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Original Article

Characteristics associated with freezing of gait in actual daily living in Parkinson's disease

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Abstract. [Purpose] Parkinson's disease (PD) patients often freeze in actual daily living but seldom in clinical setting. This study aimed to identify the factors contributing to freezing of gait (FOG). [Subjects and Methods] The participants included 28 adults with PD. Principal component analysis was used to investigate the characteristics of 14 common FOG situations adopted from previous studies. Cluster analysis classified the subjects into four groups. Kruskal-Wallis test was performed to compare the PD Questionnaire-39 mobility dimension between the groups. [Results] The major variables of the first principal component in 14 FOG situations were unfamiliar places, unpredictable schedule changes, entering an automatic door, when another person suddenly crossed, and change in the walking surface. These situations were unrelated to the second principal component. Getting on/off a public transport and crowded places were major variables for the second principal component, and related to both the first and second principal components. Although fatigue was the most frequent FOG situation, not all principal components were influenced. The values of the PD Questionnaire-39 revealed significant differences between the groups. [Conclusion] Actual FOG situations may be categorized into (1) task complexity, (2) both task complexity and emotional factors, and (3) fatigue as decreased attentional resources.

Key words: Freezing of gait, Parkinson's disease, Principal component analysis

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INTRODUCTION

Freezing of gait (FOG) is defined as a "brief, episodic absence or marked reduction of forward progression of the feet despite the intention to walk"[1, 2]. FOG is a paroxysmal disabling symptom that occurs in the later stages of Parkinson's disease (PD). As PD progresses, FOG becomes resistant to treatment with L-DOPA[3]. This leads to an increased risk of falling while performing daily activities and psychosocial consequences such as fear, anxiety, embarrassment, helplessness, despair, social isolation, avoidance of social interaction, and inability to perform social roles. As a result, the patients' quality of life (QOL) may be greatly affected[4–7].

For PD patients, walking, which is performed automatically in healthy people, becomes an impossible task without continuous attention. Loss of automaticity is the primary impairment of FOG. PD patients greatly rely on their cognitive function to compensate for the loss of automaticity (cognitive compensation)[8]. The overload on attentional resources leads to the breakdown of the cognitive compensation, resulting in FOG[8, 9]. However, FOG episodes are triggered not only from the loss of automaticity in walking but also from various contextual factors, such as environmental and psychological factors. Therefore, in many patients suffering from FOG, despite experiencing FOG during daily living, it is often difficult to observe FOG during examinations conducted in clinical settings. As a result, physicians and physical therapists may frequently underestimate the level of a patient's distress due to FOG.

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The FOG Questionnaire (FOG-Q)[10] and Movement Disorder Society (MDS)-Unified PD rating scale (UPDRS)[11] sub-item No.13 (Freezing) on Part II (Motor Aspects of Experiences of Daily Living) have been widely used as assessment tools for FOG in actual daily living. These tools can assess the frequency or severity but cannot provide information on the causative factors of the situations in which patients experience distress. Therefore, it remains unclear why PD patients freeze in actual daily situations[5, 12–14]. The present study attempted to identify the factors contributing to FOG in actual daily living in PD patients.

SUBJECTS AND METHODS

Overall, 28 individuals with PD (14 males and 14 females) participated in the study. Their ages ranged from 58 to 85 years with a mean age of 70.1 years (standard deviation, SD=7.4). The mean duration of PD was 12.1 years (SD=7.5). The patients with FOG were only included as defined by the FOG-Q and MDS-UPDRS. The severity of FOG in all patients was higher than grade 2 based on sub-item No. 3 of the FOG-Q[10] and higher than grade 1 based on sub-item No. 13 on Part II and sub-item No. 11 (FOG) of Part III (Motor Examination) of the MDS-UPDRS[11].

The participants were asked about their FOG episodes during 14 common situations in their daily living. These items were adopted based on previous studies[5, 12–14]. The participants' responses to the PD Questionnaire-39 (PDQ-39) mobility dimension were also evaluated to assess each participant's self-reported QOL[15]. The frequency of each FOG episode was analyzed. Principal component analysis was performed to identify the overall characteristics of FOG episodes that the participants experienced in their daily living. Cluster analysis was conducted using the principal component score as a variable. In addition, the Kruskal-Wallis test was performed to compare the values of PDQ-39 between the groups of participants. Statistical analyses were performed using the SPSS version 23.0 for Windows. Statistical significance was set at $p<0.05$. Approval was obtained from Bukkyo University's Research Ethics Committee (Approval number: H28-53). All the subjects were informed about the details of the study, and they provided written informed consent to participate.

RESULTS

As shown in Table 1, the frequency of FOG episodes greatly varied in the range of 25–89.3%, depending on the situations. FOG occurred most frequently when the participants felt tired. More than 70% of the participants reported FOG when trying to hurry to the toilet, being in crowded places, and answering a telephone or doorbell.

Table 2 and Fig. 1 show the coefficients of the principal components and associated plots for each situation, respectively. Table 2 also shows the contribution ratios of each principal component. The cumulative contribution ratio was 64.9%. The major variables of the first principal component include unfamiliar places, unpredictable schedule changes, entering an elevator or automatic door, when someone suddenly crossed in front of the participant, and any change in the walking surface. Except for fatigue, the other variables were moderately associated with the first principal component. Getting on/off a public transport vehicle and being in crowded places were major variables for the second principal component. Crossing the road was strongly associated with the third principal component. Fatigue was not associated with any principal component.

During the gait initiation task, entering an elevator or automatic door and answering a telephone or doorbell were related to the first principal component but not to the second principal component. In contrast, getting on/off a public transport vehicle, trying to hurry to the toilet, and being in crowded places were related to both the first and second principal components.

Cluster analysis classified the subjects into four groups (Fig. 2). In group 1, the first principal component score was high and the second principal component score was low. In group 2, the first and second principal component scores were low and high, respectively. In group 3, both principal component scores were high. The scores of both principal components were low in group 4. The values of the PDQ-39 calculated using the principal component scores as variables revealed significant differences between the groups. The PDQ-39 value was lowest in group 4 (Table 3).

DISCUSSION

This study, like the previous report[13], revealed that FOG episodes frequently occurred when PD patients were fatigued. Therefore, it is suggested that fatigue is a major triggering factor causing FOG. However, using principal component analysis, none of the principal components were associated with fatigue. This finding suggests that, unlike other situations, fatigue is an independent factor for causing FOG.

PD patients reportedly tend to be fatigued[16]. Additionally, a report indicated that PD patients experienced impaired automaticity even at a relatively early stage of the disease[9]. However, it is often difficult to compensate for the loss of automaticity for a long time, and patients become easily fatigued. Fatigue in PD appears to be correlated with prefrontal hypoperfusion on Single-photon emission computed tomography and performance on the Wisconsin Card Sort Task[16]. Therefore, it is possible that fatigue indicates a decrease in the patient's attentional resources[12]. Therefore, fatigue due to extended cognitive demand may impair the cognitive compensation, leading to FOG. In coping with FOG, identifying strategies that patients can use to accommodate fatigue may be important.

This study found that fatigue does not have an influence on the first principal component. Thus, a decrease in attentional

Table 1. Frequency of FOG occurrence

FOG episodes in actual daily living (%)	
Fatigue/When patients were tired	89.3
When trying to hurry to the toilet	75.0
Being in crowded places	72.1
When answering a telephone or doorbell	71.4
Entering an elevator or automatic door	53.6
Getting on/off a public transport	50.0
In unfamiliar places	50.0
Being in cluttered (scattered) places	46.4
When another person suddenly crossed in front of participants	39.3
Crossing roads	35.7
Change in the walking surface	32.1
Unintended thoughts while walking (e.g., suddenly remenbering something unrelated to the purpose of the walk while walking)	32.1
Unpredictable schedule change	32.1
When someone talks to patients while walking (e.g., hearing new instructions while walking)	25.0

Fatigue, when trying to hurry to the toilet, being in crowded places, and answering a telephone or doorbell were high frequent triggering factors causing FOG.

Table 2. Result of principal component analysis

		principal component		
	Triggering factors of actual FOG situations	1st	2nd	3rd
A	In unfamiliar places	0.861	−0.062	0.019
B	Unpredictable schedule change	0.767	−0.243	−0.215
C	Entering an elevator or automatic door	0.722	0.115	0.272
D	When another person suddenly crossed in front of participants	0.717	−0.150	−0.384
E	Change in the walking surface	0.709	−0.419	0.140
F	Being in cluttered (scattered) places	0.687	0.422	−0.430
G	Unintended thoughts while walking (e.g., suddenly remenbering something unrelated to the purpose of the walk while walking)	0.684	−0.385	0.056
H	Being in crowded places	0.598	0.518	0.382
I	When someone talks to patients while walking (e.g., hearing new instructions while walking)	0.556	−0.491	−0.161
J	Getting on/off a public transport	0.453	0.607	0.120
K	Crossing roads	0.553	−0.208	0.726
L	When answering a telephone or doorbell	0.511	0.163	−0.488
M	When trying to hurry to the toilet	0.459	0.416	0.081
N	Fatigue/When patients were tired	−0.096	−0.214	−0.052
	Contribution ratio (%)	41.40	12.73	10.80

Major variables.
First principal component: unfamiliar places, unpredictable schedule changes, entering an elevator or automatic door, when someone suddenly crossed in front of the participant, and change in the walking surface.
Second principal component: getting on/off a public transport and being in crowded places.
Third principal component: crossing road.
Fatigue: not associated with every principal component.
The triggering factors of actual FOG situations were categorized into (1) task complexity (A, B, C, D, L), (2) influence of both task complexity and emotional factors (F, H, J, K, M)), and (3) fatigue (N).

resources is not related to this component. Additionally, the situations associated with the first principal component seem to be cognitively challenging and complex tasks that require (1) not only motor programing but also attentional switching, divided attention, selective attention, and information processing in the frontoparietal network[17, 18] and (2) flexible adaptation to changes in the surroundings[19]. Therefore, in our participants, it is speculated that the first principal component is a

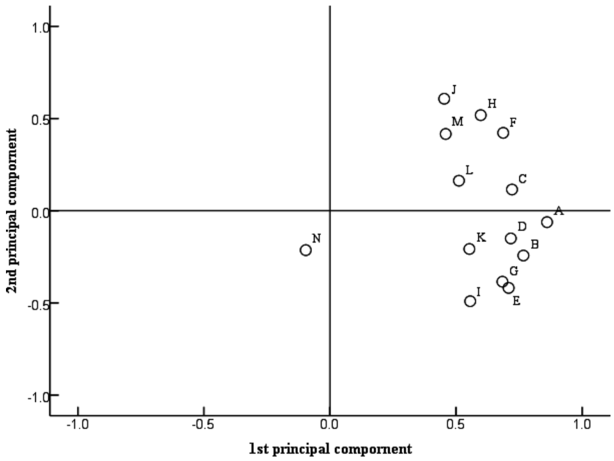

Fig. 1. Plot of principal components in each situation.
Even though the same gait initiation task, entering an elevator or automatic door (C) and when answering a telephone or doorbell (L) were related to the first principal component but not to the second principal component. In contrast, getting on/off a public transport (J), trying to hurry to the toilet (M), and being in crowded places (H) were related to both the first and second principal components. Fatigue (N) was not associated with both principal components.

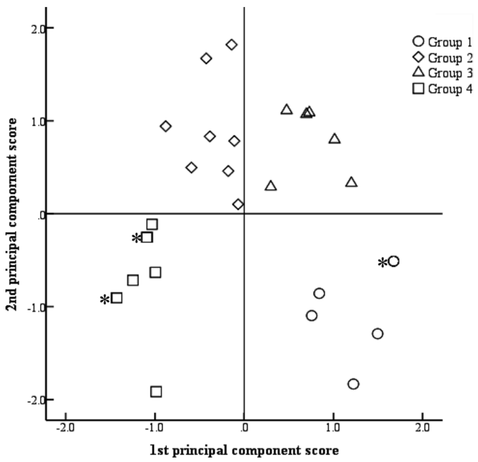

Fig. 2. Cluster analysis using the principal component score.
Group 1: First (high) and second (low) principal component scores.
Group 2: First (low) and second (high) principal component scores.
Group 3: High scores for both principal components.
Group 4: Low scores for both principal components.
Characteristics
Group 1: task complexity, Group 2: stressful situations, Group 3: both characteristics.
* Two patients (same combination of 1st and 2nd component score).

Table 3. Result of PDQ-39 mobility dimension in groups classified by cluster analysis using the principal component score as a variable

	Mean (SD)	95% CI
Overall (n=28)	16.89 (12.42)	12.08–21.71
Group 1 (n=6)	25.00 (10.24)	14.26–35.74
Group 2 (n=8)	21.00 (13.07)	10.07–31.93
Group 3 (n=6)	19.00 (11.82)	6.60–31.40
Group 4 (n=8)	5.13 (3.48)	2.21–8.04

Kruskal-Wallis test showed that there were significant changes in the values of the PDQ-39 between the groups (p=0.002).

Effect size (r) for each combination of groups

Group 4	Group 1	0.83
	Group 2	0.76
	Group 3	0.71
Group 3	Group 1	0.24
	Group 2	0.00
Group 2	Group 1	0.24

The value of PDQ-39 in group 4 was smaller than that in other groups.

concept characterized by “task complexity”[5]. This means that patients with less automaticity cannot appropriately respond to high attentional demands in these situations. Alternatively, it is speculated that the common characteristic of the second principal component is “stressful factor” such as impatience (feeling rushed), tension, and agitation.

Even during the same gait initiation task, the combinations of characteristics may differ for each situation. In entering an elevator or automatic door, and answering a telephone or doorbell, it seems that task complexity is predominantly associated with triggering an FOG episode. In these situations, planning of the timing of gait initiation in advance and concentrating on each component of movements are effective strategies[20].

In contrast, when getting on/off a public transport vehicle, trying to hurry to the toilet, and being in crowded places, an FOG episode may be provoked by various combinations of task complexity and stressful factors. It is well recognized that under time pressure, the more hurried the patient is, the more their feet seem to be glued to the floor despite the intention to move forward[21]. It has been reported that "cross talk" from concurrent competing basal ganglia inputs from motor, cognitive, and limbic cortical areas leads to FOG[22, 23]. In these situations, it is possible that the concurrent limbic load during motor tasks transiently increases the inhibitory output of the basal ganglia, resulting in excessive inhibition in the brainstem locomotor center[24]. Therefore, to overcome FOG, it may be necessary to incorporate not only the cognitive compensation but also a psychological approach to reset the limbic load into therapeutic strategies.

Although the characteristic of the third principal component, which was a powerful contributor to crossing roads, is unclear, it may present as an anxious feeling in the patient and a pessimistic prediction (fear of being stuck in the middle of the street). A past FOG experience when crossing a road may result in the patients underestimating their ability to cross safely (poor self-efficacy), leading to expected anxiety[21].

The results of this principal component analysis may indicate that the triggering factors of actual FOG situations were categorized into (1) task complexity, (2) influence of both task complexity and emotional factors, and (3) fatigue, as shown in Table 2. Designing strategies according to the characteristics of the actual situation may be necessary to cope with difficulties in daily living as a result of FOG.

Additionally, cluster analysis using the principal component score as a variable reveals the characteristics of each group. In group 1, task complexity is a common characteristic. Group 2 is characterized by stressful situations. Group 3 has both characteristics. Group 4 does not have either of the characteristics. Cognitive compensation and/or environmental modification are required to overcome FOG in group 1. In group 2, the antecedent emotions that powerfully trigger FOG episodes must be dealt with. In group 3, both characteristics should be considered. Significant changes in the values of the PDQ-39 between these groups classified by cluster analysis indicate that the two major characteristics from the first and second principal components may at least partially influence QOL. QOL may be affected if patients have either characteristic. Thus, clinicians may need to understand these characteristics to promote social participation of PD patients.

However, this study has several limitations. First, a small sample size was used. Further studies involving more PD patients are needed. Second, the concept characterized by the first principal component is extensive. Therefore, in clinical practice, to develop an effective treatment strategy for FOG, a careful evaluation of the patient's actual experience is needed to understand how various internal (personal) or external (environmental) factors lead to the overload on attentional resources. Additionally, in the situations associated with the second and third principal components, the background of emotional aspects such as negative automatic thought and environmental factors should be further investigated.

Conflicts of interest

There are no conflicts of interest for any of the authors that are relevant to the contents of the article. There was no external funding for this research.

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