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Effectiveness of Neurofunctional Physical Therapy on the Quality of Sleep of Individuals with Parkinson's Disease: Case Series

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Abstract

Objective Sleep disorders are disabling and highly prevalent comorbidities in Parkinson's disease (PD). This study's objective was to verify the effectiveness of neurofunctional physiotherapy in sleep quality, objectively and subjectively assessing it among individuals with PD.

Methods A sample of individuals with PD was assessed before and after 32 physiotherapy sessions and three months later (follow-up). The following instruments were used: Pittsburgh Sleep Quality Index (PSQI); Epworth Sleepiness Scale (ESS); Parkinson's Disease Sleep Scale (PDSS), and actigraphy.

Results Nineteen individuals aged 67.37 years old ($\pm$ 8.03) on average were included. No differences were found in any of the variables measured by the actigraphy or the ESS. Improvement was found from pre- to post-intervention in terms of nocturnal movements ($p = 0.04$; $d = 0.46$) and total score ($p = 0.03$; $d = 0.53$) obtained on the PDSS. Improvement was also found in the PDSS sleep onset/maintenance domain ($p = 0.001$; $d = 0.75$) between pre-intervention and follow-up. The participants' total score obtained in the PSQI improved from pre- to post-intervention ($p = 0.03$; $d = 0.44$). Significant differences were found in nighttime sleep ($p = 0.02$; $d = 0.51$) and nocturnal movements ($p = 0.02$; $d = 0.55$), and in the PDSS total score ($p = 0.04$; $d = 0.63$) between pre- and post-intervention when only the poor sleepers subgroup ($n = 13$) was considered, while improvements were found in sleep onset/maintenance ($p = 0.003$; $d = 0.91$) between pre-intervention and follow-up.

Discussion Neurofunctional physiotherapy was ineffective in improving objective parameters of sleep but was effective in improving the perception of sleep quality subjectively assessed among individuals with PD, especially those who perceived themselves to be poor sleepers.

Keywords
- Physical Therapy Specialty
- Parkinson Disease
- Sleep
- Actigraphy
- Rehabilitation

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Introduction

Even though conceptually, Parkinson's disease (PD) is strongly related to motor disorders, non-motor disorders, such as sleep disorders, negatively affect quality of life and cause discomfort similar to or even worse than that due to motor causes. It is a fact that dopaminergic degeneration plays a prominent role in the pathophysiology of PD. However, other pathways, such as noradrenergic, cholinergic, and serotonergic, can also explain the broad clinical spectrum of the disease.[1,2]

The latter is the one that better explains the presence of sleep disorders, considering that from 74% to 98% of the individuals with PD are affected by sleep disorders, such as nocturnal akinesia, rapid eye movement (REM) sleep behavior disorder, restless legs syndrome, excessive daytime sleepiness, obstructive sleep apnea, nocturia, and hallucinations.[3,4]

Pharmacological treatment is the approach most frequently used to manage the disease's motor symptoms, and dopaminergic agents are the most efficient[3,4]; however, it is little efficient to manage non-motor symptoms, which are often refractory to pharmacological treatments. Additionally, over time, L-dopa therapy triggers side effects like sleep disorders, negatively impacting the quality of life, memory, learning, and functioning of individuals with PD.[3,5] For this reason, studies have currently targeted non-pharmacological strategies, such as exercise and sleep hygiene (behavioral) measures to treat sleep disorders.[6]

Exercise is a side-effect-free alternative that can improve sleep quality in persons with PD.[7] A recent systematic review with meta-analysis reports that exercises (in general) positively and significantly improve subjective sleep quality. When the treatment intensity was considered, only moderate and high-intensity exercises significantly influenced the subjective quality of sleep (as opposed to mild and moderate exercise intensity). However, studies that use both objective and subjective measures for sleep assessment are necessary, since these methods assess different aspects of sleep, and the individual's perception of their sleep quality is not always in accordance with objective values.[5] Only one randomized clinical trial in the systematic review assessed sleep quality objectively (polysomnography) and reported improved sleep efficiency after a vigorous exercise protocol. Note that the methodological quality of the studies reporting positive effects on sleep quality was significantly inferior to the quality of studies that did not report such effects.[1,3]

However, some aspects should be considered. High-intensity exercises may limit patient adherence to treatment protocols as intensive treatment protocols do not favor individuals with decreased mobility, cognitive deficits, or advanced disease stages; these individuals are usually more frequently affected by sleep disorders. Finally, little is known about the application and benefits of different modalities of exercises, frequency, duration, and effects in the long run in this population.

The specialized neurofunctional physical therapy, based on controlling signs and symptoms and promoting functional independence among these individuals, gathers much evidence of its efficiency in studies mainly addressing motor outcomes.[8] These results motivated this study because, thus far, there are no studies evaluating the effectiveness of physical therapy on objective and subjective sleep outcomes with follow-ups.[1]

Therefore, this study aimed to verify the effectiveness of neurofunctional physical therapy in improving the objective sleep parameters and the perception of sleep quality among individuals with PD, especially to investigate whether there are differences in the results between individuals classified as good or poor sleepers. We hypothesized that physical therapy would have beneficial effects on the sleep quality of individuals with PD.

Material and Methods

Study Design

This case series was performed from March 2016 to March 2017 at the State University of Londrina and the Ágape Social Service Center (CASA), located in Londrina, PR, Brazil. The Institutional Review Board at the State University of Londrina approved this study (Opinion report 1.356.676 and CAAE: 50118715.0.000.5231). All the participants were volunteers and signed free and informed consent forms after receiving clarification regarding the study's objectives, assessment, and intervention procedures. The participants were first assessed and later attended a four-month intervention protocol. They were reassessed immediately after the intervention and after three months (follow-up). The study flowchart is presented in ►**Figure 1**.

Participants and Recruitment

The sample was estimated as proposed by Yang and collaborators,[6] resulting in 19 participants, considering a mean difference of 10.73 in the PDSS total score obtained between the baseline and follow-up, with the level of significance established at 5% and power at 90%.[7] The individuals were recruited from the specialty outpatient clinic at the university hospital of the State University of Londrina and screened by telephone. Standardized questions were asked concerning when PD was diagnosed, what medication was used, whether the individuals were attending a rehabilitation program,

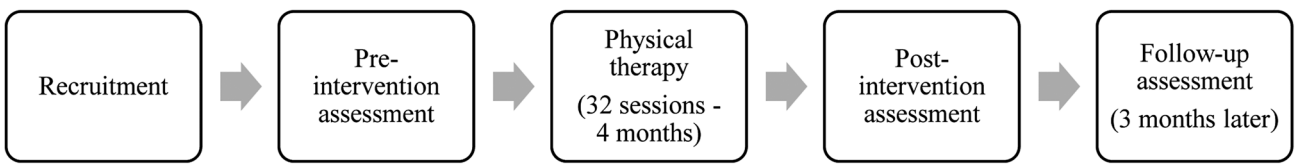

Fig. 1 Study flowchart.

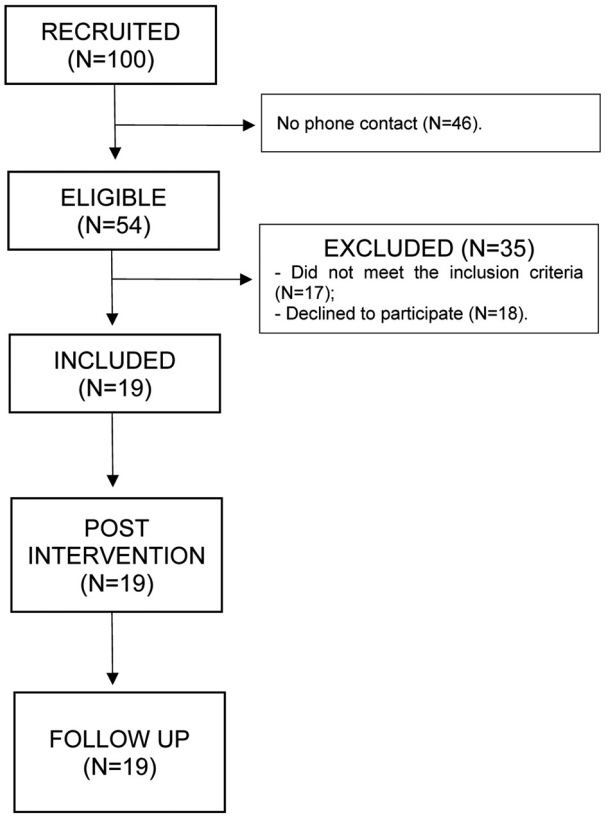

Fig. 2 Participants' flowchart.

independent gait, degree of independence when performing activities of daily living, personal antecedents, and whether they were interested in attending the physical therapy sessions. The patients selected through the interview and who met the following inclusion criteria were included in the study: being diagnosed with idiopathic PD based on the UK Brain Bank diagnostic criteria; staging between 1.5 and 3 on the modified Hoehn & Yahr scale; being 50 years old or older; walking independently, and anti-Parkinson therapy being stable for at least 4 weeks before the study's implementation. Excluding criteria were individuals with other neurological or musculoskeletal diseases, associated disorders, or cognitive impairment with the potential to interfere in the assessment process verified according to the cut-off points proposed by Bertolucci et al.[8] The loss criteria were presenting changes in the therapeutic scheme or missing more than four sessions. The flowchart for patients is presented in ►**Figure 2**.

Assessment Procedure

All the assessments were performed by the same evaluator (previously trained), always at the same time of day, when the patients' medications were on the "on" time, at three points in time: pre-intervention, post-intervention (four-month duration), and follow-up (three months after the intervention). After information regarding when the diagnosis was disclosed, weight and height information was gathered along with Levodopa equivalent daily dose calculation,[9] the patients were assessed using the following instruments: 1) the severity of the disease was assessed using the Modified Hoehn and Yahr (H&Y) and Unified Parkinson's Disease Rating Scale (UPDRS)[10]; 2) cognitive state was assessed using the Mini-Mental State Exam (MMSE)[11]; 3) sleep was assessed using the Actiwatch-2 actigraphy system (Respironics Inc, Philips) to record the individuals' periods of movement and rest, objectively measuring periods of motor activity, exposure to ambient light, and inactivity (sleep). The devices were configured according to each patient's identification data. The participants were instructed to keep the device on the wrist of their choice over a 7-day period, not removing it even for showering. Transducers and microprocessors transform acceleration into a digital signal so that each movement generates a voltage in proportion to its acceleration. Data were obtained after the recording period by connecting the device to a microcomputer and retrieved using the Respironics Actiware software (Respironics Incorporation, Philips), version 6.0. The variables obtained from the actigraphy record were: total time in bed (difference between the time the individual woke up and time s/he laid down, recorded in hours and minutes); total sleep time (difference between the time the individual woke up and sleep latency, recorded in hours and minutes); sleep latency (sleep time, recorded in minutes); sleep efficiency (total night sleep time *100/total time in bed); and wake after sleep onset (WASO recorded in minutes).[5]

A subjective sleep assessment was also performed using the Brazilian versions of the following instruments: Sleep Scale for Parkinson's Disease (PDSS): a visual analog scale specific to PD, composed of 15 sleep-related items divided into 8 domains: Overall quality of night's sleep (item 1); sleep onset and maintenance insomnia (items 2 and 3); nocturnal restlessness (items 4 and 5); nocturnal psychosis (items 6 and 7); nocturia (items 8 and 9); nocturnal motor symptoms (items 10–13); sleep refreshment (item 14); and daytime dozing (item 15). Scores lower than or equal to 100 indicate sleep disturbances[5,12–14]; Pittsburgh Sleep Quality Index (PSQI): a generic scale that assesses sleep quality, with scores ranging from 0 to 21; the higher the score, the worse the quality of sleep[5,15,16]; and Epworth Sleepiness Scale (ESS): used to measure the degree of daytime sleepiness, consisting of 8 items, with scores ranging from 0 to 3. Scores above 9 indicate the presence of excessive daytime sleepiness.[5,17]

Intervention

After the groups were formed and the assessment procedures ceased, the physical therapy program was initiated. The program consisted of 32 sessions (60 minutes each) held twice a week for four months. The therapies were performed in groups, but a trained physiotherapist individually assisted each participant. The therapists implementing the treatment were not involved in the assessment process and vice-versa.

The neurofunctional physical therapy protocol was based on Santos et al.[18] It focused on balance, sensory integration, agility, motor coordination, limits of stability, anticipatory and reactive postural adjustments, functional independence, and improving gait, with a gradual progression of exercises, as shown in ►**Figure 3** and detailed in the ►**Supplementary Material**.

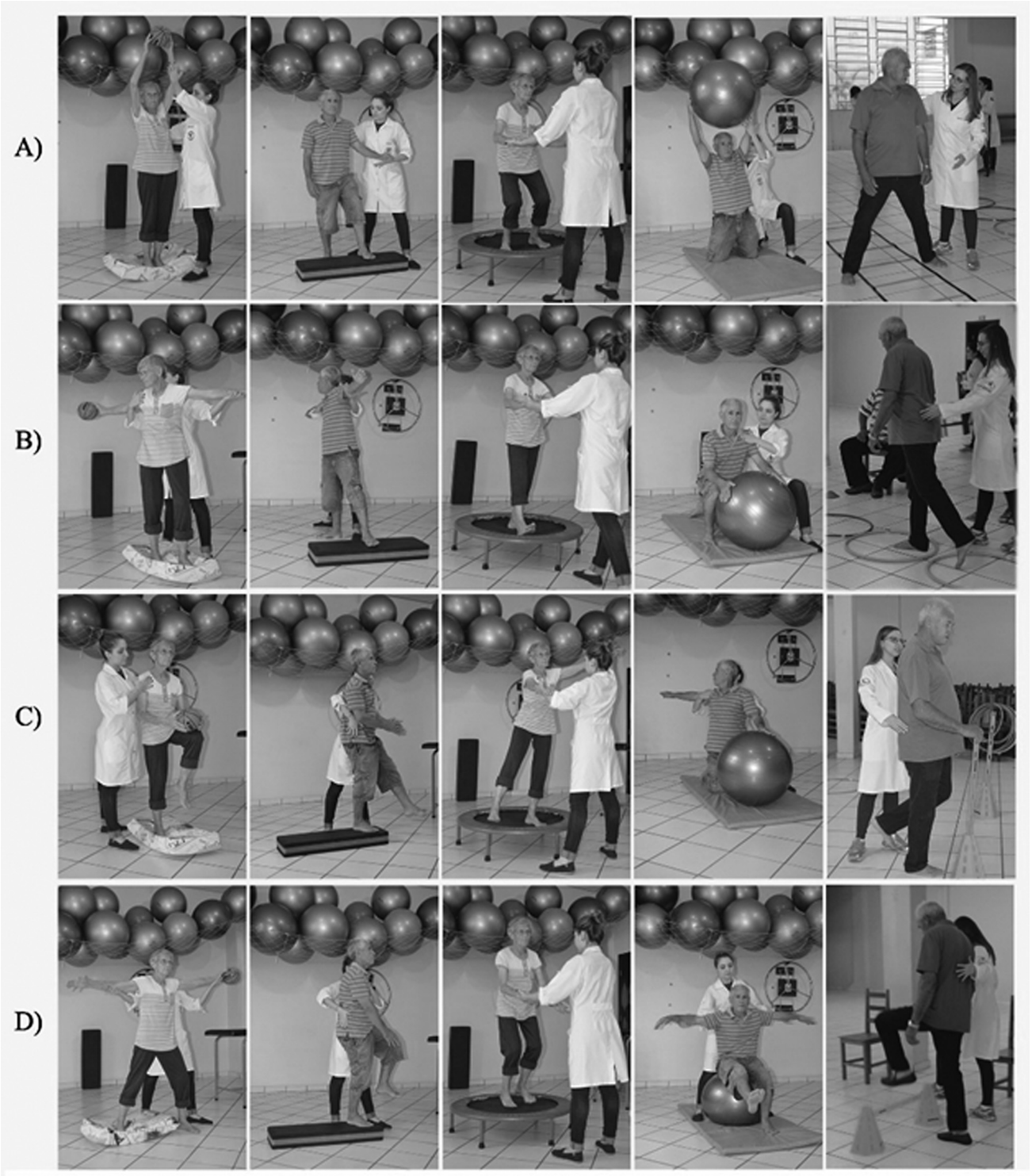

Fig. 3 Physical therapy protocol according to ►**Appendix 1**. A) 1st to 8th therapy. B) 9th to 16th therapy. C) 17th to 24th therapy. D) 25th to 32nd therapy.

Statistical Analysis

Descriptive data are presented in terms of mean and standard deviation or median and interquartile interval according to the distribution of normality, analyzed by the Shapiro-Wilk test. The Friedman test was used to compare pre-, post-intervention, and follow-up. Cohen's d effect size measures (ES) were used to determine the magnitude of post-intervention changes (ES= difference between post- and pre-intervention mean divided by pre-intervention standard deviation). The values used to interpret the effect size were insignificant <0.19, small 0.20–0.49, average 0.50–0.79, large 0.80–1.29, and very large >1.30.[19] Statistical significance was established at $p < 0.05$. The analyses were performed using SPSS for Windows, version 27.0.

Table 1 Sample characterization.

Variables	Group (n = 19)
Sex (M/F)	14 (74%) / 5 (26%)
Age (years)	67.37 ± 8.03
Time since of diagnosis (months)	48.00 [24.00–96.00]
BMI	28.15 ± 5.06
LEDD (mg)	400.00 [300.00–750.00]
MMSE	26.79 ± 2.66
Hoehn & Yahr	2.50 [2.00–3.00]
UPDRS II (ADL)	11.00 ± 3.74
UPDRS III (Motor)	22.26 ± 6.37
UPDRS (Total)	30.00 [27.00–39.00]

Legend: M = male; F = female; BMI = Body mass index; LEDD = Levodopa equivalent daily dose; MMSE = Mini-Mental State Examination; UPDRS = Unified Parkinson Disease Rating Scale; ADL = activities of daily living.

Results

The characterization of the participants, such as sex, age, time since diagnosis, Body Mass Index (BMI), Levodopa equivalent daily dose (LEDD), scores obtained on the MSSE, H&Y, and UPDRS, are presented in ►**Table 1**. All the participants completed a protocol composed of 32 therapy sessions distributed over four months. The values were expressed in terms of absolute and relative frequency and according to mean and standard deviation or median and interquartile interval based on the variables' characteristics and the normality of data.

►**Table 2** presents the results concerning quantitative sleep variables obtained via actigraphy. No significant differences were found for any of the variables measured in the pre-, post-intervention or follow-up periods.

►**Table 3** presents the results of the subjective assessment of sleep performed with the PDSS, ESE, and PSQI scales between pre-, post-intervention, and follow-up. The PDSS total score ($p = 0.03$; $d = 0.53$), as well as the nocturnal movements variable ($p = 0.04$; $d = 0.46$), significantly improved between the pre- and post-intervention. Only PDSS domain sleep onset/maintenance improved, with an average effect size, between the pre-intervention and follow-up ($p = 0.001$; $d = 0.75$). No differences were found in terms of daytime sleepiness, as assessed using the ESS. The participants' total scores in the PSQI improved from pre- to post-intervention ($p = 0.03$; $d = 0.44$).

The scores presented in ►**Table 4** compare pre-, post-intervention, and follow-up moments among "poor sleepers", classified according to the PDSS cut-off point (≤ 100).[5,12] According to this categorization, the intervention had no effect on this subgroup, when considering the actigraphy assessment, and according to the ESE and PSQI scores. However, when using the PDSS, a specific scale to assess sleep in PD, significant improvement was found in PDSS

Table 2 Comparison between pre-, post-intervention and follow-up as assessed by the actigraphy method.

Variables	Pre-intervention (n = 19)	Post-intervention (n = 19)	Follow up (n = 19)	*P*	Δ Post-Pre (95% CI) Effect size (d)	Δ FU-Post (95% CI) Effect size (d)	Δ FU-Pre (95% CI) Effect size (d)
Time in bed (h:m)	9:03 [7:34–9:42]	8:36 [7:11–9:28]	8:17 [7:35–9:43]	0.14	20.78 (-11.94; 53.52) d = 0.38	-16.04 (-52.63; 20.54) d = 0.25	4.74 (-30.44; 39.92) d = 0.10
Total sleep time (h:m)	6:55 [6:02–7:57]	7:06 [5:51–7:54]	6:23 [5:40–7:14]	0.72	-16.16 (-56.60; 24.26) d = 0.25	-6.58 (-41.58; 28.41) d = 0.01	-22.75 (-65.53–20.02) d = 0.01
Latency (m)	29.41 [14.82–48.11]	39.73 [18.33–58.84]	33.11 [14.39–65.61]	0.84	0.81 (-13.79; 15.42) d = 0.02	5.40 (-9.24; 20.05) d = 0.10	6.22 (-11.21; 23.66) d = 0.19
Efficiency (%)	78.93 [74.34–83.30]	80.94 [74.02–85.81]	75.94 [71.90–85.56]	0.91	0.01 (-3.68; 3.72) d = 0.08	-0.73 (-5.99; 4.52) d = 0.02	-0.72 (-4.49; 3.04) d = 0.03
WASO (m)	40.14 [33.08–57.77]	42.55 [28.03–54.94]	39.46 [30.64–60.61]	0.72	-2.65 (-15.63; 10.31) d = 0.08	3.88 (-12.91; 20.69) d =0.01	1.22 (-9.12; 11.57) d = 0.01

h:m= hours:minutes; m = minutes; % = percentage; WASO: wake after sleep onset.

Table 3 Comparison between pre-. post-intervention and follow-up as assessed by the PDSS. ESS and PSQI.

Variables	Pre-intervention (n = 19)	Post-intervention (n = 19)	Follow-up (n = 19)	*P*	Δ Post-Pre (95% CI) Effect size (d)	Δ FU-Post (95% CI) Effect size (d)	Δ FU-Pre (95% CI) Effect size (d)
PDSS							
Nighttime sleep	5.10 [4.60–7.90]	7.20 [4.63–8.88]	7.00 [5.20–7.80]	0.07	1.06 (0.06; 2.07) d = 0.42	-0.08(-1.64; 1.47) d = 0.01	0.97 (-0.31; 2.27) d = 0.48
Onset and maintenance	**10.70 [7.83–17.08]**	**14.85 [10.15–17.85][a]**	**16.20 [9.30–19.00] [b]**	**0.001**	**2.63 (0.65; 4.61) d = 0.55**	**1.23(-1.18; 3.64) d = 0.33**	**3.86(1.80; 5.92) d = 0.75**
Nocturnal agitation	10.55 [7.73–14.23]	10.90 [7.78–13.58]	11.10 [7.00–13.80]	0.50	0.15(-2.27; 2.58) d = 0.06	0.38 (-2.49; 3.27) d = 0.13	0.54 (-2.19; 3.28) d = 0.11
Nocturnal psychosis	15.15 [10.25–19.55]	17.85 [11.00–19.78]	13.80 [10.00–19.00][c]	0.01	2.07 (0.12; 4.02) d = 0.41	-1.96 (-3.71; -0.22) **d = 0.58**	0.10 (-2.05; 2.26) d = 0.03
Nocturia	10.05 [9.90–14.03]	10.15 [9.68–12.30]	10.00 [9.00–12.50]	0.49	0.67(-0.40; 1.75) d = 0.27	0.36 (-1.08; 1.81) d = 0.01	1.03 (-0.64; 2.72) d = 0.12
Nocturnal movements	**26.85 [20.63–34.90]**	**34.15 [24.63–36.65][a]**	**25.10 [17.70–35.90]**	**0.04**	**5.77 (0.21; 11.34) d = 0.46**	**-5.03 (-9.46; -0.59) d = 0.49**	**0.74 (-2.93; 4.42) d = 0.11**
Unsatisfactory sleep quality	6.40 [4.38–9.98]	8.75 [2.83–9.90]	6.00 [2.00–9.80]	0.99	-0.50 (-2.11; 1.10) d = 0.08	0.22 (-2.06; 2.50) d = 0.01	-0.28 (-2.71; 2.14) d = 0.01
Daytime sleepiness	8.70 [5.00–9.88]	9.55 [5.60–9.98]	8.50 [5.20–10.00]	0.14	1.53 (-0.55; 3.63) d = 0.47	-1.73 (-3.51; 0.04) d = 0.44	-0.19 (-2.37; 1.98) d = 0.09
Total	**97.90 [73.15–117.35]**	**103.75 [88.50–125.15][a]**	**86.50 [74.10–117.80]**	**0.03**	**13.42 (2.76; 24.07) d = 0.53**	**-6.61 (-13.67; 0.44) d = 0.38**	**6.80 (-2.63; 16.24) d = 0.32**
ESS (Total)	9.00 [7.00–14.00]	9.50 [7.00–13.75]	11.00 [6.00–17.00]	0.50	-0.68 (-3.27; 1.90) d = 0.17	1.11 (-0.73; 2.94) d = 0.32	0.42 (-1.60; 2.44) d = 0.08
PSQI	**6.00 [4.00–9.00]**	**4.00 [3.00–7.00][a]**	**5.00 [3.00–9.00]**	**0.03**	**-1.42 (-3.05; 0.20) d = 0.44**	**0.68 (-0.84; 2.21) d = 0.29**	**-0.74 (-2.30; 0.83) d = 0.22**

PDSS = Parkinson's Disease Sleep Scale; ESS = Epworth Sleepiness Scale; PSQI= Pittsburgh Sleep Quality Index.
[a]Significant differences were found between the pre- and post-intervention periods
[b]Significant differences were found in the pre-intervention and follow-up.
[c]Significant differences were found in the pre-intervention and follow-up.

Table 4 Comparison between pre-, post-intervention and follow-up among individuals classified as poor sleepers, according to the PDSS.

Variables	Pre-intervention (n = 19)	Post-intervention (n = 19)	Follow-up (n = 19)	*P*	Δ Post-Pre (95% CI) Effect size (d)	Δ FU-Post (95% CI) Effect size (d)	Δ FU-Pre (95% CI) Effect size (d)
Actigraphy							
Time in bed (h:m)	8:44 [5:52–9:11]	8:49 [7:11–9:56]	8:09 [7:40–9:40]	0.27	-00:28 (-70.04; 14.03) d= 0.46	00:59 (-70.63; 189.84) d = 0.31	00:31 (-91.78; 154.99) d= 0.12
Total sleep time (h:m)	6:53 [6:06–7:50]	7:12 [5:57–8:12]	6:39 [5:47–7:33]	0.87	-00:07 (-49.99; 34.30) d= 0.30	-00:31 (-72.63; 8.93) d= 0.03	-00:39 (-90.69; 11.29) d= 0.24
Latency (m)	26.68 [15.68–46.13]	33.68 [12.79–48.41]	31.50 [13.16–69.16]	0.66	-2.33 (-22.85; 18.18) d= 0.03	15.40 (-2.73; 33.55) d= 0.12	13.07 (-11.03; 37.18) d= 0.23
Efficiency (%)	80.44 [75.59–88.13]	81.75 [77.13–86.20]	83.46 [72.02–86.88]	0.87	1.50 (-2.99; 6.01) d= 0.10	-3.94 (-10.64; 2.75) d= 0.03	-2.43 (-7.34; 2.47) d= 0.04
WASO (m)	36.57 [33.66–48.11]	42.82 [33.52–63.54]	35.04 [29.48–46.84]	0.87	-4.43 (-22.07 ± 13.21) d= 0.10	3.53 (-20.39; 27.47) d= 0.02	5.15 (-12.11; 10.33) d= 0.02
ESS (Total)	11.00 [6.00–14.00]	11.00 [5.50–14.00]	11.00 [6.50–15.00]	0.69	-0.54 (-3.66; 2.58) d = 0.21	0.54 (-1.63; 2.71) d= 0.38	0.00 (-2.76; 2.76) d= 0.10
PSQI	6.00 [3.00–8.50]	4.00 [2.50–8.00]	3.00 [3.00–8.00]	0.17	-1.46 (-3.72; 0.79) d= 0.53	0.62 (-1.56; 2.79) d= 0.35	-0.85 (-2.80; 1.11) d= 0.26
PDSS							
Nighttime sleep	**4.70 [4.50–5.95]**	**7.20 [4.45–9.25]**[a]	**5.70 [5.05–7.60]**	**0.02**	**1,58 (0.52; 2.64) d= 0.51**	**-0.49 (-2.62; 1.64) d= 0,01**	**1.09 (-0.76; 2.95) d = 0.59**
Onset and maintenance	**9.10 [5.75–14.10]**	**10.90 [8.80–16.75]**	**16.20 [8.85–18.10]** [b]	**0.003**	**3.48 (0.98; 5.97) d= 0.67**	**0.61 (-2.22; 3.45) d= 0.40**	**4.10 (1.70; 6.49) d = 0.91**
Nocturnal agitation	9.80 [3.15–11.40]	9.00 [5.50–11.65]	9.50 [3.85–13.65]	0.29	0.61 (-1.81; 3.04) d= 0.07	0.82 (-2.61; 4.26) d= 0.16	1.43 (-1.74; 4.62) d= 0.14
Nocturnal psychosis	10.50 [9.45–15.55]	13.90 [10.55–18.40]	10.30 [9.90–16.00]	0.06	1.79 (-0.32; 3.91) d= 0.49	-1.06 (-3.10; 0.98) d = 0.70	0.73 (-2.31; 3.77) d= 0.03
Nocturia	10.00 [6.70–10.95]	10.00 [9.40–11.85]	10.00 [8.00–10.80]	0.48	0.23 (-0.33; 0.79) d= 0.33	0.52 (-1.18; 2.23) d= 0.01	0.75 (-0.78; 2.29) d= 0.15
Nocturnal movements	**21.30 [14.75–24.85]**	**30.20 [23.85–34.35]** [a]	**23.70 [12.75–29.95]**	**0.02**	**5.96 (-1.39; 13.32) d = 0.55**	**-5.34 (-11.63; 0.94) d= 0.59**	**0.61 (-4.12; 5.35) d= 0.14**
Unsatisfactory sleep quality	5.00 [1.80–8.60]	2.80 [1.20–9.95]	6.00 [1.70–9.55]	0.92	0.46 (-1.34; 2.28) d= 0.09	-0.09 (-3.16; 2.97) d= 0.01	0.37 (-2.83; 3.58) d= 0.01
Daytime sleepiness	8.50 [3.45–9.70]	9.90 [9.25–10.00]	8.50 [4.00–10.00]	0.32	1.86 (0.06; 3.65) d= 0.57	-1.32 (-2.95; 0.30) d= 0.54	0.53 (-2.09; 3.17) d= 0.11
Total	**75.60 [55.25–92.10]**	**95.00 [86.10–103.75]** [a]	**81.00 [67.90–103.75]**	**0.04**	**16.00 (5.07; 26.92) d= 0.63**	**-6.35 (-15.38; 2.67) d= 0.46**	**9.64 (-0.98; 20.27) d= 0.39**

PDSS = Parkinson's Disease Sleep Scale; ESS = Epworth Sleepiness Scale; PSQI= Pittsburgh Sleep Quality Index.
[a]Significant differences were found between the pre- and post-intervention periods.
[b]Significant differences were found in the pre-intervention and follow-up.
[c]Significant differences were found in the pre-intervention and follow-up.

domains: nighttime sleep ($p = 0.02$; $d = 0.51$–pre- *vs.* post-intervention), nocturnal movements ($p = 0.02$; $d = 0.55$–pre- *vs.* post-intervention) total score ($p = 0.04$; $d = 0.63$–pre- *vs.* post-intervention) and with large effect size sleep onset/maintenance ($p = 0.003$; $d = 0.91$–pre- *vs.* follow-up).

Discussion

The intervention program used in this study was based on the literature addressing the benefits of physical therapy for motor outcomes within PD.[18,20] However, this study's objective was to expand knowledge and implement physical therapy for non-motor outcomes, especially quality of sleep. In addition to the few studies correlating exercise and sleep in PD,[21] it is known that sleep quality is directly related to the restoration of the body's organic activities and well-being. Thus, investigating this outcome is relevant. Another reason is that the assessment and treatment of sleep disturbances are often underestimated in clinical practice, and, finally, physical therapy is an easy-to-apply, low-cost, and low-risk intervention. Since pharmacological therapies to treat sleep disorders within the PD context are difficult to manage, and such disorders are often refractory, physical therapy can play an adjuvant role.

As far as we know, there is no evidence that physical therapy influences quality of sleep in the short or long term, and this is the first study with follow-up to assess sleep patterns objectively and subjectively after a physical therapy protocol was implemented. This study's main results considering the whole group were: (1) no improvement was found in daily sleepiness or sleep parameters when objectively assessed by the actigraphy method; (2) improved quality of sleep was found when subjectively assessed between pre- and post-intervention, in terms of nocturnal movements and total PDSS and PSQI scores; and (3) sleep quality improved when subjectively measured (PDSS) between pre-intervention and follow-up only in terms of sleep onset/maintenance.

Improvement was only found in the subjective assessments, not in the actigraphy. This divergence between objective and subjective sleep parameters has already been reported in the literature; it is believed that the scales and actigraphy assess different aspects of sleep. While the scales address the complexity of an individual's perception of sleep, actigraphy estimates sleep parameters based on the presence or absence of movement. Thus, both assessments are important and complementary, which opens an investigation possibility for future studies.[5]

The proposed protocol did not improve the actigraphy parameters. Because there are no studies addressing individuals with PD, the comparisons utilized methodologically similar studies addressing other populations, such as hypertensive elderly individuals[22] and inactive obese individuals.[23] The first study implemented aerobic training (aerobic training, aerobic training associated with resistance training, and control), and only the training groups showed improved sleep fragmentation and efficiency, assessed by the actigraphy method. The second study assessed the effect of mild, moderate, and vigorous exercise (compared to the control group). Improvement was found after three months of training, in terms of sleep duration only, for the vigorous exercise group compared to the control group (physically inactive). The difference in both studies was high-intensity exercise implemented among populations without neurodegenerative diseases, suggesting that intensity may be a factor that improves quality of sleep measured by the actigraphy method.

The only study adopting objective and subjective sleep assessment in PD was that of Amara and collaborators.[3] They conducted a randomized clinical trial to compare the effect of 48 high intensity supervised physical training sessions (intervention group) *vs.* sleep hygiene orientation (control group) via polysomnography on sleep efficiency among individuals 45+ years old with PD. Objective measures were obtained via polysomnography and subjective measures via the PSQI. Improved sleep efficiency, slow-wave sleep, WASO, and total sleep time were found only for the experimental group (assessed via polysomnography), while improved subjective sleep assessment was found only for the control group (assessed via PSQI). Note that even though the experimental group experienced an improvement in objective sleep parameters, they started with a PSQI mean score equal to 6.9 ± 3.5 (baseline) and reached 7.0 ± 3.5 (end of intervention). Note that the control group, which was not objectively assessed by the polysomnography method, started with a mean of 8.1 ± 3.5 and reached 6.4 ± 2.9. These findings reveal difficulty in assessing objective and subjective sleep parameters, as they do not always behave in a directly proportional manner.

To reinforce how complex it is to analyze the sleep outcome (subjective *vs.* objective data), the previous study reported objective improvement (polysomnography) but not subjective improvement. In turn, we found subjective improvement in this study but not objective improvement (actigraphy). Although polysomnography is the gold standard method for measuring sleep, it may not portray an individual's habitual sleep because it occurs in an ambulatory setting. Therefore, questionnaires, sleep diaries, and actigraphy are the alternative methods most frequently applied in clinical and epidemiological studies because they provide estimates of sleep parameters based on the participants' typical routine. However, the actigraphy method presents limitations because it estimates sleep based only on the absence of body movement. Therefore, as we did in this study, the simultaneous use of questionnaires and actigraphy provides a more comprehensive perspective of sleep patterns than when applied separately. The fact that the effects of the intervention are more clearly seen when both the PDSS and PSQI questionnaires are considered and compared to the actigraphy method is not due to technical artifacts but to the fact that these methods measure different aspects of sleep. Specifically, the results reveal that the participants reported improved sleep quality perception after the intervention, though such perception did not reflect in decreased movement during the night.

Thus, considering the subjective assessment of sleep and intending to perform a more detailed analysis, the

participants who scored $\leq$100 on the PDSS – the cut-off point at which individuals are classified as "poor sleepers" – were individually analyzed.[5,12] No improvement was found in this subgroup in terms of the items assessed by the actigraphy method, though a significant improvement was found in the nighttime sleep and nocturnal movements domains, and the total score obtained in the PDSS between pre- and post-intervention, in addition to improvement in sleep onset/maintenance from pre-intervention to follow-up. Note that even though, according to the PSQI, this subgroup presented no significant sleep improvements (a total score >5 obtained on the PSQI indicates poor sleep quality), it improved from poor sleeper at baseline (median of 6.0) to good sleeper in the post-intervention (median 4.0) and remained as good sleeper in the follow-up (median 3.0). Note that the subjective and objective sleep parameters are not strongly correlated[5] because they assess different sleep aspects, considering that sleep patterns have a multidimensional nature, being influenced by various factors.[5,21,24]

Evidence reported in recent studies addressing the subjective impact of exercise on sleep among individuals with PD can guide future research, despite some methodological limitations.[1] Nascimento and collaborators[25] implemented a multimodal exercise program including balance exercises, coordination, muscle resistance, aerobic training, and gait among individuals with PD, individuals with Alzheimer's, and a control group for six months. Sleep disorders improved in both treated groups, while the control group presented worsened sleep patterns when subjectively measured using a sleep mini questionnaire that was not specific for PD. Frazzitta and collaborators[26] also report improved sleep quality among individuals with PD measured by the PDSS after applying a multidisciplinary treatment protocol of intensive rehabilitation. These results were not confirmed for the control group. Note that this was a retrospective study using the database of a previous study conducted in a hospital setting and with a training protocol that is not easy to implement in clinical practice. Silva-Batista and collaborators[27] applied a 12-week progressive resistance training protocol among individuals with PD and verified that the PSQI total score improved. After the intervention, sleep scores were similar to those obtained by healthy controls.

The physical therapy protocol used in this study emphasized balance training, gait, agility, coordination, and sensory integration. Some mechanisms implicit to changes observed in the individuals' quality of sleep, especially in nocturnal movements and sleep onset/maintenance domains, concentrate on the improvement of motor symptoms, leading to decreased muscle tone and, consequently, muscle relaxation.[18,28–31] Furthermore, recent studies confirm the importance of exercise for brain health, with the view that exercise increases neuroplasticity factors and neurotransmitters, improves tissue oxygenation, increases synaptic strength, and enhances functional circuits.[32] More specifically, regarding sleep, an increase in the brain-induced neurotrophic factor improves sleep dysfunctions, and regular and continuous exercise decreases neuroinflammation. Finally, the correlation between exercise and mood positively impacts sleep quality.[33,34]

This study presents some limitations, such as the absence of a control group. Additionally, the sample size calculation did not consider only those individuals considered to be poor sleepers. The option to establish this subgroup, though, even if the sample was not specifically calculated with this subgroup in mind, and the fact this may lead to type 1 and type 2 errors, showed important differences. Another limitation is that the objective sleep assessment was not performed using the polysomnography test. Even though polysomnography is the gold standard for objectively assessing sleep, its setup and maintenance are expensive, hindering its use with larger or population samples. In this context, the actigraphy method is a practical device that allows the assessment of individual sleep parameters at home over several nights, as we did in this study.[5]

On the other hand, the strengths include the fact that this is the first study to assess the effect of a physical therapy protocol objectively and subjectively on sleep parameters, including follow-up. As for the implications for clinical practice, PD patients need to be included in rehabilitation programs to manage various disorders (e.g., postural instability, gait deficits, and immobility, among others), and knowing that this intervention improves sleep perception represents an advantage that positively impacts the treatment's cost-benefit relationship.

Future studies with larger samples are needed and would minimize the occurrence of type 2 errors, while randomized controlled trials are a powerful tool to obtain evidence in health research. In addition, future studies with greater statistical power might focus on the subgroup of patients with poor sleep, to determine changes in objective sleep parameters measured by actigraphy. Furthermore, protocols that vary in duration and intensity can guide future research, considering that physical therapy is an accessible treatment and can be an ally in treating sleep disorders among individuals with PD.

Therefore, neurofunctional physical therapy was ineffective in improving objective parameters of sleep but was effective in improving the perception of sleep quality subjectively assessed among individuals with PD, especially those who perceived themselves to be poor sleepers.

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Conflict of Interest
None declared.

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