https://doi.org/10.5817/StS2024-1-9

Dynamic Balance in Parkinson ´s Disease Can be Ameliorated by External Focus of Attention

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ABSTRACT

Most studies on balance training in individuals with Parkinson´s disease (PD) reported ambiguous effects. Therefore, the study aimed to investigate the effect of an attentional focus and severity of PD on dynamic balance. In the study, 31 patients (11 females, 20 males) with idiopathic PD in stage I-III, aged 69.6 ± 6.6 years, performed the five times sit-to-stand in the stage (FTSS) task two times in each of three conditions: control, i.e., with no attentional focus instruction, the internal focus of attention (IFA) induced by the instruction: „concentrate on quick movement of shoulders up and down", and external focus of attention (EFA) induced by the instruction: „ concentrate on quick movement of the tape markers up and down" (the markers glued on one´s shoulders). As a result, the FTSS time was shorter, and the number of imbalance symptoms manifested while performing of the task was lower in the EFA condition than in the control and IFA conditions. No significant interaction between the focus of attention and severity of PD operationalized as the Hoehn and Yahr´s PD stage and the risk of falls suggested the generalizability of the effect of focus of attention on dynamic balance across the PD stages I-III and regardless of whether moderate risk of falls or no risk in PD patients. This study also provided evidence that these individuals with PD can adopt task-specific instructions to perform movement skills.

Keywords: imbalance; attentional focus; Parkinson´s disease; five times sit-to-stand test

INTRODUCTION

Parkinson's disease (PD) is the second most common neurodegenerative disease around the world, with an estimated prevalence in 2–3% of people over age 65 (Poewe et al., 2017). Apart from neuropsychiatric, cognitive and autonomic disorders, PD is characterized by cardinal motor symptoms such as resting tremor of legs, muscular rigidity, delayed initiation of voluntary movement (akinesis), slower speed of movement (bradykinesis), reduction of movement amplitude and force (hypokinesis), sudden freezing of movement and postural instability, whose severity depends on the disease progression (Mazzoni et al., 2012; Sveinbjornsdottir, 2016).

Results of laboratory studies showed that postural instability in patients with idiopathic PD is affected by bradykinesia, muscular rigidity, impaired proprioception and attention (for a review, see Park et al. 2015). A main pathologic structure in PD, the basal ganglia, contributes to controlling of the flexibility for postural tone, scaling up the magnitude of postural movements, selecting postural strategies for environmental context, and automating postural responses (Park et al., 2015). In the earlier stage of PD, dopamine-sensitive bradykinesia and rigidity progressively affect balance and gait, but later also dopamine insensitive-balance problems such as impaired kinesthesia, inflexible postural set, lack of automaticity, and executive dysfunction increase (Park et al., 2015).

Previous studies have brought evidence that an individual´s adopting of an external focus of attention (EFA) during the performing of a motor task may be more beneficial relative to an internal focus of attention (IFA) for learning or performing motor skills in individuals across ages, motor competencies and health conditions (Wulf, 2013; Wulf & Lewthwaite, 2016). EFA is introduced as focusing on an intended movement effect or outcome, implementation or goal, whereas IFA is defined as focusing on the body-relevant movement or position (Wulf, 2013). The theoretical explanation of the disadvantage of the IFA relative to the EFA is that the IFA induces a more conscious mode of control that leads to the disruption of automatic motor processes (Wulf et al., 2013). On the contrary, the EFA may reduce an individual's focus on oneself, increasing motor automaticity (Kal et al., 2013) and functional variability (Lohse et al., 2014), reflecting an enhanced movement outcome.

To our knowledge, only three studies examined the effect of attentional focus on the balance of individuals with PD. In the study by Jaezeri et al. (2018), when PD participants focused their attention externally (on rectangular papers that were placed on the force plate or foam without looking at them) while standing, sway measures decreased as compared to an IFA condition (concentration on feet without looking at them). Other two studies also showed the benefit of an EFA instruction given to individuals with PD over an IFA instruction and control condition (no attentional focus instruction) while standing on the inflated rubber disk and force plate, respectively (Landers et al., 2005; Wulf et al., 2009). However, these three studies only examined the effects of attentional focus on postural control in static balance conditions. Therefore, the present study examined whether an EFA may be advantageous for postural control under dynamic conditions associated with repeated body position changes in patients with PD. Based on the constrained action hypothesis and the theoretical assumption that EFA promotes goal-action coupling (Wulf, 2013; Wulf & Lewthwaite, 2016), we hypothesized that EFA relative to IFA instructions and control condition would be beneficial for enhancing dynamic balance while changing a body position, concretely during performing of the repeated sit-to-stand task in patients in the stage I-III of PD. Further, we also assumed that a potential benefit of the EFA on dynamic balance would not have to occur in individuals with larger severity of PD. Robust evidence shows that individuals with PD exhibit a substantial broad cognitive decline, including attentional and memory domains. (Dana et al., 2021). These cognitive problems may distract an individual´s adoption of a specific attentional focus for performing a particular task. Therefore, we also investigated whether the effect of FOA on dynamic balance would be affected by the degree of severity of PD.

METHODS

Participants

Thirty-one subjects with idiopathic PD, 11 females aged 66.4 ± 7.7 years and 20 men (71.4 ± 6.0 years) diagnosed by a neurologist participated in the blinded experiment. The inclusive criteria were age > 50 years, the Hoehn and Yahr´s stage I – III of PD (Hoehn & Yahr, 1967), no or middle risk of falls stated according to the Conley scale (Conley et al., 1999) and a preserved ability to change body position from sitting position to standing and back without assistive device. Individuals with other neurological disorders (other than PD), peripheral neuropathy, vestibular dysfunction, dizziness, cognitive disorders (score < 24 according to the Mini-Mental State Examination, MMSE), anxiety and depression (score ≤ 7 according to the Hospital Anxiety and Depression Scale, HADS Scale), dyskinesia, orthopaedic disorders, surgical intervention for PD, diabetes mellitus, and/or cardiovascular disease were also not included for the study. All these conditions were diagnosed by the neurological clinics of one major regional hospital where the study was conducted.

The experimental work was carried out under the approval of the Ethical committee of the Physical Education and Sport PALESTRA (the code VSP/0170/2022) and the written approval by the authority of the hospital. Written informed consent was obtained from the participants. The participants were not informed about the purpose of the study.

Experimental task, apparatus and procedures

Participants were asked to perform the five times sit-to-stand (FTSS) task as quickly as possible (for description, see Whitney et al., 2005). This task is a standardised clinical test of dynamic balance and transitional movements. Participants were randomly assigned to one of two orders of the conditions (blocks): control (Con)-IFA-EFA or Con-EFA-IFA. Before performing the task, a participant was provided with short descriptive instructions and a demonstration. A participant was also instructed to look straight ahead while performing the task. Then a participant practised the task in his/her free tempo. Subsequently, a participant performed two task trials in the Con condition (with no focus instruction). Then a red circle relief tape marker (a diameter of 7 cm) made of hard cardboard was attached to the upper side of each participant´s shoulder. Then, the participant performed two trials in the IFA and two trials in EFA conditions in an assigned order, with a rest interval of 2 min between trials in each condition. Before each IFA trial, the participant was provided with the following attentional focus instruction "Concentrate on the quick movement of your shoulder up and down", and before each EFA trial „Concentrate on the quick movement of the tape markers up and down". Before the first trial of a given condition, the nurse checks whether the participant fully understands what he/she is to concentrate on. After the execution of each block, a participant was given the following question to check the attentional focusing of the participant while performing the FTSS task: „What did you focus on?" The answers were recorded in written form. All participants performed the FTSS task in the experimental session after at least 12 h of withdrawal from regular dopaminergic medication (during the „off"- drug phase), according to Ehgoetz Martens et al. (2015).

The following variables were assessed as indicators of dynamic balance: (i) the average time of completion of the task in each of three focus conditions (FTSS time); (ii) the number of imbalance symptoms while performing the FTSS task observed by the second author of the article with the use of the Balance Inventory for FTSS (Attachment). This inventory was constructed by the authors and derived from the Tinetti test (Tinetti et al., 1986).

One day after the experimental session, the participants completed the Czech language version of the Parkinson's Disease Questionnaire (PDQ-39) (Jenkinson et al., 2012), a 39-item self-report questionnaire which assesses eight dimensions of functioning and well-being in an individual with PD – mobility, activities of daily living, emotional well-being, stigma, social support, cognition, communication and bodily discomfort. An individual's responses to each item on a five-point scale (0-4), with a score of „0" as „never" and „4" as „always" in the sense of occurence of a problem.

Data analysis

Both dependent variables showed an unimodal symmetric distribution similar to a normal distribution. The skewness and kurtosis coefficients were 0.00 and -0.59 for FTSS time and 0.13 and -0.35 for the number of imbalance symptoms. The residuals from none of the presented models differ significantly from the normal distribution (Lilliefors test, $\alpha = 0.05$).

Linear mixed-effects models with interaction terms were used to process the results of a multivariate two-factor design (the factors FOA and PD severity) with repeated measures. Thus, the effect of FOA and PD severity on the balance measures (average time, the number of imbalance symptoms) was investigated. The PD severity factor was operationalised in four ways: (i) as a Parkinson's disease stage (I, II, III), (ii) as a level of risk of falls assessed with the Conley scale (no risk - 1, middle risk - 2), (iii) as PDQ total score, (iv) as the PDQ mobility score (a range for both scores 0 – 156 and 0 – 40 respectively, "0" no difficulty). Therefore, the results of eight statistical models are presented in the Results. Since there were six measurements per respondent (2 measurements for each FOA condition), the models also included a random factor proband (31 levels). Both PDQ scores are quantitative, and we have treated them as continuous variables within the models, but for clarity, we present these scores as discrete categories (see Table 1, 2). These categories were arbitrarily set at 0 points (no or moderate difficulties) and 80, respectively 30, points corresponding to approximately the 90th percentile (significant difficulties) in our sample.

Effect sizes were calculated using partial eta squared (ηp^2) with an interpretation of $\eta p^2 = .01$, = .06, and .14 as small, medium, and large effects, respectively. Data analyses were conducted using the IBM SPSS Statistics (Version 24; IBM, Armonk, NJ, USA).

RESULTS

Effects of FOA and severity of PD on FTSS time

In all four models, the effect of FOA on FTSS time was statistically significant, with a large effect for the models that employed the PD stage and the risk of falls (Table 1). In these two models, the FTSS time was shorter in the EFA condition than in the IFA and Con conditions and shorter in the IFA condition than in the control. In the other two models employed the PDQ total score and PDQ mobility score, the effect of FOA on FTSS time was medium, ηp^2 = .103 and .115 (Table 1). In these two models, the FTSS time was shortest in the Con condition compared to the EFA and in the IFA conditions (Table 1).

The severity of PD was shown to be the significant factor for FTSS time in all four models, i.e., regardless of how the severity of PD was operationalised. The effect size ηp^2 of this factor ranged between .189 (for the PD stage) and .315 (for the PDQ mobility score) (Table 1).

The interaction of factors (FOA x severity of PD) was significant only in the model that employed PDQ total score (p = .039), However the magnitude of the observed effect has been negligible, ηp^2 = .041 (Table 1). FTSS time was shorter in the EFA condition than IFA and Con condition in each of the three stages of PD in both participants´ groups with no risk and medium risk of falls, further in both groups with no/moderate health difficulties and significant difficulties, and in both groups of no/moderate problems with mobility and significant problems with mobility (Figure 1).

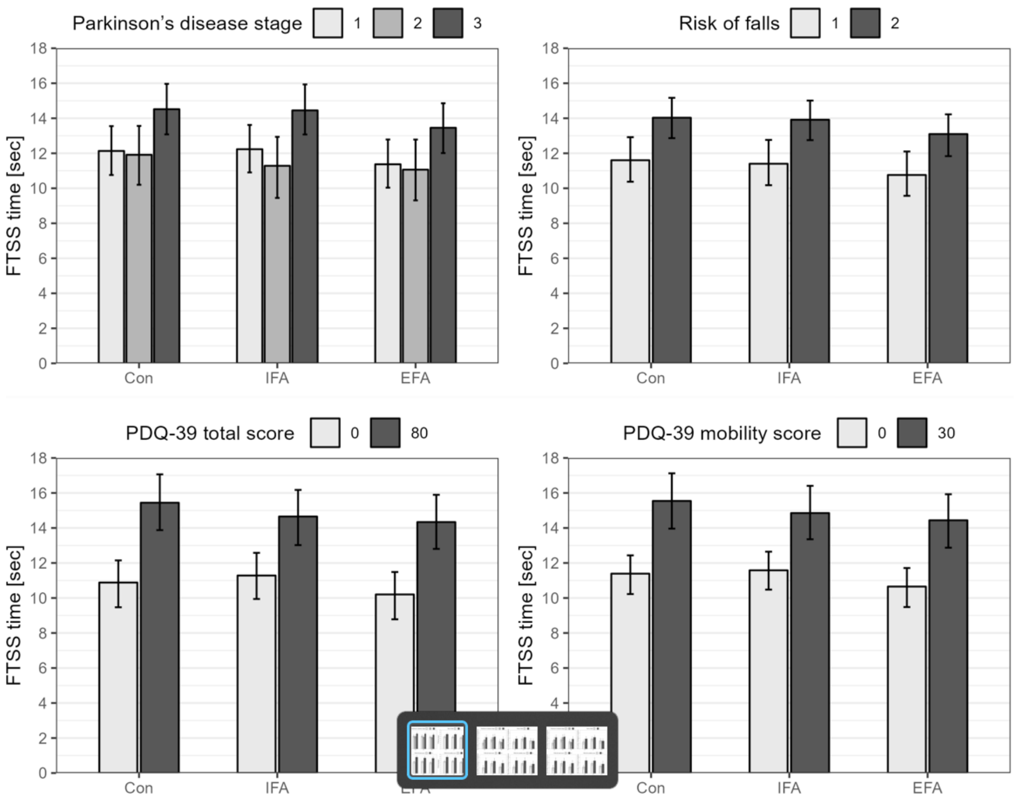
Table 1. Marginal means, standard errors, and the results of significance tests for average time (s) in the FTSS task

		All Conditions	IFA	EFA	Con	*Df*	*F*	*p*	ηp^2
FOA			12.66 ± .48	11.96 ± .48	12.86 ± .48	2, 155	16.12	<.001	.172
PD stage	1	11.92 ± .74				2, 31	3.62	.039	.189
	2	11.43 ± .90							
	3	14.14 ± .77							
FOA × PD stage	1		12.23 ± .75	11.39 ± .75	12.14 ± .75	4, 155	1.40	.238	.035
	2		11.28 ± .92	11.07 ± .92	11.93 ± .92				
	3		14.46 ± .79	13.43 ± .79	14.52 ± .79				
FOA			12.66 ± .46	11.92 ± .46	12.82 ± .46	2, 155	16.31	<.001	.174
Risk of falls	1	11.28 ± .67				1, 31	7.33	.011	.191
	2	13.65 ± .61							
FOA × Risk of falls	1		11.43 ± .68	10.79 ± .68	11.63 ± .68	2, 155	0.18	.833	.002
	2		13.89 ± .62	13.05 ± .62	14.00 ± .62				
FOA			12.93 ± .43	12.78 ± .43	12.03 ± .43	2, 155	8.95	<.001	.103
PDQ total score	0	10.76 ± .68				1, 31	12.29	<.001	.284
|	80	14.81 ± .78							
FOA × PDQ total score	0		10.87 ± .70	11.25 ± .7	10.15 ± .7	2, 155	3.32	.039	.041
	80		15.45 ± .80	14.65 ± .8	14.34 ± .8				
FOA			12.93 ± .42	12.78 ± .42	12.03 ± .42	2, 155	10.10	<.001	.115
PDQ mobility score	0	11.18 ± .56				1, 31	14.25	.001	.315
	30	14.94 ± .77							
FOA × PDQ mobility score	0		11.38 ± .58	11.55 ± .58	10.6 ± .58	2, 155	2.24	.110	.028
	30		15.54 ± .79	14.85 ± .79	14.44 ± .79				

Note. IFA – internal focus condition; EFA – external focus condition; Con – control condition; *Df* – degrees of freedom; *F* – F statistics; *p* – a level of probability; ηp^2 – partial eta squared; FOA - focus of attention; PD – Parkinson's disease; PDQ – Parkinson's Disease Questionnaire-39 (raw scores);

Risk of falls 1 – participants with no risk of falls; Risk of falls 2 – participants with middle risk of falls; PDQ total score and PDQ mobility score 0 – participants with no or moderate difficulties, and 80, respectively 30 – participants with significant difficulties (see also the Methods).

Figure 1. Means and 95% confidence intervals of the time achieved in three different attentional focus conditions – control (Con), internal focus of attention (IFA) and external focus of attention (EFA)



Note: Risk of falls 1, 2 – participants with no risk of falls and with middle risk of falls, respectively; PDQ total score and PDQ mobility score 0 – participants with no or moderate difficulties, score 80 and 30 respectively – participants with significant difficulties (see also the Methods).

Effects of FOA and severity of PD on the imbalance symptoms

In all four models, the effect of FOA on the number of imbalance symptoms was statistically significant with a medium effect (ηp^2 = .105 - .137) (Table 2). In the models that employed the PD stage and a risk of falls the less number of imbalance symptoms in participants were observed in the EFA condition as compared to the IFA and Con conditions, and in the Con than in the IFA condition (Table 2, Figure 2). On the other hand, in the models that employed the PDQ total score and PDQ mobility score less number of symptoms of imbalance were observed in the Con condition as compared to the EFA and IFA conditions, and in the IFA than EFA conditions (Table 2, Figure 2).

The severity of PD was shown to be the significant factor for the less imbalance symptoms only when it was operationalised as the PDQ total score and the PDQ mobility score. 10% of the participants with considerable difficulties across all dimensions (score ≥ 80) and in the mobility dimension of PDQ (score ≥ 30) demonstrated significantly more imbalance symptoms during the

FTSS task as compared to the participants with lesser difficulties, i.e. with score < 80 and < 30, respectively (Table 2).

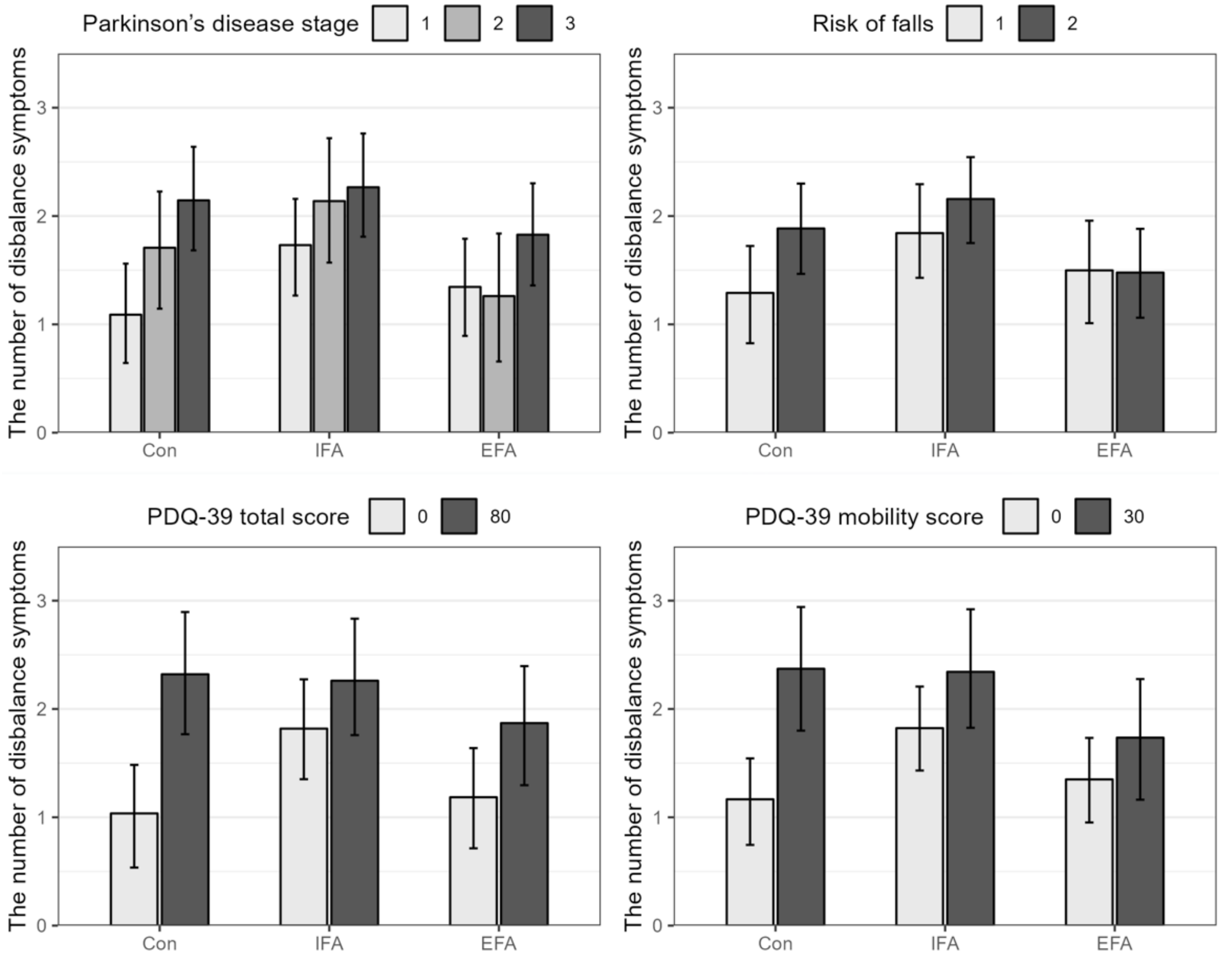
The interaction of factors (FOA x severity of PD) was significant in three models that employed the risk of falls, PDQ total score and PDQ mobility score. However the magnitude of the observed effect has been negligible, ηp^2 = .041 to .054. The number of imbalance symptoms was lower in the EFA condition than in the IFA condition in participants in each of the three stages of PD, in both participants´ groups with no risk and medium risk of falls, further in both groups with no/moderate health difficulties and significant difficulties, and in both groups with no/moderate problems and significant problems with mobility (Figure 2).

Table 2. Marginal means, standard errors, and the results of significance tests for the number of imbalance symptoms in the FTSS task

		All Conditions	IFA	EFA	Con	Df	F	p	ηp²
FOA			2.04 ± .16	1.47 ± .16	1.64 ± .16	2, 155	12.30	<.001	.137
PD stage	1	1.38 ± .22				2, 31	2.62	.089	.145
	2	1.69 ± .27							
	3	2.08 ± .23							
FOA × PD stage	1		1.71 ± .25	1.33 ± .25	1.08 ± .25	4, 155	2.23	.069	.054
	2		2.13 ± .30	1.25 ± .30	1.69 ± .30				
	3		2.27 ± .26	1.82 ± .26	2.14 ± .26				
FOA			2.00 ± .16	1.49 ± .16	1.58 ± .16	2, 155	10.98	<.001	.124
Risk of falls	1	1.55 ± .22				1, 31	1.03	.318	.032
	2	1.83 ± .20							
FOA × risk of falls	1		1.86 ± .24	1.50 ± .24	1.29 ± .24	2, 155	3.57	.030	.044
	2		2.15 ± .22	1.47 ± .22	1.88 ± .22				
FOA			1.61 ± .15	2.02 ± .15	1.48 ± .15	2, 155	9.58	<.001	.110
PDQ total score	0	1.33 ± .22				1, 31	4.81	.036	.134
	80	2.16 ± .25							
FOA × PDQ total score	0		1.03 ± .25	1.81 ± .25	1.17 ± .25	2, 155	3.29	.040	.041
	80		2.32 ± .28	2.27 ± .28	1.87 ± .28				
FOA			1.61 ± .15	2.02 ± .15	1.48 ± .15	2, 155	9.10	<.001	.105
PDQ mobility score	0	1.44 ± .19				1, 31	4.71	.038	.132
	30	2.16 ± .25							
FOA × PDQ mobility score	0		1.16 ± .21	1.81 ± .21	1.33 ± .21	2, 155	4.45	.013	.054
	30		2.37 ± .28	2.36 ± .28	1.74 ± .28				

Note: See the note for the Table 1.

Figure 2. Means and 95% confidence intervals of the number of disbalance symptoms achieved in three different attentional focus conditions – control (Con), internal focus of attention (IFA) and external focus of attention (EFA)



The check of adopting the FOA instructions

In the Con condition, 93.5% of participants focused on no cue or some irrelevant cue, 18.3% of participants internally to some aspect of the body, and 11.3% of participants externally responded to the EFA instruction. In the EFA condition, 85.5% of participants reported their attentional focus according to the EFA instruction, 6.6% of participants internally, and 7.9% of participants had no focus or focus on irrelevant cues. In the IFA conditions, 78.4% of participants concentrated according to the IFA instruction, 6.8% of participants externally responding to the EFA instruction, and 14.8% of participants to no cue or irrelevant cues.

DISCUSSION

Most participants showed adherence to a given attentional focus according to the EFA and IFA instructions provided. We also found excellent participants' adherence of 93.5% to the Con condition. Specifically, they did not concentrate their attention on a specific cue, or they did on some irrelevant cue. This no-task-specific focus was supported by the intentional ordering of the Con condition as the first for participants to perform the FTSS task. Thus, there was minimal chance for the participants to adopt the task-specific EFA or IFA instruction in the Con condition.

This good adherence of participants across the three experimental conditions supports the validity of the study findings.. In all previous studies on the effect of FOA on balance in PD patients (Jaezeri et al., 2018; Landers et al., 2005; Wulf et al., 2009), this adherence was not checked. The adherence in our sample with PD was not considerably different from adherence found in one study with young, healthy adults, 90–95% (Abdollahipour et al., 2014). Thus, the present study has shown that patients with PD in stage I-III could fully adopt specific instructions for performing motor tasks in the frame of their rehabilitation.

The study showed that when participants focused their attention on the movement effect - the movement of the markers glued on the shoulders (EFA), they were able to perform the dynamic balance task in a shorter time and with reduced imbalance symptoms as compared to focusing on owns body movement - the movement of shoulders (IFA). This advantage of EFA over IFA and the control condition without no focus instruction was found when the severity of PD was indicated by the PD stage and the risk of falls of the participants; however, was not significant when indicated by both PDQ total scores used. A possible explanation of these different results is that the PDQ-39 is a self-report questionnaire that consists of a subjective and retrospective evaluation of the responder´s functioning and feelings in the last month. The reliability of the PDQ-39 was found in the extensive range, .67–.87 (Tan et al., 2004) and .49–.96 (Jesus-Ribeiro et al., 2017) suggesting possible larger random error and/or bias of the scores. For the methodological features, the PDQ-39 does not objectively reflect the functional stage directly related to the ability to perform the FTSS balance task. On the contrary, the participant´s PD stage and risk of falls used as the indicators of the severity of PD were stated by a neurologist with the use of standardized clinical examinations on PD and Hoehn and Yahr´s classification of the PD stage (Hoehn & Yahr, 1967) and the Conley scale (Conley et al., 1999). The Conley scale is a clinical tool justified by the good margin of accuracy and predictability in identifying genuinely positives for patients truly exposed to the risk of falls (Guzzo et al., 2015).

Very good diagnostic qualities of the above-mentioned clinical examinations on PD and two tools have been supported by the findings of significantly longer time needed for performing the FTSS task observed in the participants being at a higher stage of PD while they performed the task. However, no significant interactions between the PD stage and the risk of falls on one hand, time needed for completion of the FTTS task and several imbalance symptoms observed during this task suggested the generalizability of the effect of attentional focus on dynamic balance associated with changes of body positions across the PD stages I-III and regardless of moderate risk of falls or no risk is identified in PD patients.

There is a methodological recommendation for experimental investigation on the effects of attentional focus to provide very similar wording of the EFA and IFA instructions, with differences in only one or two words, to avoid confounds with other variables (Wulf, 2013). In the present study, the only difference in wording between the EFA and IFA instruction was related to a critical cue of attention - „the tape markers" (EFA) vs „your shoulder (IFA)". It should be also noted that the spatial location of the internal cue and the external cue to which participants were to direct their attention to perform the FTSS task were very close – one´s shoulders vs. the tape markers glued on one´s shoulders. Although these close spatial locations, the participants with PD were overall able to adopt a given specific attention induced by the instruction, as the results of checking adherence to instruction showed. Also, in the study by Wulf et al., (2009), PD patients were given instructions to focus on minimising the movement of their own feet (IFA) or minimising the movement of the disk they were balancing on. Our study showed that patients with PD in stages I-III can adopt task-specific instructions so that they enter into cognitive mechanisms coupled with motor programming. Specifically for EFA, maintaining a focus externally, i.e., on the task goal or movement outcome or consequence facilitates goal-action coupling (Wulf & Lewthwaite, 2016).

CONCLUSIONS

To maintain or ameliorate balance and mobility in PD individuals, various types of physical training for balance have been examined such as perturbation-based balance training (Coelho et al., 2022), exergaming therapy (Rocha, 2023), virtual reality training (Wu, 2022) and other types of exercise intervention. However, most of these or other studies reported ambiguous effects. The present study showed that providing instruction that stimulates the adoption of external focus of attention can ameliorate dynamic balance during performing of a motor action demanding quick changes of body position in individuals with PD in the stage I-III. This work also provides evidence that these PD individuals are able to adopt task-specific instructions to perform movement tasks. The manipulation with the focus of attention via instructions can be helpful in clinical settings for interventions aimed at maintaining or improving motor functions and skills in the frame of rehabilitation in individuals with PD.

ACKNOWLEDGEMENTS

The study has been funded by the Internal Science Foundation of the College of Physical Education and Sport PALESTRA, the code of the project SV-IV-3_2022.

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ATTACHMENT

Balance Inventory for the Five times sit-to-stand task

criterion	Symptom	score
Sitting balance	Steady	0
	unsteady, lean	1
Balance while rising up	Steady	0
	unsteady, trunk sway, staggers	1
Change of sole position while rising up	No	0
	Yes	1
Standing balance	Steady	0
	unsteady, lean, trunk sway	1
Change of sole position while moving down	No	0
	Yes	1
Keeping arms crossed on the chest	Yes	0
	the palm/s leaving the chest	1
Risk of fall	No	0
	Yes	1

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