161.3 ± 9.0	160.3 ± 8.3	0.538	–	–	–
Body weight (kg)*	55.6 ± 8.6	52.0 ± 11.2	58.8 ± 10.2	0.058	–	–	–
BMI*	22.1 ± 2.5	20.0 ± 3.2	22.6 ± 2.8	0.003	0.029	1.000	0.004
					Mann–Whitney *U*-test		
Disease duration (m)*	–	56.8 ± 41.3	60.3 ± 52.9		0.949		
mRS[§]	–	3 [2–3]	4 [2–4]		0.025		
UPDRS III[§]	–	25.0 [20.5–30.5]	–		–		
PSPRS V[§]	–	–	3 [3–5]		–		
PSPRS VI[§]	–	–	9 [7–11]		–		

CON, neurologically healthy older persons; PD, Parkinson's disease; PSP, progressive supranuclear palsy; BMI, body mass index; BRS, modified Rankin scale; UPDRS III, Unified Parkinson's Disease Rating Scale part III; PSPRS-V and VI, Progressive Supranuclear Palsy Rating Scale Part V and VI.
Data are shown by *mean ± standard deviation, [#]numbers, and [§]median [interquartile range].

Table 2
The mean values of the walking ability and gait parameters and the results of the statistical analysis

	CON	PD	PSP	*P* (ANOVA/Kruskal–Wallis)	*P* (post-hoc test)		
					CON vs. PD	CON vs. PSP	PD vs. PSP
Numbers	25	25	25				
Walking ability							
Walking speed (cm/s)	119.0 ± 21.0	80.9 ± 25.4	75.1 ± 19.1	<0.001	<0.001	<0.001	1.000
Cadence (steps/min)	116.5 ± 15.1	109.6 ± 17.5	107.8 ± 16.3	0.242	–	–	–
CV of walking speed (%)	4.5 ± 2.4	6.7 ± 4.4	7.5 ± 4.9	0.070	–	–	–
CV of cadence (%)	2.6 ± 2.5	2.8 ± 2.6	5.3 ± 3.9	0.001	1.000	0.006	0.015
Gait parameters							
Step length (cm)	62.2 ± 7.1	43.2 ± 10.7	42.2 ± 8.9	<0.001	<0.001	<0.001	1.000
Step width (cm)	7.7 ± 3.4	8.6 ± 3.2	10.6 ± 3.5	0.007	1.000	0.007	0.097
Foot angle (°)	5.8 ± 4.8	5.1 ± 4.7	9.6 ± 6.9	0.010	1.000	0.047	0.016
Time of stance phase (s)	0.63 ± 0.08	0.72 ± 0.18	0.73 ± 0.12	0.031	0.142	0.059	1.000
Time of swing phase (s)	0.41 ± 0.03	0.40 ± 0.06	0.42 ± 0.06	0.893	–	–	–
Time of double supporting phase (s)	0.11 ± 0.02	0.15 ± 0.04	0.15 ± 0.04	<0.001	<0.001	<0.001	1.000

CON, neurologically healthy older persons; PD, Parkinson's disease; PSP, progressive supranuclear palsy; CV, coefficient of variation.
Data are shown by mean ± standard deviation.
The criterion for significance was set at 0.05.

Table 3

Summary of all data of patients with PSP in each subtype

	PSP all	PSP–RS	PSP–PGF	PSP–P
Numbers[#]	27	19	5	3
Age (y)*	73.4 ± 5.3	73.5 ± 5.5	73.6 ± 5.0	73.0 ± 6.6
Sex (M/F)[#]	19/8	15/4	1/4	3/0
Body height (cm)*	160.9 ± 7.4	159.8 ± 7.2	162.3 ± 9.5	165.3 ± 3.1
Body weight (kg)*	58.8 ± 10.2	57.9 ± 11.3	58.3 ± 7.7	65.0 ± 3.6
BMI*	22.6 ± 2.8	22.5 ± 3.2	22.1 ± 1.8	23.9 ± 0.5
Disease duration (m)*	60.3 ± 52.9	54.9 ± 59.9	55.8 ± 10.0	102.0 ± 30.0
mRS[§]	4 [2–4]	3 [2–4]	3 [2.5–4]	4 (2, 4)
PSPRS V[§]	3 [3–5]	3 [3–5]	3 [3–4.5]	4 (2, 7)
PSPRS VI[§]	9 [7–11]	9 [7–11]	9 [7.5–10]	10 (2, 11)
Walking ability				
Walking speed (cm/s)*	75.1 ± 19.0	75.7 ± 18.4	80.6 ± 18.4	62.2 ± 25.8
Cadence (steps/min)*	107.8 ± 16.3	110.0 ± 15.8	99.9 ± 14.1	106.8 ± 24.3
CV of walking speed (%)*	7.5 ± 4.9	6.9 ± 4.2	11.7 ± 6.0	4.1 ± 2.6
CV of cadence (%)*	5.3 ± 3.9	4.6 ± 3.0	6.0 ± 4.3	7.2 ± 8.1
Gait parameters				
Step length (cm)*	42.2 ± 8.9	42.2 ± 8.6	47.4 ± 6.3	33.5 ± 10.7
Step width (cm)*	10.6 ± 3.5	9.9 ± 2.9	10.1 ± 3.0	16.2 ± 3.5
Foot angle (°)*	9.6 ± 6.9	9.4 ± 6.7	7.4 ± 7.8	14.9 ± 6.1
Time of stance phase (s)*	0.73 ± 0.11	0.72 ± 0.11	0.76 ± 0.13	0.72 ± 0.19
Time of swing phase (s)*	0.42 ± 0.06	0.42 ± 0.06	0.46 ± 0.06	0.35 ± 0.02
Time of double supporting phase (s)*	0.15 ± 0.04	0.15 ± 0.04	0.15 ± 0.03	0.18 ± 0.08

PSP, progressive supranuclear palsy; PSP–RS, PSP–Richardson syndrome; PSP–PGF, PSP–progressive gait freezing; PSP–P, PSP–predominant parkinsonism; BMI, body mass index; BRS, modified Rankin scale; PSPRS-V and VI, Progressive Supranuclear Palsy Rating Scale Part V and VI.

Data are shown by *mean ± standard deviation, [#]numbers, and [§]median [interquartile range] or (minimum, maximum).

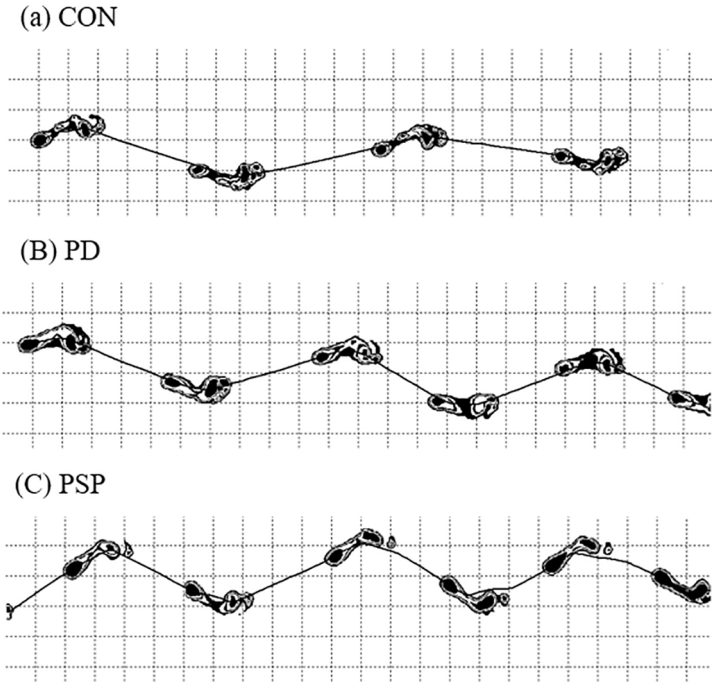

Figure 1. Each representative footprint during walking in neurologically healthy older persons (CON), patients with Parkinson's disease (PD), and patients with progressive supranuclear palsy (PSP). The representative footprint during walking CON (a), PD (b), and PSP (c). The step length was shorter in patients with PD and PSP compared with CON. Patients with PSP showed wide-based gait unlike CON and patients with PD.