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ORIGINAL ARTICLE

Feasibility of a Multidomain Intervention for Safe Mobility in People With Parkinson's Disease and Recurrent Falls

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ABSTRACT

Objective Mobility limitations and falls are common in people with Parkinson's disease (PwP). Compared with exercise alone, a tailored, multidomain intervention has the potential to be more effective in improving mobility safety and preventing falls. This study aimed to explore the feasibility and potential effectiveness of a multidomain fall prevention intervention (Integrate) designed for PwP who experience frequent falls.

Methods The home-based intervention was delivered over a span of 6 months by occupational therapists and physiotherapists. The personalized intervention included home fall hazard reduction, exercise, and safer mobility behavior training. The participants received 8 to 12 home visits and were supported by care-partners (when necessary) to participate in the intervention.

Results Twenty-nine people (recruitment rate: 49%; drop-out rate: 10%) with moderate to advanced Parkinson's disease, a history of recurrent falls, and mild to moderate cognitive impairment participated in the study, with 26 people completing the study. A moderate-to-high adherence to the intervention was observed, and there were no adverse events related to the intervention. Twenty-one (81%) participants met or exceeded their safer mobility goal based on the Goal Attainment Scale. The participants exhibited a median 1.0-point clinically meaningful improvement according to the Short Physical Performance Battery. An exploratory analysis revealed that fall rates were reduced by almost 50% in the 6-month follow-up period (incidence rate ratio: 0.51; 95% confidence interval 0.28–0.92).

Conclusion A multidomain occupational therapy and physiotherapy intervention for PwP experiencing recurrent falls was feasible and appeared to improve mobility safety. A randomized trial powered to detect the effects of the intervention on falls and mobility is warranted.

Keywords Parkinson's disease; Rehabilitation; Mobility limitation; Accidental falls.

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INTRODUCTION

Mobility limitations and falls are major problems for people with Parkinson's disease (PwP) and are only partially improved through exercise.[1,2] Parkinson's disease (PD) impairments, including poor balance, freezing of gait (FOG) and cognitive problems, contribute to mobility limitations[3] and may not respond well to medication or surgery.[3] Consequently, PwP experience falls at twice the rate of the general older population, and approximately 70% of people who experience falls exhibit recurrent falls,[4] with considerable personal and financial costs being observed.[5-7] Exercise can reduce falls in PwP with mild to moderate disease by approximately 26%[2]; however, pragmatic and sustainable, minimally supervised exercise may increase the rate of falls in people with more advanced disease.[2,8] Additionally, studies focusing on the use of exercise for fall prevention to date have largely excluded PwP with cognitive impairments,[2] thereby limiting the applicability of the current knowledge to the clinical care of many PwP. There is an urgent need to explore the design and efficacy of new interventions aimed at reducing falls in PwP, including those with more advanced disease and impaired cognition.

Current guidelines recommend the use of personalized, multidomain, multidisciplinary interventions for the general older population, including targeted exercise, home fall hazard reduction, and behavior modifications.[8] Home hazard reduction interventions (such as safety adaptations and fall risk awareness) can reduce fall rates by 38% in high-risk individuals,[9] and programs that promote safer mobility behaviors (such as the conscious performance of activities in a more slow and careful manner)[10] are also effective.[11] However, the effects of home hazard reduction and safer mobility behavior training on mobility safety and falls in PwP are unknown.

Current guidelines also conditionally recommend multidomain interventions for PwP based on individual fall risk factors,[8] as there have been few multidomain randomized controlled trials (RCTs) performed in PwP[12-14]; moreover, the overall results of these studies are uncertain. One large trial (PDSAFE) evaluated a multidomain, individualized, home-based, 6-month intervention that included minimally supervised exercise and strategies to avoid falls, where the strategies were chosen from a predefined list based on the circumstances of previous falls and were delivered by physiotherapists (PTs).[14] This trial did not identify an overall reduction in fall rates, with improvements being demonstrated in people with milder PD but not in those with more advanced PD. A recent single group feasibility study involving a multidomain occupational therapy (OT) and PT intervention for fall risk reduction delivered via telehealth revealed that the intervention was feasible and potentially effective.[15] Moreover, all of the telehealth sessions were safely completed, with excellent adherence to home safety recommendations and achievement of OT and PT goals being observed. However, this small study (n=15) did not evaluate any possible effects on falls and only included participants with mild to moderate PD who did not need an assistive device and who had a willing care-partner to assist.

Overall, previous studies have indicated a need to explore personalized multidomain interventions implemented by clinicians with relevant expertise to promote safer mobility and reduce falls in PwP, including those with more advanced disease and impaired cognition. Therefore, the primary aim of this study was to explore the feasibility of a personalized multidomain intervention delivered by OTs and PTs and designed for PwP experiencing recurrent falls, with the intervention including home fall hazard reduction, exercise, and safer mobility behavior adaptations. The secondary aim was to explore the potential effectiveness of the program on safer mobility performance, fall risk factors, concerns about falling, activities of daily living, fatigue, and falls.

MATERIALS & METHODS

A single-group investigation of a 6-month, home-based multidomain intervention designed to improve mobility safety and reduce falls in PwP was conducted in Sydney, Australia, from January 2021 until February 2024. This study was originally designed to be a RCT (Australian and New Zealand Clinical Trials Registry registration: ACTRN12619000415101). The RCT commenced in July 2019 and recruited 20 of the 40 planned participants; however, it was halted in March 2020 due to COVID-19 restrictions, and all of the data were unusable, as no participants had completed the intervention.

When the study recommenced from the beginning, a pragmatic decision was made to change the original design to a single group pre-test and post-test design, with telehealth being used to deliver the intervention and to conduct the post-test assessments (if needed). Therefore, the primary outcomes were changed from the Goal Attainment Scale[16,17] and Short Physical Performance Battery (SPPB)[18] to measures of feasibility and acceptability. Acceptability data from semi structured interviews exploring the experiences of the participants will be presented in a separate article. The study and all of the amendments were approved by the University of Sydney Human Research Institutional Ethics Committee (IRB #: 2019_034), and all of the participants provided written informed consent. This report addresses the results of the single-group study.

Participants

Twenty-nine PwP were recruited through the research team's databases of PwP who had consented to be contacted about research participation, Parkinson's New South Wales (a consumer support organization), private neurology clinics, written media publications, and websites. To be eligible for inclusion in the study, PwP were required to have fallen at least twice in the prior 6 months, be diagnosed with idiopathic PD by a neurologist, able to walk at least 10 m with or without a walking aid and receiving a stable dose of PD medication or deep brain stimulation (including no treatment changes for >2 weeks and no imminently planned changes). Volunteers were excluded if they had medical conditions that could interfere with the safety of the study, the conduct of the study or the interpretation of the results (such as unstable or severe chronic health conditions, as well as neurological conditions other than PD), or very severe cognitive impairment (Montreal Cognitive Assessment [MoCA]<5).[19] People with impaired cognition (MoCA<19 or a level of functional cognition where the researcher determined that assistance was required to participate safely in the study) were included, provided that they had a willing and able care-partner who could provide assistance to them.

Demographic information, disease duration and severity,[20] and an estimate of the number of falls experienced in the year prior to the study were collected to characterize the participants.

Intervention

The Integrate program consisted of a 6-month, home-based, personalized multidomain program designed to promote safer mobility and was delivered collaboratively by OTs and PTs (intervention protocol described in Supplementary Material 1 in the online-only Data Supplement). All of the therapists had prior clinical experience working with PwP and underwent training in the study protocol (involving three 2-hour sessions). The program included home fall hazard reduction, exercise, and safer mobility behavior strategy training. Each participant's program was tailored within the intervention protocol based on their functional cognition level (as assessed by the OT),[21,22] physical ability, home environment, and support from their care-partner. The program was delivered using shared goal setting and problem solving between therapists, participants, and care-partners. In situations where a care-partner was required to support participation, the partner was present at and involved in the home visits. Additionally, the partners were involved in discussions and decision-making for home fall hazard reduction and assisted in implementing these changes. Therapists instructed the care-partners in how to safely supervise and assist the participants with the exercise program, as well as how to prompt safer mobility behaviors. Written and pictorial information on the participants' individual goals, recommendations, and exercises were provided in booklet form. The participants received 8–12 home visits depending on their specific needs, with at least three OT visits, four PT visits, and one joint therapy visit being performed for each participant. If required by COVID-19 public health regulations or if requested by the participants, home visits were replaced by telehealth consultations. The participants also received at least five phone calls between visits to monitor progress and address any intervention-related difficulties.

Home fall hazard reduction recommendations were coordinated by the OT and involved systematic and collaborative risk assessments, as guided by the Westmead Home Safety Assessment.[23] Recommendations were individualized and included the minimization of clutter, improvement in lighting, and provision of assistive equipment (Supplementary Table 1 in the online-only Data Supplement).

Exercises were prescribed by a PT and designed to address remediable fall risk factors (including leg muscle weakness, poor balance, and FOG). PTs could create exercises that were specifically tailored to the participants and choose from exercises that were used in previous studies[24,25] or PD-specific exercises from "PhysioTherapy eXercises for people with injuries and disabilities" (www.physiotherapyexercises.com) (Supplementary Table 2 in the online-only Data Supplement). The participants were required to exercise at least three times per week, with each session lasting approximately 30 minutes, which could be split into smaller blocks. The participants received help in planning their exercise schedule, and exercises were progressed according to their physical and cognitive abilities. Care-partners were involved in assisting in the exercise sessions when necessary.

The safer mobility behavior adaptations were jointly implemented by the OT and PT in collaboration with the participant and care-partner and involved shared problem solving. The adaptations were guided by the participants' results on the Falls Behavioral Scale[10] and the Characterizing Freezing of Gait Questionnaire.[26] Strategies were separately introduced during the intervention period to promote the formation of new movement habits. Situational cues (e.g., signs) and mantras (e.g., "stop, think, be safe") were used as prompts to reinforce safer mobility behaviors (Supplementary Table 3 in the online-only Data Supplement).

The participants were encouraged to continue all aspects of the intervention during the 6-month follow-up period, including continuing with the exercises that they had been prescribed at the final home visit. However, further support was not provided.

Measurements

The primary outcome measured the feasibility of the inter-

vention. These measurements included the recruitment rate (% of screened participants who were recruited), drop-out rate (% of participants who consented to participate in the study but dropped out), adverse events related to the intervention (including falls that occurred while participating in the intervention or excessive muscle soreness), and intervention adherence, which was assessed during the 6-month intervention period. Adherence to the home fall hazard reduction recommendations was defined as the percentage of recommendations that were fully or partially completed as recorded by the OT. Exercise adherence was calculated as the percentage of prescribed sessions that were completed, as recorded in the participants' diaries and according to the PT intervention notes. To assess adherence to safer mobility behavior strategies, participants assessed how often they implemented the prescribed strategy on a scale ranging from 0% to 100%, and care-partners commented on the rating. An indication of habit formation was assessed using a question from the Self-Report Behavioral Automaticity Index.[27] The participants rated the extent to which the behavior that they learned represented something that they performed automatically from 1 (strongly disagree) to 5 (strongly agree).

Secondary outcomes were collected at pre- and post-test to assess potential effectiveness of the intervention. Pre-test assessments were conducted one to 2 weeks before the intervention, and they were usually performed by the PT who delivered the intervention. Post-test assessments were conducted 1 to 2 weeks after the 6-month intervention by a different PT. All of the physical measures were performed while the participant was "ON" their PD medication at a time when they reported that their functioning was optimal. This was typically approximately 1 hour after a dose of levodopa medication was taken. All of the pre-test assessments and most of the post-test assessments were performed at the participants' homes. However, six of 26 (23%) post-test assessments were conducted via telehealth (Supplementary Material 2 in the online-only Data Supplement) using videoconferencing software chosen by the participant, due to COVID-19 public health restrictions that were being implemented at that time.

The Goal Attainment Scale[16,17] was used to set a goal related to improving mobility safety. The goal was collaboratively established between the PT and the participant at the pre-test assessment (Supplementary Table 4 in the online-only Data Supplement). The extent of goal attainment was evaluated using a five-point scale and was not seen by the assessor or discussed until the end of the post-test assessment session, in order to minimize bias when the other items were assessed.

The SPPB[18] was used to assess balance and mobility. A composite score was calculated from balance (standing in different foot positions), five times sit-to-stand time and comfortable walking speed (over the middle 4 m of a 6 m walkway). The duration of the five times sit-to-stand time and comfortable walking speed were also analyzed separately. Knee extensor muscle strength was measured while each participant was sitting with their knee placed at approximately 90 degrees via a strain gauge. The Iconographical Falls Efficacy Scale was used to assess concerns about falling while performing daily activities.[28] At the post-test assessment, participants rated their global perceived effect from -5 (very much worse) to 5 (very much better) in relation to changes in mobility, balance and fall risk over the course of the 6-month intervention.

Questionnaires completed were the New Freezing of Gait Questionnaire,[29] the Multidimensional Fatigue Inventory,[30] the Incidental and Planned Exercise Questionnaire[31] and the Movement Disorder's Society sponsored version of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS) Patient Questionnaire (Part 1B [nonmotor aspects of daily living] and Part 2 [motor aspects of daily living]).[20] When participants had a consenting care-partner, the care-partner completed the Zarit Burden Interview questionnaire.[32]

At the end of each assessment session, participants were fitted with a triaxial activity monitor (MoveMonitor; McRoberts) on their lower back to measure physical activity (average steps per day and percentage of sedentary time) over 7 days (Supplementary Material 3 in the online-only Data Supplement). Falls were measured for 2 months prior to the pre-test assessment, during the 6-month intervention period, and for an additional 6 months of follow-up. The participants returned completed fall diaries on a monthly basis and received a phone call to confirm the number of falls that had occurred.

Data analysis

We analyzed the data for the 26 participants who provided data at the post-test. Feasibility and secondary outcomes were explored using descriptive statistics, with adherence data presented for the whole group and for groups based on the MoCA score (<26 vs. ≥26), given a score ≥26 is considered to indicate normal cognitive function.[19] Within-group changes in continuous data between the pre-test and post-test were assessed using paired samples *t* tests or Wilcoxon signed-rank tests, depending on whether the data were normally distributed. Global perceived effects were analyzed using one-sample *t* tests and frequencies. The number of falls experienced by each participant in each time period (including the pre-test, post-test and follow-up periods) was used to model fall rates using negative binomial regression, with days of follow-up for each period included as an offset to adjust for varying exposure. Fall rates were compared between the following periods: pre-intervention and intervention periods, intervention and post-intervention follow-up peri-

ods and pre-intervention and post-intervention follow-up periods. Analyses were completed using SPSS version 29.0 (IBR Corp.), with the exception of analyses of fall rates, which were performed via SAS Enterprise Guide v7.1 (SAS Institute Inc.). Alpha was set at $p<0.05$.

RESULTS

Twenty-nine people provided consent to participate in the study, 13 (45%) of whom had MoCA scores <26 (Table 1). Most of the participants lived with their spouses, who also took on the role of care-partner. One participant lived with an adult child, and another had an adult child who lived nearby; both of the individuals provided a caring role. The participants had moderate to advanced PD (mean MDS-UPDRS motor score: 47.3 [standard deviation: 21.4]) and experienced frequent falls. Additionally, most of the participants demonstrated FOG, as determined via the New Freezing of Gait Questionnaire.[29] Participants with MoCA scores <26 tended to be older and demonstrated more advanced disease and more falls in the past year, with all of these participants experiencing FOG and living with a care-partner. Overall, the mean daily levodopa equivalent dose did not change between the pre-test and post-test (1,109 mg vs. 1,098 mg).

The first six participants received a block of home visits (mean: 4 visits; range: 1–8 visits), followed by a block of telehealth sessions (mean: 5 visits; range: 3–7 visits) due to COVID-19 restrictions. There were no indicators that these participants performed differently compared to the other participants. Once the restrictions were lifted, no participants elected to receive telehealth, with the remaining 20 participants who completed the intervention receiving an average of 10 home visits (range: 8–12 visits).

Feasibility

The progression of the participants throughout the study is presented in Figure 1. Fifty-nine people were screened for eligibility, of whom 29 (49%) agreed to participate. Three participants (10%) dropped out for reasons unrelated to the study. There were no significant adverse events related to the intervention.

Adherence data for each component of the intervention are presented for the 26 participants who completed the study and for the participants who were grouped according to the MoCA score (<26 vs. ≥26) in Table 2. Most of the participants either fully or partially completed the home fall hazard reduction recommendations; however, those participants with a MoCA score <26 reported fully completing these recommendations less often than those with a MoCA score ≥26 (median: 57% vs. 67%, respectively). Exercise adherence was variable but was observed to be generally high, with no apparent differences according to the MoCA score. One participant discontinued the exercise program after the first month because of preexisting knee pain. After excluding this participant, exercise adherence ranged from 22%–221%. Safer mobility strategy adherence data revealed

Table 1. Participant characteristics at baseline

Variable	All participants (*n*=29)	Participants with adjusted MoCA <26 (*n*=13)	Participants with adjusted MoCA ≥26 (*n*=16)
Age (yr)	73.9±6.7	76.4±6.6	71.8±6.2
Sex (male)	20 (69)	10 (77)	10 (63)
Living with a care-partner	25 (86)	13 (100)	13 (81)
MoCA (0–30)	24.5±4.6	20.6±4.4	27.6±1.2
Disease duration (yr)	13.6±7.2	14.0±7.9	13.2±6.7
MDS-UPDRS motor score "ON" (0–132)*	47.3±21.4	55.6±20.9	40.5±19.9
Hoehn and Yahr Stage (0–5)*			
1	-	-	-
2	1 (3)	-	1 (6)
3	13 (45)	4 (31)	9 (56)
4	15 (52)	9 (69)	6 (38)
Daily levodopa equivalent dose (mg)	1,109±628	1,028±573	1,175±680
Deep brain stimulation (yes)	4 (14)	2 (15)	2 (13)
Freezing of gait (yes)	24 (83)	13 (100)	11 (69)
New Freezing of Gait Questionnaire (0–28)*	16.6±9.2	21.2±4.7	12.8±10.2
Number of falls in past year†	12 (5.5–38)	24 (6–70)	11 (5.8–27)

Values are presented as mean±standard deviation or number (%) unless otherwise indicated.
*higher score is worse; †median (IQR) reported due to skewed data distribution.
MoCA, Montreal Cognitive Assessment; MDS-UPDRS, Movement Disorder's Society sponsored version of the Unified Parkinson's Disease Rating Scale; IQR, interquartile range.

Table 2. Participant adherence to the Integrate intervention components

	All participants	Participants with adjusted MoCA <26	Participants with adjusted MoCA ≥26
Home fall hazard reduction recommendations			
Number of participants with data	26	11	15
Number of recommendations	5±2	6±2	5±2
Fully completed (%)	67 (41–75)	57 (30–67)	67 (47–80)
Partially completed (%)	32 (21–43)	33 (25–60)	27 (10–33)
Declined (%)	0 (0–20)	0 (0–22)	0 (0–19)
Exercise			
Number of participants with data	21	10	11
Number of prescribed sessions/week	4±2	4±2	4±2
Prescribed sessions completed (capped at 100%)	95 (54–100)	89 (54–100)	95 (65–99)
Prescribed sessions completed (uncapped %)	95 (54–134)	89 (54–112)	95 (65–135)
Safer mobility strategies			
Number of participants with data	14	4	10
Number prescribed strategies	3.9±2.0	4.2±1.0	3.7±2.3
Frequency of use of strategy (%)	75 (50–87)	50 (25–75)	75 (62–87)
Habit strength score (0–5)*	3.5±1.1	2.6±0.9	3.9±0.9

Values are presented as number, mean±standard deviation, or median (interquartile range).
*higher score is better.

that overall participants reported using their strategies approximately 75% of the time, and these strategies were becoming habitual. However, those participants with a MoCA score <26 reported using the strategies less with a lower habit strength score being observed. The care-partner generally agreed with the participant's assessment; however, one care-partner disagreed, reporting that the participant performed the strategies less often.

Secondary outcomes

Of the 26 participants who completed the intervention, 21 (81%) achieved or exceeded their safer mobility goal on the Goal Attainment Scale. Twelve (46%) participants met the goal, 6 (23%) performed somewhat better than expected, and 3 (12%) performed much better than expected. The remaining five (19%) participants did not meet their goal but remained at their pre-test ability.

Pre-test and post-test scores, as well as within-group differences, for the physical tests and questionnaires are presented in Table 3. A statistically and clinically significant[33] improvement of 1 point in the SPPB score was demonstrated. Additionally, there was a 1.7-point reduction in mental fatigue and a 4-hour increase in self-reported weekly hours of physical activity, with both changes approaching statistical significance (p=0.05 and p=0.06, respectively). However, the reported increase in physical activity was not reflected in the activity monitor data. There was no increase observed in care-partner burden.

For the global perceived effect scale measured at the post-test, there were no significant improvements observed in everyday mobility (mean difference: 0.6; 95% confidence interval [CI] -0.5 to 1.6), balance (mean difference: 0.1; 95% CI -0.7 to 1.0), or reduction in perceived fall risk (mean difference: 0.7; 95% CI -0.1 to 1.5). An exploration of score frequencies revealed that 13 (50%) participants believed that their mobility and fall risk had improved, with an additional 2 (8%) participants reporting unchanged mobility and 6 (23%) reporting unchanged fall risk. Most of the participants reported that their balance was either unchanged (8 [31%]) or improved (9 [35%]).

The number of falls that occurred in the different time periods is shown in Table 4. All of the participants completed 2 months of pre-intervention fall diaries. Most of the participants completed all of the fall monitoring requirements over the 6-month intervention (with 28 [97%] participants completing all diaries and 5 participants missing 1–2 months) and follow-up (with 26 [90%] completing all diaries) periods. The rate of falls was not significantly different between the pre-intervention and intervention periods (incidence rate ratio [IRR]: 0.91; 95% CI 0.50 to 1.68; p=0.77). In contrast, the rate of falls was significantly lower in the follow-up period compared with the intervention period (IRR: 0.51; 95% CI 0.28 to 0.92; p=0.03). The rate of falls was also lower in the follow-up period compared with the pre-intervention period, although this difference was not statistically significant (IRR: 0.46; 95% CI: 0.21 to 1.03; p=0.06). One participant experienced a fall-related hip fracture during the intervention period.

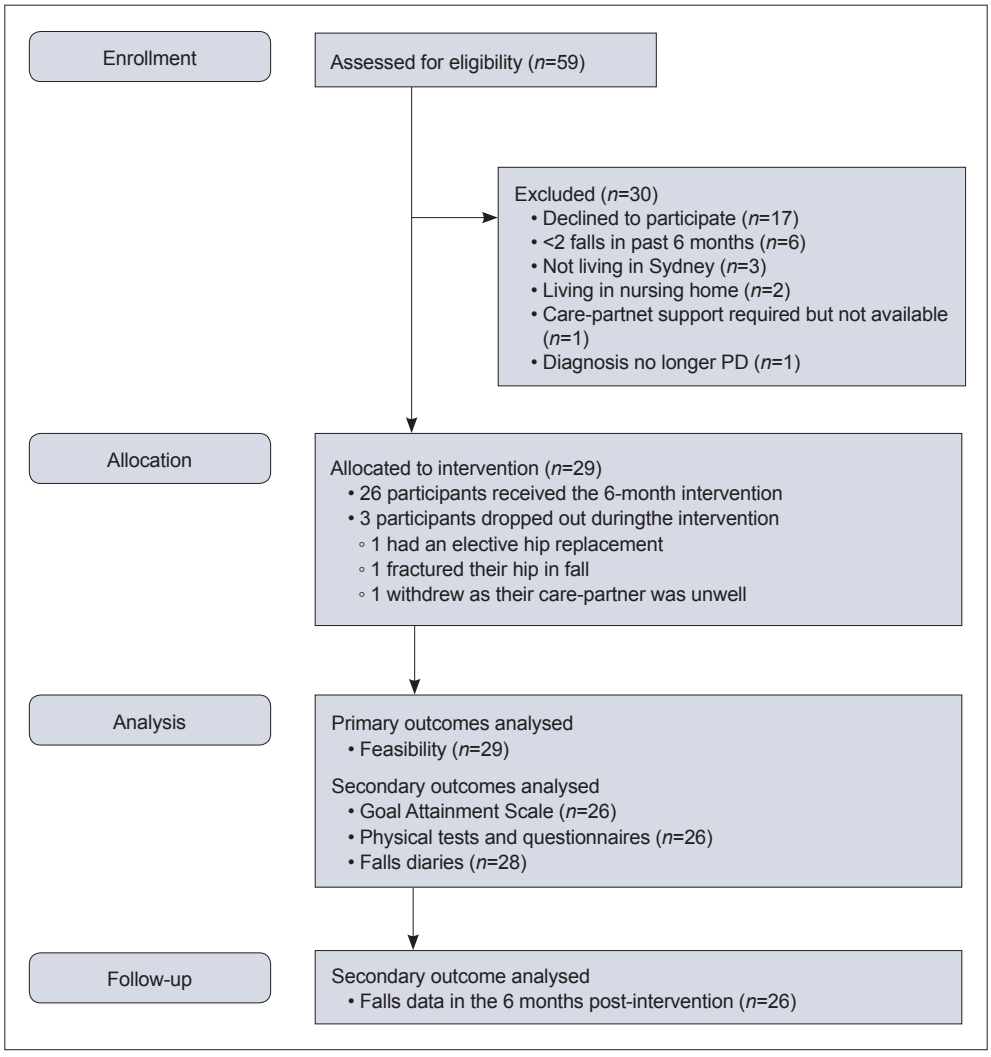

Figure 1. Flow of participants through the study. PD, Parkinson's disease.

DISCUSSION

This single group feasibility study of a personalized, multidomain fall prevention intervention delivered by OTs and PTs working together with PwP and care-partners yielded promising results. The intervention was demonstrated to be feasible, with good retention and adherence rates, no related adverse events and no increase in care-partner burden being observed. Notably, analysis of secondary outcomes indicated that the intervention may be effective in achieving safer mobility goals, improving overall mobility and reducing falls. These results were demonstrated in the context of a pragmatic, home-based intervention designed for people with advancing PD, including those with moderate cognitive impairment.

The intervention was deemed to be safe and feasible, with rates of recruitment, adherence and adverse events being similar to or more favorable than those reported in other studies of multidomain fall prevention interventions. Although the recruitment rate was relatively low (49%) compared with other home-based trials for people with mild to moderate PD,[12,14] it was similar to that of a trial focusing on balance training for people with more advanced PD[34] and higher than the rate reported in a trial involving a similar multidomain fall prevention intervention for people with dementia.[25] Furthermore, the low drop-out rate observed in the present trial supports the feasibility of the intervention for PwP who experience frequent falls. The adherence to the home hazard reduction recommendations was demonstrated to be good, with the proportion of recommendations that were fully completed (median: 67%) being similar to that in the dementia trial[25] but lower than that reported in a small feasibility study conducted using telehealth in people with mild to moderate PD.[15] Notably, exploratory descriptive analysis suggested that participants with MoCA scores <26 completed fewer recommendations, thereby suggesting that people with impaired cog-

Table 3. Changes in secondary outcome measures from pre-test to post-test

Outcome	Pre-test (*n*=26)	Post-test (*n*=26)	Difference (95% CI)†	*p* value
Short Physical Performance Battery (0–12)	9.5 (8.0–10.8)	11.0 (9.0–11.5)‡	1.0 (0.5–1.5)§§	0.01§§
Comfortable walking speed (m/sec)	0.9±0.3	0.9±0.2‡	-0.03 (-0.15–0.08)	0.55
5×sit to stand time (sec)*	12.9 (11.5–16.4)§	12.5 (10.3–14.3)‖	0.2 (-0.8–1.3)	0.65
Knee extensor strength (average of both legs, kg)	25.0±8.2‖	30.8±6.5¶	Unable to assess due to missing data	
Iconographical Falls Efficacy Scale (10–40)*	23.9±6.3	25±6.7	-1.2 (-3.1–0.6)	0.18
New Freezing of Gait Questionnaire (0–28)*	20.0 (10.0–24.5)	18.0 (10.0–23.0)	-0.5 (-2.5–1.0)	0.51
Multidimensional Fatigue Inventory (4–20 for each subscale)*				
General fatigue	14.2±3.6	13.2±3.5	1.0 (-0.4–2.5)	0.16
Physical fatigue	13.7±4.1	13.5±3.2	0.2 (-1.3–1.8)	0.76
Reduced activity	13.5±3.6	13.0±3.8	0.5 (-1.0–2.0)	0.47
Reduced motivation	10.6±3.1	10.4±3.1	0.2 (-1.4–1.7)	0.84
Mental fatigue	13.0±4.7	11.3±4.0	1.7 (0.0–3.3)	0.05
Incidental and Planned Exercise Questionnaire (hr/week)	13.7 (8.9–22.6)	17.3 (10.8–25.9)‡	3.8 (-0.2–7.6)	0.06
MDS-UPDRS Patient Questionnaire (0–80)*	34.5±11.7	33.2±9.5	1.3 (-2.1–4.6)	0.44
Steps per day*††	2980 (1972–5559)**	3031 (2306–3939)‖	-129 (-1322–423)	0.65
Sedentary time per day*†† (%)	45.2±7.7**	46.1±8.1‖	-0.2 (-3.5–3.2)	0.92
Zarit Burden Interview (0–48)*	15.0±8.9‡‡	16.4±9.3**	-2.2 (-6.4–2.0)	0.28

Values are presented as mean±SD or median (interquartile range) unless otherwise indicated.
*higher score is worse; †normally distributed data: mean difference (95% CI) and non-normally distributed data: median difference (95% CI); ‡*n*=25; §*n*=24; ‖*n*=23; ¶*n*=15 (14 not collected: 6 due to telehealth assessment, 3 dropped out, 3 unable to sit on assessment stool safely, 2 unable to complete the test due to knee pain); **n*=21; ††average of 6.8 (SD 1.0) valid days of activity monitor wear at pre-test and 5.8 (SD 1.2) days at post-test; ‡‡*n*=22; §§this result indicates a statistically significant effect.
CI, confidence interval; MDS-UPDRS, Movement Disorder's Society sponsored version of the Unified Parkinson's Disease Rating Scale; SD, standard deviation.

Table 4. Number of falls and fallers, and change in the rate of falls, across the three time periods for the 26 participants completing the study

	Pre-intervention (2 months)	Intervention (6 months)	Follow-up post-intervention (6 months)
Number of fallers	24 (92)	25 (96)	22 (85)
Total number of falls per month	165	151	76
Number of falls per person per month	6.4	5.8	2.9
IRR		0.91 (0.50–1.68)*	0.51 (0.28–0.92)† 0.46 (0.21–1.03)‡

Values are presented as number (%), number, mean, or mean (95% CI). Note that the pre-intervention period was 2 months, whereas the intervention and follow-up periods were 6 months.
*intervention vs. pre-intervention; †follow-up vs. intervention; ‡follow-up vs. pre-intervention.
IRR, incidence rate ratio; CI, confidence interval.

nition may require additional support to complete recommendations. Similar to previous studies in PwP, adherence to exercise was variable but overall good.[35,36] The absence of adverse events related to the intervention is also similar to that reported in previous fall prevention trials involving PwP,[2,15] which is an encouraging result given that the PwP included in the present trial demonstrated greater disease severity and cognitive impairment than did those included in previous trials. This finding indicates that PwP with moderate to advanced disease can safely perform multidomain fall prevention interventions at home, provided that these interventions are appropriately tailored to their functional cognition and physical abilities and supported by care-partners (when needed).

The safer mobility behavior training represents a relatively novel initiative. Previous studies have embedded this concept within interventions such as movement strategy training,[12,13] with the PDSAFE trial[14] including strategy training within exercise programs delivered by PTs. The present trial separated safer mobility strategies from exercise and used techniques such as signs, mantras and prompts from care-partners to help PwP integrate these strategies into daily life, thereby aiming to create safer habitual movements. A similar approach was used in a recent telehealth feasibility study that included behavioral counselling targeting fall prevention provided by an OT.[15] However, the process and potential success of developing new movement habits in PwP (including those individuals with cognitive impairment)

remain unclear because of deficits in automaticity and motor learning.[37] The present study utilized a tool that is unvalidated in PwP[27] to collect adherence data from only 14 participants; however, the results suggest that they may have begun to form new movement habits, with exploratory results demonstrating that participants without cognitive impairment (MoCA ≥26) reported using their strategies more often, as well as exhibiting a stronger habit strength score. Future research to clarify the concept of safer mobility behavior, optimal training and assessment methods, and its effectiveness in reducing falls in PwP is required, with particular consideration for people with cognitive impairment.

COVID-19 necessitated the use of telehealth, thereby impacting the intervention and possibly affecting the results of this study. Six (23%) participants received approximately half the intervention plus post-test assessments via telehealth. Previous evidence supports the use of telehealth as a safe and effective method for delivering exercise interventions[38] and a safe approach for providing multidomain fall risk reduction interventions[15] to people with mild to moderate PD. The present study found telehealth could also be safely delivered to people with more advanced PD and varying cognitive function with the support of care-partners (when needed). However, once COVID-19 restrictions were lifted, no participants requested telehealth sessions, thereby suggesting that they preferred in-person home visits. Furthermore, telehealth use in the present trial occurred in a block manner due to COVID-19 restrictions, whereas a mix of in-person and telehealth sessions may be preferable.[38] The use of telehealth to deliver the intervention during a pandemic may have influenced participant adherence and intervention fidelity, which could influence the generalizability of these results. Telehealth use for the post assessment led to missing data for knee extensor strength and may have affected the results of the SPPB. Balance and gait assessments using telehealth have been shown to be reliable and valid in healthy older adults[39] and safe in people with mild to moderate PD who have previously received in-person training.[40] However, the robustness of such measures in people with advancing PD without prior in-person training is unknown. Future research should explore the feasibility and acceptability of telehealth for fall prevention assessments and interventions in PwP with advanced disease, considering its cost benefits and accessibility for house-bound or rurally located people.

The results from the secondary outcomes measuring efficacy suggest that the intervention may improve mobility safety and reduce falls. Most of the participants met their safer mobility goals and exhibited improved scores in the SPPB, despite no improvements in comfortable walking speed or the five times sit-to-stand time components. This suggests that the improvement was due to the standing balance component; however, we were unable to evaluate standing balance as a continuous outcome, as we only recorded the total SPPB scores and did not separately record each specific component. Notably, the study intervention focused on safety and not on increasing speed; therefore, improvements in standing balance rather than walking speed or sitting-to-standing time may reflect the focus of the intervention. Additionally, although this study was not powered to find an effect on falls, the results suggest that the rate of falls between the post-test and follow-up may have decreased by approximately 50%. These results should be interpreted with caution, due to the fact that this study was uncontrolled (with a single group and unblinded assessment being used); therefore, biases may influence the results. Furthermore, most of the PwP were supported by care-partners, and the intervention was delivered by therapists who were skilled in PD, meaning that these findings may not be generalizable to settings where there is less support provided. However, given that exercise is known to lead to an approximately 26% reduction in fall rates in PwP with mild to moderate disease and that home-based exercise alone could increase the occurrence of falls in people with more advanced disease,[2] the present results suggest that a large-scale trial of a personalized multidomain intervention is warranted. Such a trial should include cost effectiveness analyses to inform future decisions regarding fall prevention interventions for PwP who experience recurrent falls.

Conclusions

A personalized, home-based multidomain intervention delivered by OTs and PTs using a collaborative, shared problem-solving approach with PwP and their care-partners was feasible and might improve mobility safety and reduce falls. The encouraging results that were obtained from this small single-group study warrant further research to determine the efficacy of the intervention on falls in PwP, including those with advancing disease and cognitive impairment.

Supplementary Materials

The online-only Data Supplement is available with this article at https://doi.org/10.14802/jmd.24237.

Conflicts of Interest

The authors have no financial conflicts of interest.

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