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Effects of trunk mobility exercise and treadmill training on functional performance of patients with Parkinson's disease: a single-subject experimental study

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Hye-seong Jo[1], Duck-Won Oh[2]

[1] Department of Physical Therapy, Rehabilitation Center, Yemidam Hospital, Cheong-ju, Republic of Korea

[2] Department of Physical Therapy, College of Health and Medical Sciences, Cheongju University, Chungbuk, Republic of Korea

Abstract

Introduction. This study aimed to investigate the effects of integrating treadmill training with trunk mobility exercise on functional performance in patients with Parkinson's disease (PD).

Methods. Fourteen patients with PD volunteered for this study. This single-subject experimental study used an A-B-C design: (A) baseline, (B) intervention-1 (trunk mobility exercise alone), and (C) intervention-2 (trunk mobility exercise and treadmill training). No intervention was performed during the A phase. Trunk mobility exercise focusing on large trunk and limb motions was performed during the B phase. The C phase included treadmill training in addition to trunk mobility exercise. Outcome measures included the 10-m walk test (10MWT), timed up-and-go (TUG) test, unified Parkinson's disease rating scale Part III, Berg balance scale, dynamic gait index, and new activities of daily living questionnaire.

Results. In the comparison of individual data, most participants showed improved 10 MWT and TUG test scores during the B and C phases when compared with those in the baseline phase, except for one participant for the TUG test score. Moreover, group data comparison revealed significantly improved scores for all parameters after the B phase ($p < 0.05$), and these gains improved synergistically after the C phase ($p < 0.05$).

Conclusions. These findings suggest that trunk mobility exercises are beneficial for enhancing balance and walking function in patients with PD; furthermore, the benefits are improved synergistically by integrating treadmill training.

Key words: function, exercise, treadmill, Parkinson's disease

Introduction

Parkinson's disease (PD) is a progressive idiopathic neurodegenerative disease caused by dopamine depletion due to basal ganglia dysfunction [1]. Clinical symptoms include resting tremors, gait and postural instability, and rigidity [2]. In PD, reduced limits of stability and impaired postural reflexes make maintaining timing and an appropriate response to external demands difficult. That is, when external perturbation occurs while standing, it is difficult to use efficient movement strategies, helping to prevent a stooped posture and limitation of movement. These problems are closely associated with a high fall risk [3]. Consequently, these reduce the patient's quality of life [4]. Generally, during walking, patients with PD often experience freezing episodes that impede sustained limb motions, and their walking exhibits a shuffling pattern that is characterised by reduced step and stride lengths and increased velocity [5]. In patients with PD, tremors of the whole body and an abnormal posture contribute to slow movements and a decreased arm swing while walking. Functional decline caused by symptoms of PD is a major reason for decreased quality of life and increased caregiver burden [6]. Therefore, development of physiotherapy strategies is required to address the functional issues associated with PD.

The consensus is that exercise therapy may facilitate neuromuscular control by inducing positive neurotrophic changes in neural networks. Previous animal studies have demonstrated the effects of exercise in improving neural activities in the brain and in delaying neuronal apoptosis by preserving glial cell line-derived neurotrophic factor [7]. Aerobic exercises increase the protein content in cells by reducing neuronal necrosis, increasing cell viability [8], and delaying neural regression, which may be helpful in diminishing the side effects of sustained medication use and facilitating functional recovery [9]. In addition, exercise therapy prevents negative physical changes due to rigidity and bradykinesia over time in patients with PD, resulting in improved walking, activities of daily living, and quality of life [10].

The Lee Silverman Voice Treatment (LSVT)-BIG program has been developed as an exercise program for patients with PD to enhance motion amplitude and accuracy and induce fast movements through standardised large range of motion training [11]. Positive effects of this exercise program have been reported on functional activities, such as balance, walking, dual-task performance, and reaching [12, 13]. Based on the principle of the task-oriented approach, treadmill training is known to be suitable for enhancing aerobic capacity and walking function in patients with PD [14]. It mandates the use of the lower limbs, thereby improving the qualitative aspects of walking, walking speed, and endurance [15].

Clinicians commonly use trunk mobility exercise or treadmill training to promote functional recovery in patients with PD. However, the effects of integrating these interventions

Correspondence address: Duck-Won Oh, Department of Physical Therapy, College of Health and Medical Sciences, Cheongju University, 298 Daeseong-ro, Cheongwon-gu, Cheongju, Chungcheongbuk-do, Republic of Korea, 28503, e-mail: odduck@cju.ac.kr; https://orcid.org/0000-0001-7430-7134

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are unknown because they have been implemented separately, and most studies have not focused on investigating the benefits of this integration on daily functioning. Furthermore, a previous study reported that clinical trials investigating the effects of treadmill training should be interpreted cautiously, as there are variations between studies with regard to patient characteristics and training details [16]. This suggests that further studies are needed to demonstrate the improved effects of training in clinical practice. Therefore, this study aimed to determine the effects of integrating treadmill training with trunk mobility exercise on functional performance in patients with PD.

Subjects and methods

Participants

Fourteen patients with PD who received inpatient rehabilitation services volunteered to participate in this study. The selection criteria were as follows: (1) diagnosis of PD (stages 1–3 according to the Hoehn and Yahr Scale); (2) ability to walk for 10 m; (3) no dysphasia; (4) no cardiopulmonary, orthopaedic, or other neurological impairments except PD; and (5) no cognitive deficit (> 19 points in the Korean version of the Mini-Mental State Examination) [17]. During the initial screening, 31 patients were recruited; however, 10 were ineligible as per the selection criteria, whereas 7 (3 in the baseline phase and 4 in the intervention phase) dropped out by discharge and decondition. Data from the remaining 14 participants were included in the final analysis. Prior to the beginning of the study, the participants signed an informed consent form, with the first author explaining the study's procedure and safety to them. Table 1 summarises the general characteristics of the participants.

Study design

This single-subject experimental study used an A-B-C design comprising a baseline phase (A), which did not include any interventions, and two intervention phases. The intervention-1 phase (B) included trunk mobility exercise alone, and the intervention-2 phase (C) included both trunk mobility exercise and treadmill training. All three phases had eight measurement sessions of the 10-m walk test (10MWT) and the timed up-and-go (TUG) test. Furthermore, the unified Parkinson's disease rating scale Part III (UPDRS-3; motor function test), dynamic gait index (DGI), Berg balance scale

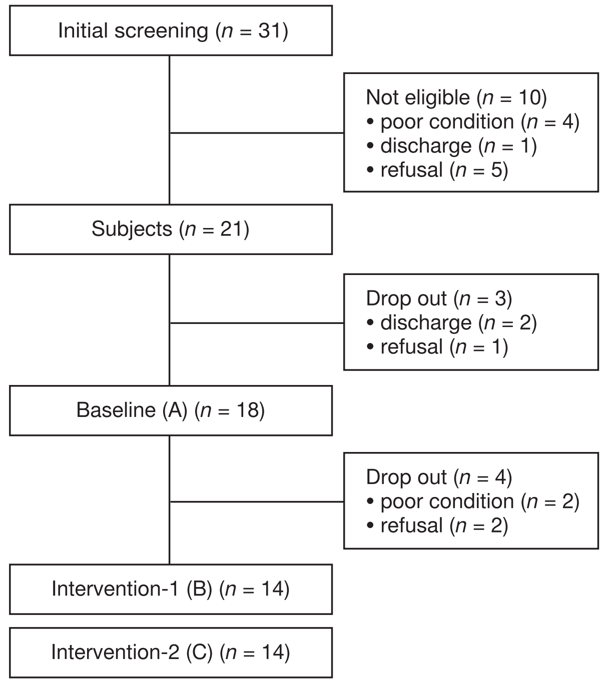


Figure 1. Flow chart of the study

(BBS), and new activities of daily living questionnaire (NADLQ) were assessed at each final session of the baseline (A) and intervention phases (B and C; see Figure 1).

Outcome measures

10MWT

In the 10MWT, the time taken to walk the middle 10 m of a 14-m straight route as fast as possible is recorded. A stopwatch was used to record the time. Walking aids were used when the participants requested for them. Values were averaged over triplicate trials with a 1-min rest interval. The 10MWT has excellent reliability (r = 0.89 to 1.00) [18].

TUG test

The TUG test is a simple test to assess a participant's mobility and requires both static balance and dynamic balance. It considers the time taken to rise from a chair, walk for 3 m, turn around 180°, walk back to the chair, and sit on

Table 1. General characteristics of the participants (N = 14)

	Participants													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Gender	female	female	male	female	male	male	female	female	female	male	female	male	male	female
Onset time (months)	82	8	39	21	63	9	40	45	57	75	51	23	35	51
Age (years)	82	79	71	82	62	67	78	76	85	66	75	59	74	78
Height (cm)	152	162	170	158	163	169	158	163	158	168	164	171	169	161
Weight (kg)	47	49	57	54	56	56	44	53	54	59	47	54	50	52
MMSE-K (scores)	24	24	25	26	24	23	24	24	23	24	21	20	21	25
MHY scale	1.5	2.5	1	2	1	2.5	1	2	3	2.5	2.5	2	2.5	2
Walking aids	Cane	Walker	–	Cane	–	Walker	–	Cane	Walker	Walker	Walker	Cane	Walker	Cane

MMSE-K – Korean version of Mini-Mental State Examination, MHY scale – modified Hoehn and Yahr scale the chair again. Values were averaged over triplicate trials with a 1-min rest interval. The intra- and inter-rater reliabilities are $r = 0.99$ and $r = 0.98$, respectively [19].

UPDRS

The UPDRS is a rating tool used to gauge the course of PD. It consists of four parts: part I – mentation, behaviour, and mood; part II – activities of daily living; part III – motor examination; and part IV – complications of therapy. This study used only part III (UPDRS-3), with a rating scale of 0–4. The test-retest reliability appears to be high for clinical use (UPDRS, 0.92; UPDRS-3, 0.90) [20].

DGI

The DGI assesses the participants' ability to maintain walking balance in the presence of external perturbations. The scores were based on a 4-point scale (0, severely impaired; 3, normal), and the highest score is 24 points. Tasks comprised gait level surface, change in gait speed, gait with horizontal head turns, gait with vertical head turns, gait and pivot turn, step over obstacle, step around obstacles, and steps. It shows a high inter-rater reliability ($r = 0.96$) [21].

BBS

The BBS is a commonly used clinical test that is used to assess static and dynamic balance. It includes a set of 14 task-related items: sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing with eyes closed, standing with feet together, reaching forward with an outstretched arm, retrieving an object from the floor, turning to look behind you, turning 360°, placing an alternate foot on a stool, standing with one foot in front, and standing on one foot. Each item was scored on a 5-point ordinal scale ranging from 0 (unable) to 4 (independent). The value is the sum of all scores. The inter-rater reliability is $r = 0.95$ [22].

NADLQ

The NADLQ is a self-administered questionnaire to assess how difficult it is for people with Parkinson's disease to perform their activities of daily living (ADL). The NADLQ consists of 45 ADL items rated on a 6-point scale (0 = no problem and 5 = incapable of performing the activity). Higher scores indicate greater difficulty in performing ADL. This scale exhibits high internal consistency (Cronbach's $\alpha = 0.962–0.966$) and acceptable test-retest reliability ($r = 0.632–0.984$) [23].

Intervention

During the experimental process, the participants underwent daily routine rehabilitation therapy for 30 min, which consisted of bridging, flexibility exercises, postural correction, and balance and walking training. The bridging exercise was performed in five sets of 10 repetitions, and the balance training was performed in two sets of 30 s of standing: one with eyes open and the other with eyes closed. Flexibility exercises (neck flexors, pectoral and abdominal muscles, hip flexors and adductors, knee extensors and flexors, hamstring, ankle dorsiflexors, and plantar flexors) were performed in two sets of 30 s of elongation. The walking training was conducted by going back and forth between two points at intervals of 10 m, performing five sets of 10 repetitions. The trunk mobility exercise program consisted of seven exercises (neck mobilisation, arm reach, trunk mobilisation, one-leg standing, stepping, big arm swing, and walking), as described in previous studies [11, 24]. The exercises were performed for 30 min in a standing position; however, sitting was performed if necessary. The therapist guided the participants while standing behind them. The details are provided in Appendix 1. Furthermore, the treadmill training was initially performed at comfortable speeds for 30 min, and the speeds were gradually increased within the tolerable range of the participants [15]. To ensure the safety of the participants during treadmill training, they were allowed to hold the guardrail during the training whenever needed, and the therapist was placed behind them while they were walking. Treadmill training was discontinued if the patient complained of severe fatigue and discomfort, became pale, or experienced shortness of breath.

Data analysis

Visual analysis using graphs was used to compare the scores of each parameter in the three phases (A, B, and C). The two-standard deviation (2-SD) band method was used to support visual analysis of the data of each participant during the three phases; clinical improvement was inferred when data of the intervention phases were located outside the 2-SD band calculated using data from the A phase [25]. Data are presented as the mean ± *SD*. SPSS version 22.0 (IBM, Chicago, USA) was used for statistical analysis of the data collected from the three phases. The Kolmogorov–Smirnov test showed that our data were not normally distributed; therefore, we used the Friedman test for analysis of the data collected from the three phases. When statistical significance was found, a post-hoc test was performed using the Wilcoxon signed-rank test. The significance level was set at $p < 0.05$.

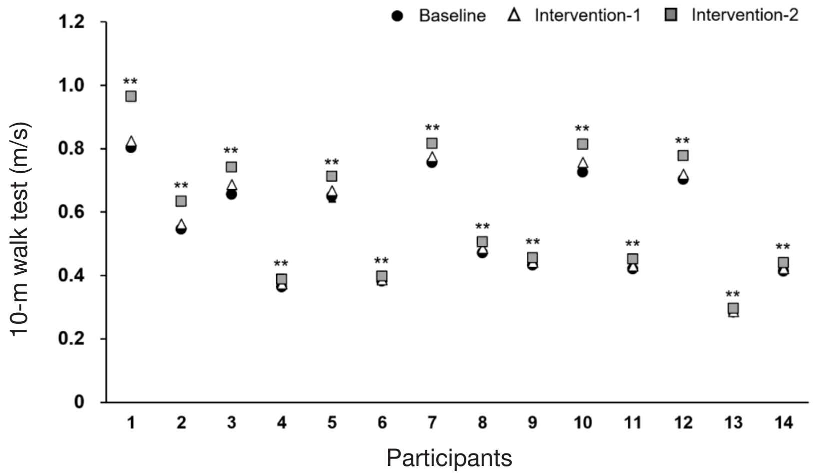
Results

Comparison of individual data

Figures 2 and 3 show the comparison of the 10MWT and TUG scores of each participant. For the 10 MWT, all participants had data on the B and C phases located outside the 2-SD band of the A phase. Furthermore, for the TUG test, 11 and 2 participants had data for the B and C phases and data for the C phase located outside the 2-SD band of the A phase, respectively.

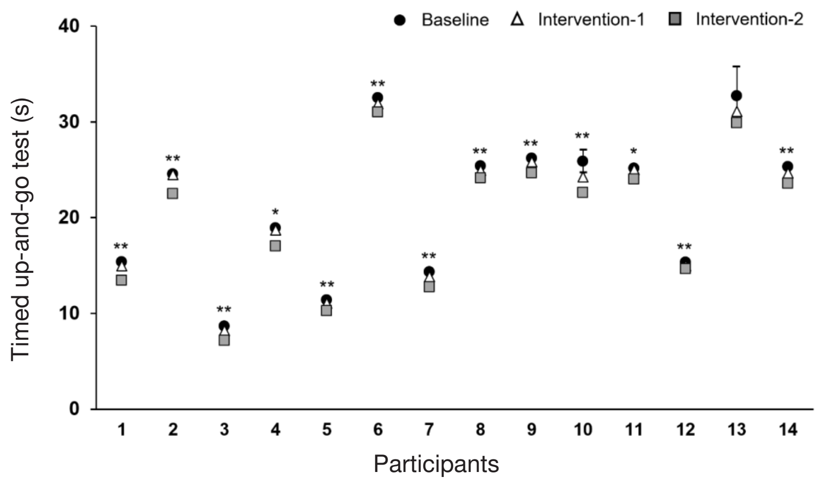
Comparison of group data

Table 2 summaries the comparison of the UPDRS-3, DGI, BBS, NADLQ, 10MWT, and TUG scores collected from the A, B, and C phases. The UPDRS-3, DGI, BBS, NADLQ, 10MWT, and TUG scores significantly differed among the three phases ($p < 0.05$), with the post-hoc test showing differences between the A and B phases (UPDRS-3: $z = –2.828$, $p = 0.005$; DGI: $z = –3.276$, $p = 0.001$; BBS: $z = –3.217$, $p = 0.001$; NADLQ: $z = –3.207$, $p = 0.001$; 10MWT, $z = –3.296$, $p = 0.001$; and TUG test, $z = –2.521$, $p = 0.012$), between the A and C phases ($z = –3.397$, $p = 0.001$; DGI: $z = –3.241$, $p = 0.001$; BBS: $z = –3.304$, $p = 0.001$; NADLQ: $z = –3.178$, $p = 0.001$; 10MWT, $z = –3.296$, $p = 0.001$; and TUG test, $z = –2.524$, $p = 0.012$), and between the B and C phases ($z = –3.464$, $p = 0.001$; DGI: $z = –3.071$, $p = 0.002$; BBS: $z = –3.071$, $p = 0.002$: NADLQ: $z = –2.658$, $p = 0.008$; 10MWT, $z = –3.296$, $p = 0.001$; and TUG test, $z = –2.521$, $p = 0.012$).



Intervention-1 – trunk mobility exercise alone
Intervention-2 – trunk mobility training and treadmill training

Figure 2. Results of the 10-m walk test for each subject. Bars from the baseline data represent the 2-SD band of the baseline data. Two asterisks (**) represent data of the Intervention-1 and -2 phases outside the 2-SD band of the baseline data



Intervention-1 – trunk mobility exercise alone
Intervention-2 – trunk mobility training and treadmill training

Figure 3. Results of the timed up-and-go test for each subject. Bars from the baseline data represent the 2-SD band of the baseline data. One asterisk (*) and two asterisks (**) represent data of the Intervention-2 phase and data of the Intervention-1 and -2 phases outside the 2-SD band of the baseline data, respectively

Table 2. Comparison of the UPDRS-3, DGI, BBS, NADLQ, 10MWT, and TUG scores collected from the baseline and intervention phases

Outcome measures	Baseline mean ± *SD*	Intervention-1 mean ± *SD*	Intervention-2 mean ± *SD*	χ^2	*p*
UPDRS-3 (scores)	29.28 ± 4.79 [a]	28.71 ± 4.77[§]	27.85 ± 4.97[§†]	24.500	< 0.001
DGI (scores)	13.28 ± 4.32	14.28 ± 4.37[§]	15.28 ± 4.58[§†]	24.531	< 0.001
BBS (scores)	28.07 ± 12.11	29.14 ± 12.41[§]	30.14 ± 12.39[§†]	24.531	< 0.001
NADLQ (scores)	37.35 ± 14.48	31.21 ± 13.23[§]	29.21 ± 12.32[§†]	17.714	< 0.001
10MWT (m/s)	0.54 ± 0.17[a]	0.56 ± 0.18[§]	0.60 ± 0.20[§†]	28.000	< 0.001
TUG (seconds)	21.56 ± 0.15	20.99 ± 0.25[§]	19.84 ± 0.34[§†]	16.000	< 0.001

UPDRS-3 – unified Parkinson's disease rating scale: part III – motor examination, DGI – dynamic gait index, BBS – Berg balance scale, NADLQ – new activities of daily living questionnaire, 10MWT – 10-metre walking test, TUG – timed up-and-go test
Intervention-1 – trunk mobility exercise alone, Intervention-2 – trunk mobility exercise and treadmill training
[§] significant difference compared with data of the baseline phase
[†] significant difference compared with Trunk mobility exercise

Discussion

Clinicians are increasingly using various exercise therapies to enhance balance and walking in patients with PD; however, the benefits of repeated exercise do not guarantee an improvement in overall functional ability. Patients must be given an opportunity to intensively practice the walking motion in appropriate spatiotemporal patterns using treadmill training [14]. Based on this concept, this study aimed to combine exercise therapy with treadmill training. In addition, despite the fact that previous studies showed the positive effects of training on PD [12–14], symptoms vary from person to person, so questions remain as to what type of exercise is appropriate for the personal rehabilitation of patients with PD [26]. Therefore, changes and trends in individual data over the course of an intervention require clarification in clinical practice. While group studies provide conclusive results for functional recovery, this could be the basis for using a single-subject experimental design [25], which would validate the causal relationship between the intervention and its consequences, and the generalisations of the results [27].

In this study, following exercise, the UPDRS-3 and NADLQ scores improved, with treadmill training resulting in additional gains. Given that the UPDRS-3 and NADLQ examines motor function and ADL in PD, respectively, these results were expectedly associated with improved BBS, TUG test, DGI, and 10MWT scores. Over time, regular exercise and physical activity promote the regulation of the dopaminergic system, resulting in higher circulating levels of dopamine and greater availability of dopamine receptors [28]. This prevents dopamine deficiency in neural structures by protecting dopamine-producing neurotransmitters [29], thereby leading to improved motor function. Previous studies have demonstrated the effects of exercise on the UPDRS-3 [30] and ADL [31]. In PD, impaired function of neural circuits in the basal ganglia sequentially hinders proper motor processing while performing movements, and this limits the start and end of movements and the successive transition to additional tasks. Therefore, beneficial strategies must be designed to facilitate functional recovery. In general, treadmill training [32] and walking exercises [33] have been used by patients with PD to practice intensive repetitive walking motions in clinical settings.

As shown in this study, the 10MWT, TUG test, BBS, and DGI scores significantly increased after the intervention, with greater improvements in the phase with treadmill training integration. These findings are congruent with those of previous studies that investigated the effects of exercise therapy on motor function and walking in patients with PD [11, 30]. Using visual, auditory, and tactile cues, exercise is advantageous for improving self-awareness, acquiring self-management skills, and varying movement patterns, thus leading to improved balance confidence and reduced risks of falls [34]. Furthermore, a previous study reported that aerobic exercise is beneficial for motor function and balance in patients with PD, which are closely related to enhanced walking velocity and step and stride lengths [35]. Thus, our findings also are consistent with those of these studies.

Since the physical symptoms of PD gradually worsen over time, patients are less likely to recover from functional problems without appropriate intervention. In the later stages of PD, they commonly suffer severe functional decline [6], which greatly affects the effects of training during the rehabilitation process. In this study, five of the 14 participants were in the 2.5 stage of the modified Hoehn and Yahr scale, suggesting difficulty in walking due to bilateral rigidity and a high risk of falls [36]. A comparison of individual data showed improvements in balance and walking function during the intervention phases (trunk mobility exercise and treadmill training), which were similar to those of other participants with relatively mild symptoms in the early stages of PD. This indicates that our intervention could benefit dysfunctional patients with PD if independent ambulation is possible, with or without a walking aid.

Furthermore, in the 2-SD band method for visual data analysis for each participant, the 10MWT and TUG test scores of the C phase, which integrated treadmill training with mobility exercises, were mostly located outside the 2-SD band, except for the 13th participant in TUG test. This suggests the clinical benefits of including treadmill training [25]. Therefore, our findings indicate that treadmill training can have additional beneficial effects on functional performance, including balance and walking, in patients with PD. A possible explanation for these findings is that treadmill training requires the lower extremity to move at a constant speed, concurrent with the speed of the treadmill belt, which can be the basis for the rhythmic utilisation of the limbs that simulates ground walking [14]. In PD, postural instability causes narrowing of the stride length, freezing, and unstable control of walking movements, thereby decreasing the walking speed. During treadmill training, patients with PD should maintain a higher level of attention to ensure continuous steps without any difficulty. Along with the physical benefits of treadmill training, it might restore the dopaminergic system and improve neural plasticity [7], which may slow PD progression [37]. Furthermore, reducing rigidity, strengthening the limb muscles, and facilitating postural control are possible through repeated limb use during treadmill training. These effects might be a reason for using treadmill training to promote balance and walking function in patients with PD.

Limitations

This study had several limitations that should be addressed in further studies. First, this study used a single-subject experimental design, which has the advantage of highlighting the clinical aspects of the intervention by clarifying individual responses to the intervention in a small-sized sample. This design may be beneficial for clinicians with limited study resources [38]. However, caution must be exercised when generalising the results to other groups. Second, because of the absence of a control group, our study provides insufficient information regarding the priority of exercises for clinical use. Third, long-term follow-ups were not conducted in this study; therefore, we could not describe the long-term effects of the intervention. Fourth, the interaction effect between interventions may have influenced the research results. Finally, the absence of quantitative analysis makes describing the changes in gait parameters difficult. Therefore, larger-scale studies with robust designs should be performed to confirm our findings. Despite these limitations, this study provides useful information for clinicians and researchers exploring beneficial interventions for PD.

Conclusions

In PD, numerous motor symptoms result in functional impairments, such as slow movements, postural instability, tremors, balance disturbances, and changes in walking patterns. To manage these problems, clinicians have routinely used exercise therapy and walking training as therapeutic strategies for PD. This study aimed to clarify the effects of integrating treadmill training with trunk mobility exercise in patients with PD. The results revealed that trunk mobility exercise may be beneficial for balance and walking function in patients with PD and the benefits were synergistic with the integration of treadmill training. The results of this study suggest that our exercise program may improve balance and walking function in patients with PD both in the clinic and at home, with greater benefits with the addition of treadmill training. Further studies are required to confirm these findings.

Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Cheongju University Institutional Review Board (approval No: 1041107-202108-HR-032-01).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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Appendix 1. Trunk mobility exercise program

Exercises	Details
Neck movement	Starting position: sit or stand facing forward. Move your neck up, down, left, and right as much as possible and hold it for 10 s. Subsequently, look forwards and bend the neck from side to side. Hold it for 10 s at each side Repetitions: 10 repetitions of each
Big arm reach	Starting position: sit on a chair with your arms at your sides With arms extended, touch the floor. Subsequently, reach your arms forwards and lift them up towards the ceiling until they are in line with your shoulders. Hold the position for 10 s and then return them to the starting position Turn your body to the right and stretch your left arm towards the right. Simultaneously, stretch your left leg backwards. Repeat this on the left side. Hold the position for 10 s each Repetitions: 10 repetitions of each
Trunk movement	Starting position: sit or stand with your feet shoulder-width apart Hold your waist with both hands. Extend your trunk and open your chest up as much as possible. Hold the position for 10 s and then return to the starting position Bend your trunk to the right side as much as possible and hold the position for 10 s. Repeat this on the left side Repetitions: 10 repetitions of each
One-leg standing	Starting position: stand with your feet shoulder-width apart Grab the wall and lift your right foot for 10 s. Repeat this on the left side Repetitions: 10 repetitions of each
One-step movement	Starting position: sit or stand with your feet shoulder-width apart Extend your trunk and spread your arms shoulder-high with your palm facing the ceiling. Subsequently, take one step forwards, backwards, and then sideways. Return to the starting position. Repeat this on the other side Place your arms at shoulder-level with your palms facing the ceiling and your feet wider than shoulder-width apart. Subsequently, turn your body to the right as far as possible. Repeat this for the left side Repetitions: 10 repetitions of each
Big arm swing	Starting position: sit or stand with your feet shoulder-width apart Take one step forwards and shift your weight onto your front foot. Subsequently, swing the same arm back and the opposite arm forwards. Repeat this on the other side Repetitions: 10 repetitions of each
Walking	Starting position: stand with your feet shoulder-width apart Walk with your arms wide swinging and your feet wide apart for 10 min Grasp the guardrail, and place one foot on one step of the stairs, shifting the weight alternately on the front and rear feet. Repeat this on the other side. After 10 repetitions, ascend and descend the stairs Duration: 10 min of each

The physical therapist instructed the participants to make large motions with their limbs. If necessary, the physical therapist assisted while standing behind them to ensure their safety. The participants were asked to count the number of times they were performing each task as loudly as possible.