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Neurofeedback and physical balance in Parkinson's patients

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A B S T R A C T

The primary goal of the present research is to study the effect of a neurofeedback training (NFT) period on balance problems associated with Parkinson's disease. Sixteen patients were selected through purposive sampling and were randomly divided into experimental and control groups. The research procedure included eight sessions. Prior to and after training, pre-tests and post-tests of static and dynamic balance were administered using "limit of stability" for the Biodex as well as the Berg scale. The results revealed that, after neurofeedback training, a statistically significant improvement in both static and dynamic balance in the experimental group was achieved. The means of the Biodex and Berg scores in the experimental group increased from 18.87 to 42.87 and 17.62 to 46.37, respectively. The means of the Biodex and Berg scores in the control group in the pretest were 18.25 and 17.75 and increased to 20.00 and 20.50, respectively. The results suggest that NFT can improve static and dynamic balance in PD patients.

1. Introduction

Over the past 60 years, it has been discovered that it is possible to reconstruct and retrain brainwave patterns [1]. Brainwave training, called EEG biofeedback or neurofeedback training (NFT), can help in the treatment of many diseases that originate in the brain [2]. Neurofeedback is a kind of biofeedback in which people receive feedback of input signals that are related to their subconscious neural activities [3]. A patient who observes their brainwaves on a computer screen can control these waves and change them based on requirements. This leads to the patient learning to subconsciously control their brainwaves in the other conditions of life [3]. Neurofeedback can regulate brain function and has been successfully used to treat balance problems in some diseases, such as attention deficit hyperactivity disorder (ADHD), fibromyalgia, and chronic stroke [1,2]. Hammond [4] reported on the successful treatment of balance problems in four clinical patients utilizing a specific protocol. Recent research by Thornton and Carmody [5] suggests that neurofeedback can often produce significant improvement, even many years after a head injury. Parkinson's disease (PD) is a particularly suitable target for such neurofeedback intervention because imbalance between cortical and subcortical motor circuits is at the heart of pathophysiological models [6]. Because balance and gait in Parkinson's disease are attention process demands, any improvement in the patient's attention can lead to an increase in the maintenance of balance [7,8]. Several studies have shown that NFT can alter the beta frequencies that influence participants' attentional processing. Rasey et al. [9] reported on 20 training sessions to enhance beta (16–22 Hz) and inhibit high theta (4–8 Hz) in the CPz–PCz. Egner and Gruzelier [10] trained 22 participants to enhance low beta and inhibit theta. They concluded that a successful enhancement of attentional performance in healthy volunteers through EEG-operant conditioning techniques can be achieved. Others studies reported that neurofeedback training to enhance beta activity may influence semantic working memory performance. Vernon et al. [11,12] suggested that enhancing 12–15 Hz helps the maintenance of the working memory representation utilized in semantic working memory. Egner et al. [13] reported that enhancing low beta and beta1 may have differential effects on attentional processing. In a subsequent study, they found [14] that focusing on beta1 enhancement can improve musical performance. However, the effectiveness of neurofeedback training in these waves is not limited to attentional processing or working memory [4]. Furthermore, it should be noted that treatment of patients with motor deficiencies has been considered by researchers as another application of neurofeedback training [15]. Since there is a relationship between specific patterns of cortical activity and particular levels of performance, the use of neurofeedback to train patients with motor deficiencies to recreate patterns of cortical activity can result in enhanced performance [16]. This study can be considered proof of concept for the application of neurofeedback

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for patients with a neurodegenerative disorder. We furthermore wanted to assess whether neurofeedback provides clinical benefits to patients with early-stage PD. However, to the best of our knowledge, the treatment of PD patients with balance problems has not been investigated previously and the main purpose of this study is to evaluate the effects of neurofeedback training on both dynamic and static balance in Parkinson's patients.

2. Material and methods

2.1. Participants

The participants of the current study were 16 PD patients in stage 1.5–2 on the Hoehn and Yahr scale [17]. The participants were selected using purposive sampling, and they provided informed consent to participate in the research. They were randomly divided into experimental and control groups. Each group consisted of eight patients (four women and four men). All participants lived at home and were tested while on medication. Levodopa-equivalent dosages were calculated to express dose intensity of different anti-Parkinsonian drug regimens on a single scale. The main exclusion criteria included an inability to walk without walking aids, other kinds of balance disability, and psychiatric or cognitive disturbances [18]. Ethical approval was granted by the local ethics committee. Characteristics of participants are presented in Table 1.

2.2. Materials

The following components were used in this study: (a) Three specific electrodes: Active (blue wire) and reference (yellow) electrodes for head and grand (black) electrodes for earlobe. Biograph Infiniti Software system (version 5.0) filtering at a set frequency of 60 Hz, the ProComp differential amplifier (Thought Technology Ltd, Montreal, Quebec) for NFT sessions (FlexComp Infiniti encoder, TT-USB interface unit, fiber optic cable, USB cable) that provide 24-bit analog-to-digital conversion with an internal sampling rate of 2048 samples/second and 256 sps data rate to the PC; (b) The computer (Microsoft Windows XP, CPU 3.30 GHz and 317GB of RAM) and all relevant hardware; (c) The Biodex Balance System (SD) – limit of stability test level 8 to measure static balance [19]; (d) Berg Balance scale (BBS) to measure dynamic balance [20].

2.3. Scoring method

To measure static balance, level 8 of the Biodex "limits of stability" test was used. During each trial, patients were asked to shift their weight to move the cursor from the center target to a blinking target and return quickly with as little deviation as possible. This test has adequate reliability (intraclass correlation coefficient $r = 0.82$ to 0.48 and internal consistency $r = 0.42$ to -0.65) [19]. The Berg balance scale was used to measure dynamic balance. An independent researcher who was unaware of the patient groups scored the Berg balance scale in the pre- and posttest conditions. Two other raters checked the first rater's assessment. Fourteen items, including standing from a sitting position and standing on one foot, were used. The degree of success in achieving each task was given a score of zero (unable) to four (independent), and the final measure is the sum of all the scores. This test has excellent intra-rater reliability (ICC = 0.98), and is internally consistent (0.96) [20].

2.4. Experimental procedure

The period of the research was two-and-a-half weeks with three sessions per week (eight sessions). Before the training sessions, a pretest of static and dynamic balance was administered. During training sessions, subjects comfortably sat in an armchair in front of a computer monitor. The international 10–20 system of electrode placement was used to locate electrodes on the scalp. Two sensors were attached to the left and right occipital (O1, O2) and one to the subject's left earlobe. In each session, an EEG baseline was recorded using the electrodes and neurofeedback software to determine the level of brainwaves in CZ (central zero) of the scalp with eyes open and closed. Blue and yellow electrodes were placed on the O1-O2 by the operator, respectively. Then the subject underwent the training session. The patient played three video games on the computer screen for 30 min. The game was set by the subject in a way that increases beta 1(12–15 Hz) and decreases theta (4–7 Hz) activity in a wave needed for the protocol. When the activity increased or decreased in an incorrect band, the game or amplifications were stopped. Video games included boat sailing (10 min), puzzles (10 min), and moving animations (10 min) (Fig. 1).

After the training sessions, the posttest of static and dynamic balance was recorded. The control group training had a similar process as the experimental group, but in the training session, a

Table 1
Characteristics of participants.

	Experimental group ($N=8$)		Control group ($N=8$)		*P*-value[g]
	Mean	Std	Mean	Std	
Age (year)	74.23	3.51	75.16	3.64	0.79
Weight (kg)	60.67	2.79	60.62	2.19	0.92
Tall (cm)	155.37	4.37	155.12	3.48	0.89
DD[a] (year)	8.5	2.00	9.5	1.77	0.77
Y&h[b] (1–5)	2.35	0.08	2.09	0.89	0.84
DBPR[c] (56)	17.62	2.38	17.75	2.86	1.00
SBPR[d] (65)	18.87	6.70	18.25	6.22	1.00
DBPO[e] (56)	46.37	4.10	20.50	3.02	0.001
SBPO[f] (65)	42.87	5.81	20.00	6.34	0.001

[a] Disease duration.
[b] Hoehn and Yahr scale.
[c] Dynamic balance pretest.
[d] Static balance pretest.
[e] Dynamic balance posttest.
[f] Static balance posttest.
[g] Significance was assessed by a Student's *t*-test ($P < 0.05$).

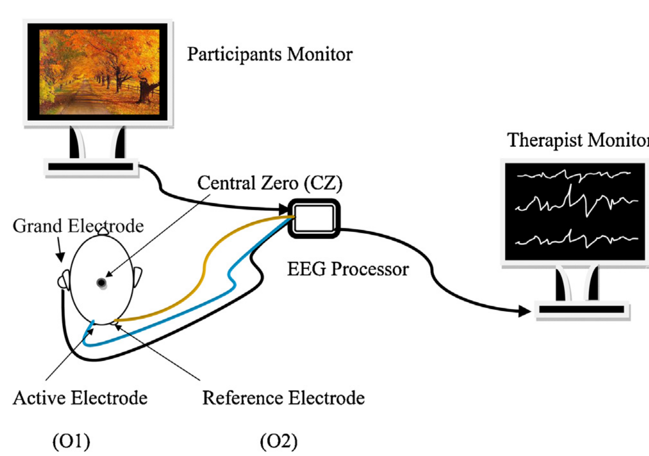

Fig. 1. Schematic illustration of the neurofeedback system. Electrode placement in the 10–20 electrode system on O1 & O2 which are left & right Occipitals of the scalp. Subjects play games without using hands and therapist control these games based on subjects' mental waves.

Table 2
Test of repeated measure ANOVA for static and dynamic balances (group as a factor and pre and posttest (time) as a condition).

	Sum of squares	df	*F*	*P* value
Static balance				
Group	1326.125	1	191.894	0.00
Group × time	990.125	1	143.274	0.00
Time	1104.500	1	15.333	0.02
Dynamic balance				
Group	1984.500	1	258.447	0.00
Group × time	1352.000	1	176.074	0.00
Time	1326.125	1	108.098	0.00

Table 3
Tests of repeated measures ANOVAs for beta and theta waves during eight sessions in experimental and control groups.

	Experimental		Control	
	Beta1	Theta	Beta1	Theta
Df	7	7	7	7
Mean square	6.63	7.11	0.25	0.46
F	29.06	227.8	0.579	2.70
P value	0.001	0.001	0.567	0.131

sham EEG generator replaced the subject's EEG signal. The sham-NFT condition was similar to the experimental condition in all aspects (equipment, duration, frequency, and videogame choices) except that the interface module which presented random feedback was not based on the subject's EEG. Prior to the testing, an offsite consultant with no connection to the participants or data programmed the software interface devices.

2.5. Data analysis

To evaluate behavioral responses, descriptive and inferential statistics were used. Data analysis was carried out in SPSS 19. For each variable (static and dynamic balances), a repeated measures analysis of variance (ANOVA) was performed to determine statistically significant differences among the conditions (pretest and posttest) with groups as a factor, and an alpha level set at 0.05. Since the assumption of sphericity was violated, a Greenhouse–Geisser correction was applied. Differences among each pair of conditions were presented as means and confidence interval (CI) of 95 percent was considered.

3. Results

Repeated measures ANOVA for static and dynamic balance scores indicated that differences between factors and conditions were statistically significant (Table 2). Specifically, in the experimental group, static and dynamic balance scores improved ($p \leq 0.001$).

The mean amplitude for the training frequencies across the eight sessions is shown in Fig. 2. The experimental group showed an increase in beta1 mean and decrease in theta mean from session one to eight. Table 3 shows beta and theta wave variations during sessions in experimental and control groups. As can be seen in this table, the *p*-values for the experimental group were 0.001 for both beta and theta waves, while those of the control group were greater than 0.05. This implies that the variations of beta and theta waves were significant and those of the control group were not significant.

4. Discussion

In this study, we examined the effect of neurofeedback training on PD patient's balance. The results provided evidence that 30 min of NFT inhibit 4–7 Hz while reinforcing 15–18 Hz activity over eight sessions. This can contribute, at least temporarily, to the improvement in both static and dynamic balance of PD patients. Previous studies have shown the effect of neurofeedback balance training on patients with Parkinson's disease [21]. They reported that neurofeedback balance training could reduce the number of patient falls. Furthermore, one recent study conducted by Subramanian et al. [22] showed that PD patients can change local brain activity to improve motor function during NFT. In addition to these results, we have shown that static and dynamic balance improved simultaneously based on data depicted in Table 2. According to Table 3, the experimental group showed clear evidence of neurofeedback learning as demonstrated by increased beta1 mean and decreased theta mean. It is clear that the experimental participants were able to learn to selectively enhance their beta1 and reduce their theta activity during training (Fig. 2). This result implies that eight sessions of training of EEG activity are sufficient to create significant changes in a specific EEG frequency in PD patients. The fact that the control group failed to represent any indication of "learning" (Table 3) suggests that the protocol used was efficient [12,13]. In Parkinson's disease, the connection

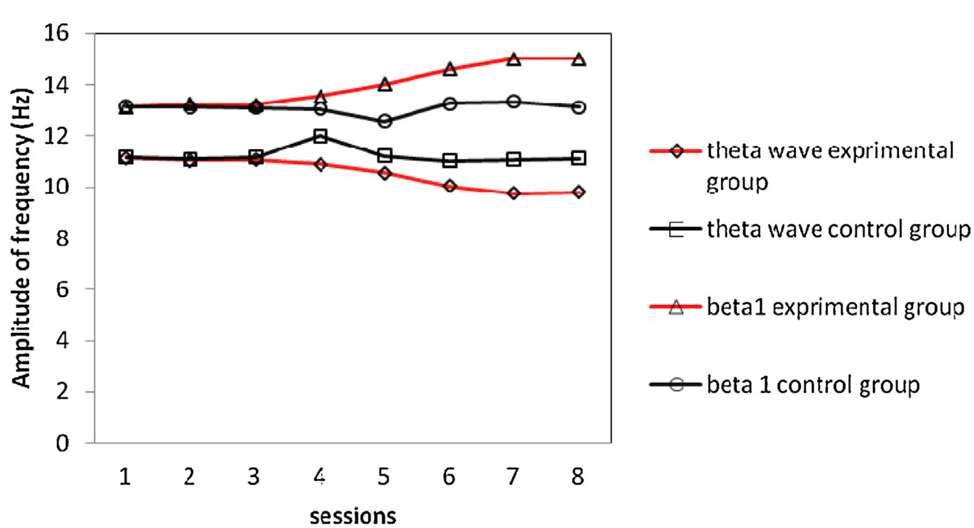

Fig. 2. Mean amplitude frequency of beta1 and theta waves of subjects during training sessions.

between the brain and the patient's movement is unavoidable [23]. Due to the disruption of neuronal cells, maintenance and preservation of remaining cells is essential for optimum performance [24]. Regarding principles of neurofeedback, at first more information about body functions is presented to the brain and then the range of brain waves can be modified voluntarily. This study found that during NFT training, patients were able to manage their body movements based on the self-regulation of the brain [12]. Assuming that patients can learn to transfer the strategies used during neurofeedback into real-life settings, it might also become possible to sustain the clinical benefits without regular stimulation sessions. According to Table 3, during NFT (with our protocol), beta1 increased. Thus, we conclude that alertness and effectiveness of the individual improved. This is important because PD patients must be alert, attentive, and apply problem-solving to maintain their static and dynamic balance [7,17]. Other studies have claimed that improving alertness leads to subjects becoming increasingly aware of themselves, their bodies, and their environments [10,11]. Meanwhile, theta inhibition (Table 3) helps this process by diminishing sedation syndrome, blackouts, and introspection, which have already been reported by Leins et al. [25]. It seems that by increasing beta and decreasing theta (Fig. 2), patients can create self-regulation and self-efficacy. If patients are self-aware and trying to achieve good physiological skills, they will manage to control their brainwaves in other circumstances [3]. Similar to our findings, several studies have already shown that the enhancement of awareness and self-regulation can improve balance and decrease fear of falling [7,8,26,27].

The position of electrodes on the scalp is important in attaining balance improvement. In the present study, the electrodes were placed at "O1-O2" of the scalp. These points are close to the occipital lobe, substantia nigra, basal ganglia, and cerebellum, which play important roles in maintaining balance [4]. In this manner, NFT may regulate the appropriate pulses for brainwaves and may have an effect on the cortical and sub-cortical motor loops. Consequently, patients learn to enhance desirable EEG frequencies and suppress undesirable frequencies at selected scalp locations and their balance is expected to improve [15]. So an NFT protocol improves compensatory mechanisms that have no known side effects while directly involving the patients by providing control over their treatment and probable improvement of symptoms [22]. Since the training protocol is very specific and specialized, to prevent possible injuries arising from improper protocols, it is recommended that this training be conducted at a clinic under the supervision of an NFT expert.

5. Conclusion

In this study, the effects of neurofeedback on balance of patients with Parkinson disease were successfully verified. The results showed that this method can be effective for improving the dynamic and static balance of PD patients. The research concluded that during NFT, subjects can learn to selectively control their brain waves. These results confirm previous studies that claimed that neurofeedback could treat other kinds of diseases. The results also demonstrated that NFT can complement treatment processing and can enhance traditional methods. Regarding the interesting findings of the present study, it is recommended that this method be part of the treatment process to improve PD patient balance. This approach may be more effective if associated with traditional medical treatments.

6. Limitations and perspectives

The research showed that NFT can improve PD patient balance, but much more work remains. The present intervention was brief and not intensive. Also a lack of follow-up measurements was a limitation of this study. It would be interesting to investigate the effects of longer-term or more intensive NFT on PD patients as well as long-term effects of neurofeedback. In the current study, the number of participants was low and disease severity was mild, without cognitive decline. We suggest that future studies focus on the effects of NFT in a larger number of participants with more advanced PD, more distinct balance disorders, and with cognitive deficits.

Conflict of interest statement

We confirm that this study has not any financial and personal relationships with other people or organizations that could inappropriately influence (bias) our work. Also there is not any potential conflicts of interest include employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, and grants or other funding.

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