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Original Article

Behaviour Change for Parkinson's Disease: A Randomised Controlled Feasibility Study to Promote Physical Activity and Exercise Adherence Among People with Parkinson's Disease

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Abstract

Objective: Exercise reduces fall risk, sarcopenia and frailty in Parkinson's disease, but motor and non-motor symptoms hinder adherence. This study aimed to feasibility test an exercise intervention with behaviour change techniques, examining recruitment, procedures, and measure responsiveness. **Methods**: A mixed-methods parallel-arm, single-blinded, randomized feasibility study. Participants (Hoehn and Yahr 1–3) were randomly allocated to intervention or control groups. Both received 12-weeks of education, supervised exercise, and home exercises. The intervention group received additional behaviour change techniques. Enrolment, attendance, adherence, and adverse events were recorded. Outcomes included walking activity, balance, falls, strength, and exercise self-efficacy. Surveys and interviews explored acceptability. **Results**: Twenty-six people were screened; sixteen randomized, fourteen completed. Exercise class attendance in both groups was high. Adherence to home exercises was higher in the intervention group (70% vs 63%). No serious adverse events. Time resources were acceptable. Walking activity and aerobic endurance reached minimally important differences. Interviews indicated participants enjoyed the group dynamic and gained skills. Feedback will improve acceptability **Conclusion**: The intervention is feasible and well-accepted. While not designed to measure frailty, sarcopenia, or fall risk directly, enhancing adherence through behaviour change techniques and tailoring interventions to individual preferences maybe a promising strategy to support long-term exercise engagement. **ClinicalTrials.gov ID:** NCT06192628

Keywords: Parkinson's disease, Information Motivation Behaviour Skills Model, Self-efficacy, Exercise therapy

Introduction

Parkinson's disease is a progressive neurological condition involving motor and non-motor symptoms that contribute to declining mobility, increased fall risk, and frailty[1]. Deteriorating symptoms can lead to a sedentary lifestyle[2], which further accelerates functional dependence[3]. People with Parkinson's disease (PwPD) are three times more likely to develop sarcopenia and experience four times as many falls as age-matched healthy controls[4-7]. With an annual falls incidence of 60%[8], and around 66% of these falls being recurrent, it highlights falls are a serious

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concern. A recent systematic review by Allen et al[1] found that exercise can reduce the rate of falls by 26% and slightly reduces the number of PwPD experiencing at least one fall by 10%[1]. It is further estimated that exercise can lead to long term fall prevention in PwPD[9], with one-year falls rates dropping from 8,250 to 6,105 per 1,000 PwPD[9].

Exercise not only improves mobility and physical function[10], but may also offer neuroprotective effects[11,12]. Despite these benefits, only 30% of PwPD meet the recommended activity guidelines[2,13] and most PwPD are one-third less active than age-matched peers[13,14].

Self-efficacy and outcome expectations are stronger predictors of sustained exercise adherence than disease severity[15]. PwPD report that lack of motivation prevents regular physical activity[16]. Dopamine depletion associated with disease progression may result in lack of motivation (apathy), loss of interest in pleasurable activities, and pessimistic views of exercise capability[17,18]. However, encouraging enjoyable and meaningful exercise experiences can drive motivation[19,20].

We recently completed a systematic review of behaviour change interventions targeting exercise self-efficacy and exercise adherence in PwPD[21]. While these approaches yielded small improvements in adherence, physical function, and quality of life compared to exercise alone, they had limited impact on self-efficacy—possibly due to a lack of focus on the most relevant behavioural determinants.

The Theoretical Domains Framework (TDF)[22] was used to frame the narrative synthesis of the review. The TDF is an integrative framework remodelled from a combination of psychological theories as a tool to help implement theoretical approaches to interventions aimed at behaviour change[22]. The framework consists of 14 domains generated from 128 constructs, which were developed from 33 theories of behaviour change[23]. It provides a high level of explanation for constructs related to individual level change while it also contains combined (e.g., organization) level constructs[24]. The domains include knowledge, skills, social/professional role and identity, beliefs about capabilities, optimism, beliefs about consequences, reinforcement, intentions, goals, memory, attention, and decision processes, environmental context and resources, social influences, emotion and behaviour regulation[22].

Mapping the literature to the Theoretical Domains Framework identified five key domains − belief about capabilities, goals, behaviour regulation, social influences and reinforcement − as the most effective domains of exercise-related behaviour change in Parkinson's disease[21]. While our systematic review used the TDF to map existing interventions, it revealed that many studies lacked a targeted focus on the five most effective domains[21]. This may explain the suboptimal results in terms of improving exercise self-efficacy.

Study rationale

The only large, multicentre trial to date —ParkFit[25]— compared a two-year physiotherapist-led behaviour change programme in PwPD to a safety-focused (falls prevention) control. No difference was detected in self-reported physical activity. However, ParkFit did not measure self-efficacy as a primary outcome. Also, a broad, long-term approach to behaviour change was used (activity monitors with real time feedback, coaching, health contract and long term goal setting), that may have lacked sufficient specificity or feasibility for everyday clinical practice.

In contrast, the current study embeds targeted behaviour change techniques into an existing 12-week Parkinson's disease Exercise and Education Programme (PEEP). Guided by the TDF, our approach focuses specifically on the five domains the review showed to influence self-management and exercise adherence in PwPD. This design allows us to explore the feasibility and acceptability of a more focused, time-limited, and theory-driven strategy that aligns closely with both behavioural science and real-world service delivery. By testing whether these targeted techniques can improve exercise self-efficacy and self-management within a short-term, group-based intervention, we aim to lay the groundwork for a more scalable and person-centred approach to care.

Research objectives

Based on the review findings, and previous qualitative work exploring exercise motivation and supports[21,26], we aim to test the feasibility of additional behaviour change (BC) techniques, delivered alongside an existing 12-week exercise and education intervention called the Parkinson's disease Exercise and Education Programme (PEEP). The BC techniques aim to improve self-efficacy and self-management of exercise/physical activity.

Using mixed methods, the objectives were to:

a) Examine recruitment process, and resulting sample characteristics (screen failures, consent refusals).
b) Feasibility test the study procedures: time, equipment, data collection procedures, and set-up administration time.
c) Examine attendance, adherence and safety of the program.
d) Explore the acceptability of the intervention and the study procedures.
e) Estimate the responsiveness of measures to change.

Materials and Methods

Study design

A detailed description of the trial protocol has been presented previously[27]. A parallel single- blinded feasibility study comparing the PEEP Programme (PEEP; control) with the same programme augmented with behaviour change techniques (PEEP+BC; intervention). The study received

local ethical approval (ECM 5 (4) 06/07/2023) and was conducted from September 2023 to January 2024. This study is reported in line with the Consolidated Standards of Reporting Trials (CONSORT) statement extension for randomized pilot and feasibility studies[28]. The intervention description, guided by the Template for Intervention Description and Replication (TIDieR)[29] is previously published[27]. The study is registered on ClinicalTrials.gov (NCT06192628), registered on 5 January 2024.

Subjects and recruitment

We aimed to recruit 20 participants from the existing PEEP programme waiting list, estimating a 20% attrition rate based on previous PEEP programmes and the available literature[30,31]. The stop-go criteria was implemented for recruitment, the pre-determined thresholds were; go (90-100% of the target), amend/monitor (60-89% of the target) and stop (<60% of the target). Participants were screened using the following eligibility criteria:

- Diagnosis of idiopathic Parkinson's disease, confirmed by neurologist or geriatrician.
- In the early stages of Parkinson's disease, as determined by Hoehn & Yahr Stage 1-3 using the Unified Parkinson's disease Rating Scale[32]).
- Able to walk independently (with/without a walking aid).
- Able to attend classes, follow instructions and complete the exercises independently at home (as self-reported, or reported by the referring healthcare provider/carer).
- Participants must be stable on their medications (i.e. no changes to medication or dosage in past three months).

Exclusion criteria:

- Diagnosis of atypical Parkinson's disease (e.g., progressive supranuclear palsy, multiple system atrophy), vascular parkinsonism or drug-induced parkinsonism.
- Completed the PEEP programme previously.
- Hospital admission < 6 weeks ago.
- Serious medical conditions/illnesses preventing safe exercise.
- Identified as a high falls risk, at pre-screening, using the Short Physical Performance Battery (a score of ≤6 indicates falls risk in old adults[33]) and/or subjective reporting of frequent falls in the past year (two or more falls)[34].

Recruitment and baseline assessment procedure

The waiting list for the PEEP programme was used to identify suitable participants, who were screened and invited to participate by phone. If eligible, the study was explained to them, and a copy of the participant information leaflet was sent to them by post. Those that were interested were invited for assessment. Confirmation of the screening and baseline data was completed one week before the programme, at the primary care centre. Those who did not reach eligibility were offered alternative appropriate treatments. The participants were given the opportunity to ask further questions, and written consent was sought before baseline data was gathered. Participants were assessed one week before the 12-week programme by a member of the research team (LA). Baseline data included demographics, medical, medication, social history, and disease severity (UPDRS–motor exam). All assessments were completed in one hour, and during the participants ON phase (medication is effectively reducing symptoms, allowing smoother movement) for consistency (i.e., 1-2 hours post medications, at their stated "good time of day"). While mobility assessments are often conducted in the "Off" state to capture baseline impairment, we chose the "On" state to reflect participants' typical daily functioning and to minimize discomfort associated with medication withdrawal. Furthermore, this study involved the intervention group to discuss, report and goal set for the following week, which could have been distressing were they in an "Off" state with communication difficulties. This approach aligns with recent studies focused on real-world function and ensures consistency across participants[35,36]. The Modus HealthTM Stepwatch4 Activity Monitor (SAM) was programmed as per manufacturer instructions to each participant and worn on the dominant ankle continuously for seven days.

The participants were then randomised using a computer-generated randomisation sequence and sealed envelopes (see below). Those assigned to the intervention group were given an activity diary, showed how to complete it and informed it would be reviewed each week. Participants were also taught how to record any falls and/or near fall events in the activity diary.

Randomization process

Randomisation was conducted by a member of the research team not involved in the assessment or delivery of the program. Eligible participants were allocated in a 1:1 ratio, stratified by sex, using a computer-generated random number sequence (Excel, Microsoft Corporation) and sealed envelopes, to the PEEP or the PEEP+BC group. To limit contamination, study participants were asked not to share information on group activities with other PwPD.

Intervention for PEEP and PEEP+BC groups (Table 1 for further detail)

Usual Care (control): Parkinson's disease Exercise and Education Programme (PEEP):

The Parkinson's disease Exercise and Education Programme (PEEP) is an on-going 12-week programme run in an urban primary care centre in Ireland. A detailed description of the interventions is described in Ahern et al[27]. Briefly, the program, informed by existing literature, was developed (LA) in 2021 and modified with physiotherapy colleagues' and patients' reviews. The programme is targeted for PwPD at Hoehn and Yahr Stage 1-3 (i.e., physically independent).

The classes and education sessions were each provided once weekly for twelve weeks. The exercise classes were 45

	Intervention (PEEP+BC)	Control (PEEP)
Exercise component	• Progressive strength, balance and functional exercises. • 1x hour classes in groups of 4 with physiotherapist • 2x hour of independent home exercises • Progressively challenging cognitive tasks incorporated weeks 6-12 • Exercise logs (for the 1-hour group exercise class) completed by physiotherapist week 1-5 and completely independently by participants from weeks 6-12	• Progressive strength, balance and functional exercises. • 1x hour classes in groups of 4 with physiotherapist • 2x hour of independent home exercises • Progressively challenging cognitive tasks incorporated weeks 6-12 • Exercise logs (for the 1-hour group exercise class) completed by physiotherapist week 1-12
Education component	• Weekly education sessions delivered by multidisciplinary team. • Sessions included • Signpost to services • The role of the healthcare profession • Initial education on medication, symptoms, diet, and aids.*	• Weekly education sessions delivered by multidisciplinary team. • Sessions included • Signpost to services • The role of the healthcare profession. Initial education on medication, symptoms, diet, and aids.*
Behavioural change component	<u>Exercise specific education</u> Participants were: • Informed about the functional benefit of each exercise within the classes, • Educated how to monitor and progress their own program, including monitoring exercise intensity, logging sets and reps and progressing and regressing exercises and • Informed about muscle soreness and fatigue symptoms that may occur from exercising <u>Activity diary</u> • Participants completed weekly activity diaries at home, logging all activities they completed during the week and reflecting on progress, expectations <u>Goal setting and barrier identification</u> • Activity diaries were reviewed weekly by the research physiotherapist • Discussions with the participants about solutions to barriers, and assisted with setting activity goals <u>Peer support</u> A WhatsApp group was set up among the participants and was encouraged to drive peer-support and self-management.	N/A

***PEEP**: Parkinson's exercise and education programme; BC: behavioural change.* * Education regarding self-management only included the self-management of medication, no education was provided regarding the role of exercise in self-management.

Table 1. Details of usual care and intervention components.

minutes in duration including strength, balance, functional and dual tasking exercises. Home exercises were individually prescribed, to be completed twice weekly. The education sessions were delivered by different healthcare professionals explaining their role and signposting to services.

Intervention: Parkinson's Exercise and Education Programme with the Behaviour Change techniques (PEEP+BC)

Similarly, the PEEP+BC is described in detail in Ahern et al[27]. The PEEP+BC incorporated four behaviour change techniques to promote exercise self-efficacy and self-management; (1) *Exercise specific education*: the participants were explicitly taught the functional benefit of each exercise, participants were educated how to monitor and progress their own program, including monitoring exercise intensity, logging sets and reps and progressing and regressing exercises. (2) *Activity diaries* were completed weekly at home, reflecting on progress, expectations, (3) *solutions to barriers*, and to set activity goals for the following week and, (4) finally, *a WhatsApp group* was encouraged to drive peer-support and self-management. The activity diary completion was monitored and reviewed

by LA each week during a brief weekly discussion prior to the exercise classes.

Intervention (PEEP + BC) group attended their exercise class on a separate day to the control (PEEP) group. To prevent the repetition of the weekly education sessions, both the PEEP and PEEP+BC attended the same education sessions. Every attempt was made to keep the groups separate. Table 1 shows further details between the groups.

Time and equipment resources for the study

Each arm was split into two groups of four participants, to allow space and safety (four classes weekly (n=4 per class), two classes per each arm). The required equipment was routine; chairs, steps (10cm and 15cm), varying resistance bands, and weights. Forty-five minutes provided for warm-up, cool down and a five-minute break between the exercise and education sessions worked well. The additional debriefing sessions before the classes were feasible and straightforward.

Set-up administration time required

Administration per person in either arm of the study was the same, taking approximately two hours, organization of education sessions and guest speakers took approximately four hours with additional time for printed handouts, pamphlets, and session information (approx. 20-30 mins per session).

Outcome assessment procedure

Participants were assessed one week after the programme (Week 13) by the same member of the research team (LA). All assessments were completed in one hour, and during the participants ON phase (exactly 13 weeks after the baseline assessment, on the same day and time.) The SAM was programmed as per manufacturer instructions, participants were asked to wear the accelerometer for the final week of the programme (week 12) on the dominant ankle continuously for seven days (returned on the assessment day, week 13). Activity diaries and feedback surveys were also collected on the assessment day (week 13).

Outcomes

The study used quantitative and qualitative data to evaluate the feasibility of the intervention, while outcome data was used to estimate its effects.

The quantitative measures to examine feasibility included:

- Recruitment and retention rates: The numbers approached, screened and consented.
- Feasibility of the intervention and research procedures: The adherence to in-class and home exercises, data collection completeness, staff and equipment resources were examined. Full adherence to the programme was defined as: 1) attendance at all assessments, 2) completion (at least 50% completion rate) of twelve, weekly activity diaries and 3) documented attendance at 12 exercise/education sessions. The weekly activity diaries completion was scored using a three-tier classification system: 0%, 50%, or 100%. A score of 0% was assigned when no activities were documented; A 50% score was applied when participants recorded any activity-related data but failed to provide consistent information on reflective components (feelings after exercise/reasons for not exercising), or when complete entries were provided for fewer than five days per week. Diaries were rated as 100% complete if participants provided detailed information on type of activity, setting, duration, sets, reps, intensity, feelings after exercising, and—where applicable—reasons for not exercising for at least five of the seven days per week.
- Programme safety: This was checked weekly against a predetermined list of serious adverse; (falls [number and frequency], injuries [cuts, bruises, muscle pains]), emergency department attendance or hospitalization, and death). All unaccounted non-attendances were followed up.

The qualitative data to examine the feasibility (acceptability) included:

- All participants completed a feedback survey [*see Supplementary Material 1*] with open- ended questions exploring the acceptability and suitability of the programme, elements of the programme they felt were not required, or elements they believe should have been included in the programme, and their opinions of the topics covered during the education sessions. The week after the programme, online semi- structured interviews conducted with the intervention participants only by an independent interviewer (RMcC) to prevent the physiotherapist-patient relationship affecting open dialogue and participant responses. The interviews explored the acceptability and perceived impact of the BC techniques among the PEEP+BC participants only. The interview guide [*see Supplementary Material 1*] was informed by our systematic review and previous research examining the acceptability of BC techniques[37-39], coded under the domains of the Theoretical Domains Framework[22].

The quantitative measures to estimate the effects of the intervention included:

- Measures of physical activity, function and self-efficacy (detailed under Outcome measures) were examined to explore their responsiveness to change, and floor and ceiling effects. Within group differences were compared to published minimal important differences, as significant differences between groups were not anticipated with low numbers.

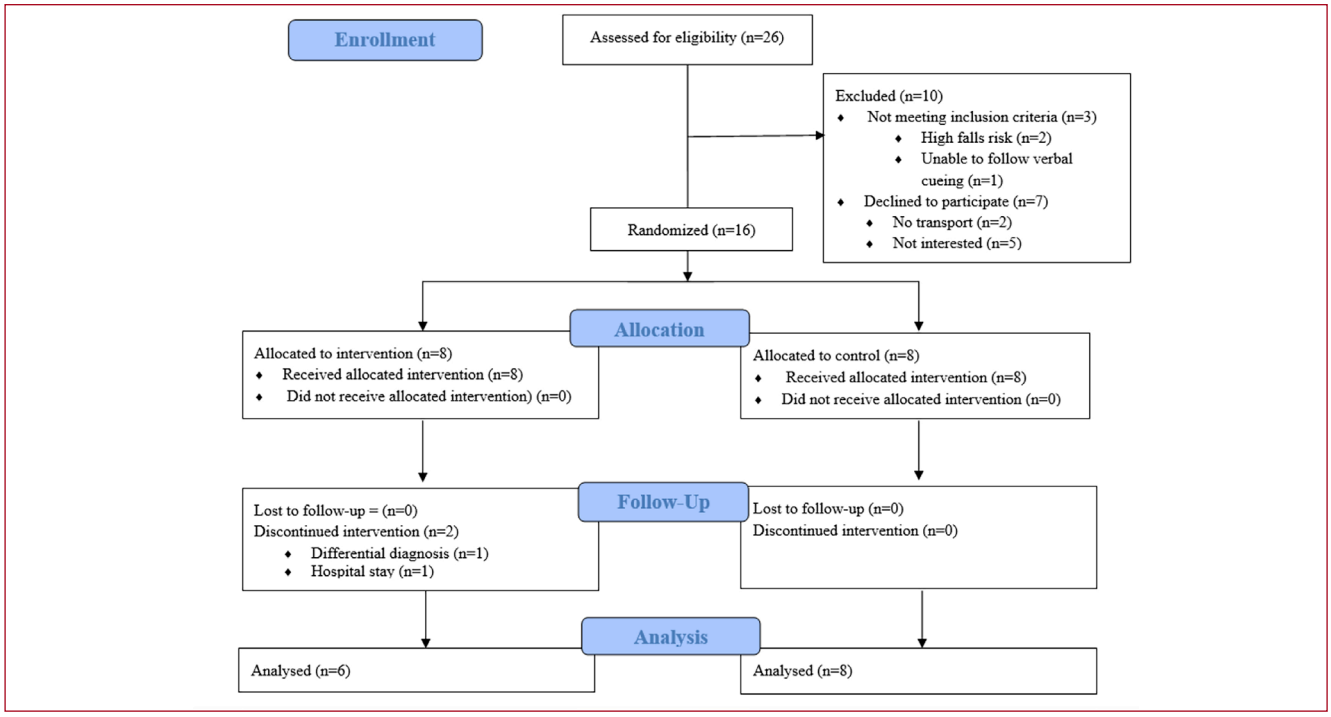

Figure 1. CONSORT Flow Diagram.

Outcome measures

As described in our protocol[27], the primary outcome measures included walking activity and falls events, gait, balance and strength, and exercise self-efficacy,

Walking activity and fall events

We used the Modus HealthTM Stepwatch4 Activity Monitor (SAM), to compare 7-day average daily step-count from baseline to the last week of the programme. This ankle-worn, waterproof accelerometer has excellent accuracy in PwPD[40]. The SAM was worn continuously for seven days. A courtesy call was made mid-week, and participants were encouraged to contact the researcher with any concerns.

Falls and 'near falls' were self-reported in the weekly. Participants in the PEEP + BC group were asked to document in the activity diary if they had a fall. Participants were also asked about falls every week, during the weekly discussions before the exercise class, and the activity diary were updated as required. Participants in the PEEP group were asked weekly before the exercise classes, any falls were logged by the physiotherapist.

Exercise self-efficacy

Self-efficacy was measured using the Exercise Self-Efficacy Scale41 (ESES). The ESES is a self-report instrument, validated in PwPD[41].

Gait, balance and strength

We used the validated[42] APDM Mobility Lab system™ to objectively measure a Timed Up and Go Test (TUG) and a 2-minute free walk test (at the participants self-selected pace). Five Opals™ (accelerometers) were attached at the ankles, wrists, and waist. To explore the value of measuring the TUG objectively the assessor also used a stopwatch timer.

Five time sit-to-stand (5TSTS) was used to measure functional mobility and lower limb strength[43]. JAMAR handheld-dynamometer was used to measure grip strength.

Secondary outcomes

Quality of life (QoL)

The Parkinson's disease Questionnaire[44] (PDQ-39) was used to assess Parkinson's disease-specific health- related QoL[44]. The PDQ-39 is validated in PwPD[44].

Aerobic endurance

Aerobic endurance was measured with the six-minute walk test[45] (6MWT) at a self-selected pace. A 10m indoor hallway was used, and total distance was recorded.

	PEEP+BC (n=8) Median [IQR]	PEEP (n=8) Median [IQR]
Age (years)	72 [66.3 - 77.8]	68.5 [56.5-81.5]
Height (cm)	172.5 [165.3-179.8]	175.5 [172.6-178.4]
Weight (kg)	78.1 [66.6-89.6]	91.9 [79.2-104.6]
Sex (M/F)	6/2	6/2
UPDRS Part III Motor Exam	14.5 [3-26]	12 [20.5-3.5]
PDQ-39 SI	2.5 [-1.9-6.9]	5.5 [2.5-8.5]
PDQ-Mob	7.5 [3.8-26.3]	26.3 [9.4-23.8]
PDQ- ADLs	2.1 [0-10.4]	14.6 [-8.1-0.6]
PDQ- Emot Well	20.9 [16.7-40.8]	35.2 [28-41.6]
PDQ- Stig	18.8 [7.8-25]	12.5 [0-28.3]
PDQ- SS	0 [-4.7-0]	12.5 [0-25]
PDQ- Cog	19 [9.4-32.9]	31.4 [17.2-47.1]
PDQ- Comm	21 [10.5-43.8]	16.7 [14.6-52]
PDQ- Body Dis	16.7 [4.2-23]	41.7 [23-41.4]
ESES	31 [25.8-36.3]	34 [25.5-42.5]
SPPB	11 [7-15]	10 [8.8-11.3]
TUG (seconds)	9.9 [4.5-15.2]	10.0 [7.8-12.2]
5TSTS (seconds)(total)	13.7 [8.6-18.8]	12.1 [5.8-19.3]
5TSTS (male only)	14 [13.6-16.8]	11.3 [8.4-15.2]
5TSTS (female only)	9.9 [9.9-10]	13.3 [12.3-14.3]
6MWT (m)(total)	337.5 [268.5-406.5]	337.5 [222.8-452.3]
6MWT (male only)	327.5 [305-338.8]	305 [300-387.3]
6MWT (female only)	415 [396-434]	392.5 [378.8-406.3]
Walking activity (SAM) (average daily step-count)	7880.5 [2755.3-13005.8]	8594 [2286.2-14901.8]
Gait speed (m/s)	1.06 [0.8-1.1]	1.06 [0.6-1.3]
Grip strength (kg)(total)	R 25.9 [19.9-31.0] L 20.9 [17.1-24.7]	R 26.6 [15.2-38.0] L 25.8 [18.9-32.7]
Grip strength (male only)	R 26.2 [25.9-27.9] L 22 [20.8-24.6]	R 30.3 [24.8-40.1] L 28.4 [25-30.3]
Grip strength (female only)	R 19.2 [19.1-19.3] L 18.7 [17.7-19.6]	R 22.5 [21.1-24] L 21.6 [20.9-22.4]

IQR = interquartile range, **cm** = centimetre, **kg** = kilogram, **M** = male, **F** = female, **UPDRS** = Unified Parkison's Disease Rating Scale (range 0-132, ≤32 indicates mild disease)[59], **PDQ-39 SI** = Parkinson's disease Questionnaire-39 Summary Index (range 0-19.5, higher indicates worse)[41]. Mob = Mobility, ADLs= Activity Daily Living, Emot Well = Emotional Wellbeing, Stig = Stigma, SS = Social Support, Cog = Cognition, Comm = Communication, Bod Dis = Bodily Discomfort (all PDQ-39 subscales range 0-100, higher indicated worse)[41]. **ESES** = Exercise Self-Efficacy Scale (range 10- 40, higher indicates better)40. **SPPB** = *Short Physical Performance Battery (range 0-12, higher indicates better[31], ≤ 8 indicator for sarcopenia[4]).* **TUG** = *Timed Up and Go (<10 seconds indicates normal mobility; >11.5 seconds indicates a falls risk in Parkinson's disease[45]. ≥ 20 sec indicator for sarcopenia[4]).* **5TSTS** = *Five time sit to stand (> 16 sec indicates falls risk in Parkinson's disease[39], > 15 sec indicator for sarcopenia[4]).* **6MWT** = *6-minute walk test (< 320m (aged 65-74 years) and 295 m (aged 75 years and older) indicates risk of fall in elderly[60] < 400m indicator for sarcopenia[4]).* **Gait speed** *(<1.1 m/s indicates falls in PwPD[61], ≤ 0.8m/s indicator for sarcopenia[4]) m/s = metres/second.* **Grip Strength** *(< 16kg for women; < 27 kg for men indicator for sarcopenia[4]),* **m** = *metres,* **R** = *right,* **L** = *left.*

Table 2. Baseline Demographics and Baseline Outcome Data.

PEEP + BC			
Participant ID	% exercise attended (classes offered, n=12)	% education attended (classes offered, n=12)	% Overall Attendance (exercise + education classes offered n=24)
ID1	83	83	83
ID2	75	92	83
ID3	92	92	92
ID4	100	92	96
ID5	50*	8*	29
ID6	92	92	92
ID7	50**	33**	42
ID8	92	92	92
% Total PEEP+BC class attendance (total number of classes attended/total number of classes offered)	79	73	76
% PEEP+BC class attendance *excluding dropouts (ID5 and ID7)*	89	90	90
ID9	67	58	63
ID10	83	75	79
ID11	100	92	96
ID12	83	42	63
ID13	92	75	83
ID14	67	75	71
ID15	75	67	71
ID16	83	83	83
% Total PEEP class attendance (total number of classes attended/total number of classes offered)	81	71	76

**ID5 100% (6/6) attendance to exercise; 17% attendance for education (1/6) before excluded at week 7 with a serious medical condition preventing safe exercise. **ID7 100% (6/6) attendance to exercise; 67% attendance for education (4/6) before excluded at week 7 with a diagnosis of atypical Parkinson's disease.*

Table 3. Participant level attendance.

Data analysis

Quantitative analysis

Attendance rates were determined for each group for the 12-week programme. Attendance was calculated as the percentage of the number of classes attended relative to the number of classes offered (i.e. Total number of exercise + education classes attended/Total number of exercise + education offered).

Given the small number of participants, we treated all continuous data as not normally distributed (see Table 2), non-parametric t-tests were used to analyse the quantitative measures for pretest and post-test evaluation data.

Qualitative analysis

Content analysis methods were used with qualitative data from the surveys. The recordings from the semi-structured interview were transcribed verbatim, with thematic analysis of the coded transcripts.

Results

Participants

Twenty-six people were invited to participate. Three did not fit the eligibility criteria, and seven declined to participate (Figure 1). Sixteen participants were randomized and commenced the intervention (control (PEEP) n=8; intervention (PEEP+BC) n=8). Group demographics and baseline scores are presented in Table 2.

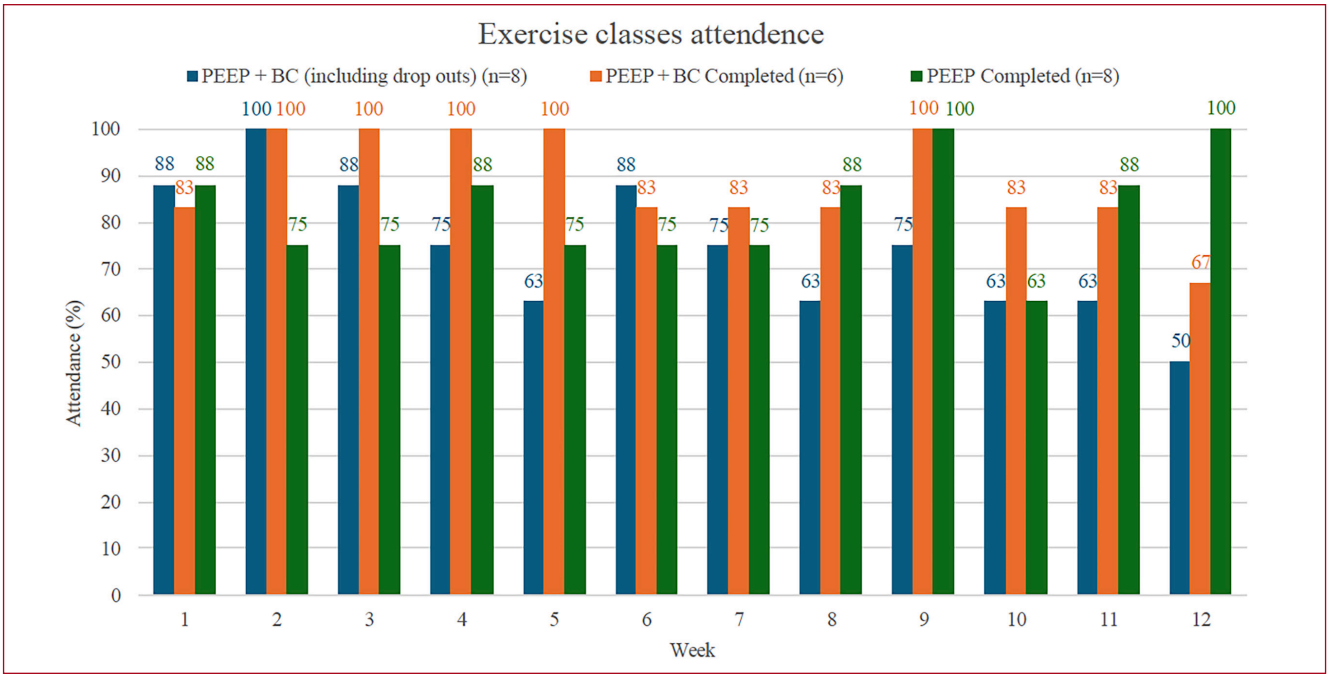

Figure 2. Attendance rate per group (exercise classes only).

Recruitment process and resulting sample characteristics

Overall, the recruitment process was satisfactory with an uptake rate of 62% (see Figure 1, seven declined to participate (five were not interested and two had no transportation). Participants (age 56.5 - 81.5 years) were mostly male (75%), with low levels of disability, and relatively high self-efficacy and quality of life (see Table 2). Gait speed scores of 1.06 m/s suggesting both groups were not a falls risk[46-48]. The control group were heavier in weight (median +14kg heavier) and walked more (median +713 steps per day) at baseline, suggesting they may have been a more robust group. Both groups were comparable for all other measures.

Feasibility of study procedures

Baseline data collection took approximately 30 minutes per visit (total 15 hours), and methods were acceptable for both staff and participants. Two participants found the phrasing of the PDQ-39 and ESES questionnaires unclear, but with simple explanations, could complete them independently. Three needed assistance to write answers.

We used the SAM and APDM to measure outcomes. The SAM were easy to use, requiring little set-up time. One participant found the SAM uncomfortable at night, hence they removed it nightly. We used the APDM to measure gait and balance. The time to calibrate, set-up and analyze the data was lengthy, and did not provide any additional data than a simple timed test.

Adherence and fidelity to the programme

Overall, attendance (exercise and education) for both intervention and control groups were high (76%, (146/192)) (see Table 3, Figure 2, Figure 3). Reasons for non-attendance included personal reasons (35%), illness (31%), unavailability (27%) and unspecified reasons (15%). Attendance showed that the PEEP group attended their education sessions (71% (68/96) noticeably less than their exercises sessions (81% (78/96)). Home exercise adherence showed considerable differences between the groups. The PEEP+BC participants adhered better to the twice-weekly prescribed home exercises than the PEEP group (70% (135/192) vs 63% (120/192)). Furthermore, four of six PEEP+BC participants completed additional home exercises, exercising at least four times weekly by the end of the programme. Conversely, some PEEP participants did not complete any of their home programme (n=3); while the rest remained at twice weekly sessions (n=5).

In the exercise class, PEEP+BC participants showed improving confidence with the weekly exercise progressions (any progressions were noted in the exercise logs); at Week 6, participants started leading the classes with some prompting. By Week 10, the participants were fully

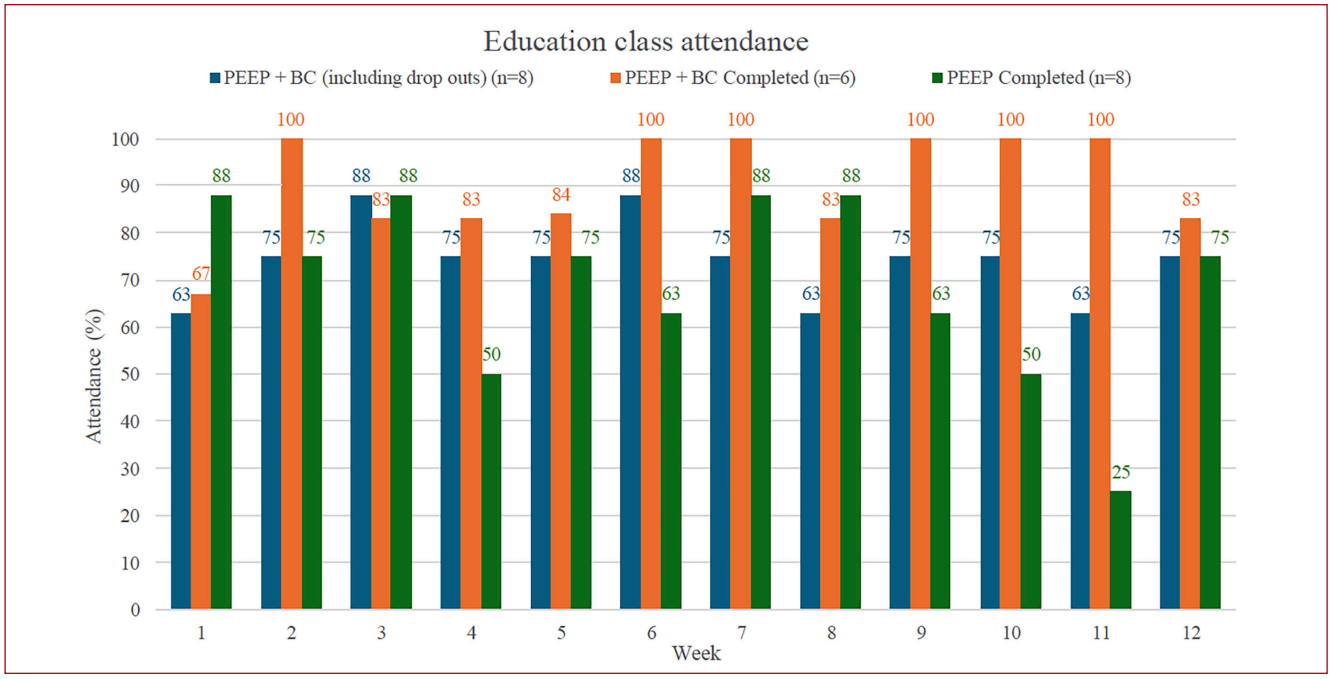

Figure 3. Attendance rate per group (education classes only).

leading the exercise classes with supervision only, while PEEP participants required encouragement and prompting through the programme entirety.

Acceptability of the exercise intervention

The feedback surveys and exit interviews showed that all participants enjoyed the exercise programme, e.g. "*it is the best exercise class I have been to since [diagnosis]…. other classes…aren't hard enough*" and would recommend it to others. Five out of six reported they would continue with the classes if available, and all reported they plan to continue exercising after the programme. All participants agreed that 12 weeks was appropriate for the programme. *"…the 12 weeks is fine, to make it any shorter wouldn't do it justice. There is a lot in the programme, and I think the progressions are nice and subtle every week*". Any longer "*would be taxing*" and "*would lose the focus*". All participants reported enjoying the group classes, e.g. "*there was a good spirit generated there was a very, very good atmosphere, a kind of a fun atmosphere*". Four participants reported peer support in class was key to maintaining exercise intensity, e.g. "*It was never hard [exercising at home] because you were doing it on your own…you would be nice to yourself … as opposed to in the class*" and "*I was glad to [have] monitoring there. It kept you going." and "being in the group was very helpful*". Most PEEP+BC participants (4/6) enjoyed the additional dual-cognitive tasks in the last six weeks, "*And then when we did the cognitive bit…that was excellent…it made it a bit more interesting*".

Acceptability of the multidisciplinary education

The results of the survey showed that all participants indicated the sessions were appropriate and helpful (12/12 100%). In the exit interviews (conducted with the intervention group only), four out of six reported they would have preferred the exercise and education classes on the same day, especially those who travelled a distance. Other suggestions included: limiting the education sessions to fortnightly (on the same day as the exercise classes); combining some education sessions; making them interactive; including support services education for carers; and a debrief session (facilitated by the physiotherapist) after the education sessions in smaller groups to discuss the information they learned.

Acceptability of behaviour change techniques (PEEP+BC only)

Completion of the *activity diary* was mixed (one was 0% completed, two were 50% completed, and three were 100% completed), with all but one returned post-assessment, but with varying levels of completion. Half of the interviewees (3/6) reported it as most important as it created "*structure*", "*routine*" and "*accountability*". Participants "*did not want to leave a blank space*". Despite

	PEEP+BC (n = 6)		PEEP (n = 8)	
Outcome Measure	**Post-intervention Median (IQR)**	**Δ**	**Post-intervention Median (IQR)**	**Δ**
PDQ-39 SI [0-19]	2.75 [0.2-5.4]	+0.3	4.07 [2.4-5.8]	-1.4
PDQ-Mob	12.5 [-6.9-31.9]	+5.0	18.75 [-1.3-38.8]	-7.5
PDQ- ADLs	6.24 [2.0-10.4]	+4.2	14.59 [5.2-24.0]	0
PDQ- Emot Well	31.25 [9.4-53.2]	+10.4	25 [17.7-32.3]	-10.3
PDQ- Stig	6.25 [-7.9-20.4]	-12.5	12.5 [-7.8-32.8]	0
PDQ- SS	8.32 [2.0-14.6]	+8.3	8.33 [-8.0-24.6]	-4.2
PDQ- Cog	12.5 [0-25]	-6.5	21.88 [-0.02-43.9]	-9.5
PDQ- Comm	12.5 [-7.6-22.6]	-8.5	25 [22.9-27.1]	+8.3
PDQ- Body Dis	16.67 [-6.2-39.6]	-0.2	29.17 [12.3-46.6]	-12.5
ESES [0-40]	32.5 [26.3-38.8]	+1.5	30.5 [26.8-32.3]	-3.5
SPPB [0-12]	12 [0]	+0.5	11.5 [10.25-12]	+1.5*
TUG (secs)	7.15 [6.1-8.3]	-1.1	8.52 [6.4-10.6]	-1.4
5TSTS (secs)(total)	9.77 [8.4-11.1]	-2.0	8.43 [6.4-10.5]	-3.7*
5TSTS (male only)	10.4 [10-10.8]	-3.6*	8.8 [7.2-9.1]	-2.5*
5TSTS (female only)	8.7 [8.6-8.9]	-1.2	7.8 [7.4-8.1]	-5.5
6MWT (metres)(total)	399 [361.5-436.5]	+43*	393.5 [314.3-472.8]	+56*
6MWT (male only)	374.5 [342.8-399]	+47*	356 [329-401.8]	+51*
6MWT (female only)	439.5 [419.8-459.3]	+24.5	414.5 [412.3-416.8]	+22
Walking Activity (steps/day)	11074 [5559.2-16588.8]	+1697*	8691 [7157.2-10224.8]	+97
Gait Speed (m/s)	1.28 [1.0-1.6]	+0.22*	1.26 [1.0-1.6]	+0.2
Grip Strength (kg)(total)	R 23.8 [14.9-32.7] L 23.3 [9.4-37.2]	+0.1 +2.6	R 26.7 [17.0-36.4] L 25.7 [20.0-31.3]	+0.1 -0.1
Grip Strength (male only)	R 27.8 [25.1-30.3] L 28.5 [24-30.3]	+1.6 +6.5	R 29.2 [25.2-38.2] L 27.1 [25.5-29.4]	-1.1 -1.3
Grip Strength (female only)	R 16.5 [15.3-17.8] L 16.3 [14.9-17.8]	-2.7 -2.4	R 25.3 [23.9-26.7] L 21.8 [21.2-22.3]	+2.8 +0.2

PDQ-39 SI = *Parkinson's disease Questionnaire-39 Summary Index (0-19.5, higher indicates worse)*[41] **Mob** = *Mobility*, **ADLs**= *Activity Daily Living*, **Emot Well** = *Emotional Wellbeing*, **Stig** = *Stigma*, **SS** = *Social Support*, **Cog** = *Cognition*, **Comm** = *Communication*, **Bod Dis** = *Bodily Discomfort*, **ESES** = *Exercise Self-Efficacy Scale (10- 40, higher indicates better)*[40], **SPPB** = *Short Physical Performance Battery (0-12, higher indicates better*, **MCID**=*1)*[31], **TUG** = *Timed Up and Go (<10 seconds indicates normal mobility; 11.5 seconds indicates a falls risk in Parkinson's disease, MDC 3.5)*[45], **5TSTS** = *Five time sit to stand (normative values 60-69 yrs: 11.4 seconds; 70-79 yrs: 12.6 seconds; 80-89 yrs: 14.7 seconds, > 16 sec indicates falls risk in Parkinson's disease, MCID 2.4 secs)*[39] **6MWT** = *6-minute walk test (metres) (MCID 30.5m)*[38]. **IQR** = *Interquartile range*, **m** = *metres*, **m/s** = *metres per second*, **secs** = *seconds* **kg** = *kilogram*, **R** = *right*, **L** = *left*, **Cohens' d** = *Effect size (small (d = 0.2), medium (d = 0.5), and large (d = 0.8)) * = outcomes reaching minimally clinically importance difference scores.*

Table 4. Overview of assessments.

it being viewed as a "*chore*" by two participants, it was valued, and they suggested changes in wording, removal of unimportant headings, and the use of more tick boxes.

All participants reported the *WhatsApp group* as the least important and used it to enquire rather than for peer support. Barriers included difficult with texting, "*not good with technology*". All the participants preferred the peer support in class; reporting the break time between sets helped build a rapport. "*You know, I think among the three of us, there was a good relationship, and I just feel we didn't need the WhatsApp you know*".

One participant reported education as most important

because "*it provided understanding why…and provided context and meaning*". However, two keen exercisers, reported "*no real benefit*"; "*I suppose we all had a fair idea…before we started*".

Only two participants reported goal setting as the most important behaviour change technique, they "*liked the accountability of having the goals reviewed*" and enjoyed "*learning the skills to adapt and modify goals*". However, difficulties remembering their goals existed also.

Four of the six interviewees showed good *self-management skills* by completing their exercise logs independently from Week 4 onwards, with many documenting sets and reps at home. Five interviewees found the Rate of Perceived Exertion scale very helpful to determine the exercise intensity and planned to continue its use. Three participants enjoyed taking responsibility in leading the classes as the programme progressed "*it brought a fun competitive atmosphere*" and "*ownership of a particular exercise*". "*Testing your cognitive function as well as your physical fitness…I really enjoyed that*".

Safety and Adverse Events

No serious adverse events (e.g., falls, injuries) occurred within the classes. Two (both in PEEP+BC group) reported delayed shoulder and arm muscle soreness, which fully resolved. Beyond the classes, muscle soreness (unattributed to the programme) (n=1; PEEP+BC), non-injurious fall (n=1; PEEP), and a fall with a long lie resulting in hospital admission (n=1; PEEP+BC) were reported.

Trends in the outcomes (Table 4)

The *SAM, 6MWT, TUG* and *5TSTS* tests detected within-group improvements. The PEEP+BC *SAM* showed increased walking activity (+1697 steps), reaching the minimal clinical importance difference (MCID) of 800 steps/day[49]. Furthermore, the group walked notably faster (+0.22 m/s), reaching the MCID for a large improvement of 0.22m/s[50]. No notable changes were detected in PEEP group SAM data (+97 steps/day).

As noted above, a non-injurious fall (n=1; PEEP), and a fall with a long lie resulting in hospital admission (n=1; PEEP+BC) were reported.

The *6MWT* detected improved walking endurance in both groups (PEEP +56m; PEEP+BC+43m), both exceeding the MCID of 30.5m[51]. *TUG* improvements did not reach the MDC of 3.5 secs (PEEP -1.06 secs; PEEP+BC -1.05 secs)[52]. The *5TSTS* improved in both groups, (PEEP -3.7 secs; PEEP+BC -2 secs); with only the PEEP group reached the MCID of 2.4 secs[53]. Similarly, the SPPB showed clinically meaningful (MCID of 1)[54] improvements in the PEEP group only (PEEP +1.5; PEEP+BC +0.5).

The *PDQ-39 SI* scores, near minimal scores at baseline, showed small changes in both groups. Similarly, the *ESES*, near maximum score at baseline, detected only small changes, with slight improvements in the PEEP+BC group (+1.67), and declines in the PEEP group (-0.875). These extreme scores in the *PDQ-39 SI* and *ESES* at baseline may have limited their scope to detect improvements. Issues in scheduling, transport and illness led to APDM Mobility Lab system™ data being collected on three participants only (n =2 in PEEP+BC group; n = 1 in PEEP group). Therefore, this limited data was not used in the analysis. The simple timed results are presented in Table 4 with the ADPM data presented in *Supplementary Table 1*.

Discussion

This study aimed to examine the feasibility and acceptability of adding BC techniques to an existing exercise and education programme. Recruitment was feasible, at 62% (16/26), the time and staff resources are acceptable and similar to routine care. The overall programme is acceptable and safe, with good adherence and no clear concerns about adverse events. Qualitative data showed that it was acceptable with positive feedback and good suggestions from participants. Outcome measures are feasible, and the most sensitive measures has been identified.

Recruitment

Recruitment rates were good (62%, 16/26). However, at baseline participants reported good exercise self-efficacy and low impact of Parkinson's disease on their QoL, and a low score in the UPDRS Motor Exam. These factors may have hindered the ability to detect improvements in QoL and self-efficacy. Therefore, future studies should widen the sample of participants, by recruiting through Parkinson's disease support-groups (and the health services) and recruit people with poorer physical function. We will consider involving family members/carers, to allow familiarity with the exercises and to encourage family support when exercising at home.

Behaviour change techniques

The *activity diary* was viewed as cumbersome by two participants but as the most important BC technique by three of the six participants. Helpful suggestions included providing tick box exercise options; and embedding the goals into the activity diary to help self-monitoring of progress.

The exit-interviews gave useful insights into the individual's motivation to exercise. One woman explained how the weekly diary review encouraged exercise (extrinsic motivator) while others (both men and women) found it stimulated routine, accountability and the "*feel good factor*" (intrinsic motivator). Good self-efficacy at baseline may have hindered detection, but the BC techniques appeared to influence self-efficacy. While most of the control group reported lower self-efficacy (5/8), most in the intervention group reported higher self-efficacy (4/6) (they displayed extrinsic motivation in the interviews). Haughton McNeil

et al.[55] highlighted a positive association between intrinsic motivation and self-efficacy, suggesting that enhancing exercise self-efficacy and identifying motivation type is important when considering BC techniques.

Social engagement during the in-person group sessions helped all participants to push themselves and it made the sessions enjoyable. The WhatsApp group seemed superfluous.

Goal setting was deemed important by two participants; reporting it promoted exercise adherence. Research has highlighted a strong association between goal setting, physical activity, and self-efficacy[56,57]. Hence it will be reviewed to make it meaningful and continued as good practice.

Participants who were keen exercisers did not value the *exercise specific education* as much as others. Self-selecting and recording exercise intensity/progression at home was mixed, suggesting lack of confidence, or lack of interest. More support to participants to independently record sets and repetitions will be developed for future studies. Five participants highly valued the Rate of Perceived Exertion[58] (RPE) to monitor their exercise intensity. Collado-Mateo et al.[59] found improved knowledge and skills about exercise improves self-efficacy[60,61], which can lead to better adherence[62,63]. Therefore, the education should be tailored to the patient's baseline knowledge, and tools such as the RPE can be valuable.

Our *outcome measures* included SAM (walking activity), ESES (exercise self-efficacy), SPPB (gait, balance and strength), 6MWT (aerobic endurance), and PDQ-39 (QoL). The PEEP+BC group showed small improvements in walking activity, aerobic endurance, and gait speed, all exceeding the minimum clinically important difference (MCID) thresholds. Similarly, the PEEP group achieved small improvements, exceeding the MCID scores in aerobic endurance, strength, and balance. However, both the ESES and PDQ-39 SI showed floor/ceiling effects, as the participants had low disability. Generic measures may detect improvements better, such as the exercise self-regulation questionnaire which can also indicate motivation type and the EQ5D to measure health status. The APDM would not be used in future studies, and is more suited to monitor disease progress, as recommended[42]. Given the limited sample size and exploratory nature of the study, these findings are promising but need to be further tested in a larger pilot study.

Comparison to previous literature

As previously mentioned, The ParkFit trial is the only large, multi-centered randomised controlled trial of behaviour change interventions for PwPD[25]. Our findings contrast with the ParkFit trial, which reported no significant improvement in total physical activity levels despite a multifaceted, long-term behavioural intervention. Several key differences may help contextualize our preliminary findings. First, our intervention was embedded within a structured 12-week programme that fostered strong group cohesion – a factor that four participants identified as a key motivator for sustained engagement. Second, our use of targeted, evidence-informed BC techniques allowed us to tailor the intervention more closely to known psychological barriers such as apathy and self-efficacy. While ParkFit utilized a range of BC techniques, it did not explicitly examine self-efficacy — a construct repeatedly identified as one of the strongest predictors of physical activity participation, maintenance, and functional independence in PD and other chronic conditions[64,65]. In contrast, our intervention focused strategies to directly enhance self-efficacy, such as goal setting, feedback on performance, and graded task progression, enabling a more individualized approach compared to the broader strategy used in ParkFit.

Our individualized approach represents a novel and pragmatic method that enhances the relevance and feasibility of real-world implementation. This person-centered strategy aims to improve engagement and adherence more than a one-size-fits-all intervention. If confirmed in larger cohorts, this approach has the potential to offer an impactful and scalable model for clinical practice in supporting sustained physical activity among PwPD.

Additionally, our focus on early-stage, low-disability participants allowed us to detect subtle changes in mobility and behaviour, although ceiling effects in our self-efficacy and QoL measures may have masked potential benefits. Overall, these differences in intervention length, delivery format, theoretical grounding and population may help explain the observed trends and support the need for further evaluation in a larger, powered trial. Nonetheless, due to the small sample size and exploratory design, the results should be viewed as preliminary, interpreted with appropriate caution, and not considered definitive evidence of efficacy.

Strengths and limitations

This study aimed to test the feasibility and acceptance of the programme with BC techniques. Outcome assessments were not blinded. Although efforts were made to limit contamination, we cannot guarantee it did not occur; we would consider cluster randomization or separate educational sessions for both groups in future studies. Participant numbers were low, the small sample size of both groups limits the transferability of this study. However, the interviews with the PEEP+BC group gave good insight into their experience of the programme, with a direct comparison of the different behaviour change techniques. The effect of external factors, such as unrelated health issues, and emotional or social supports should also be monitored more closely.

The 6MWT was conducted over 10m because a 30m walkway was not available. However, Beekman et al.[66] found that people with COPD walked 42.5m less when the

test was completed over 10m compared to 30m[66]. This may have impacted our findings, PwPD can experience issues with freezing of gait and difficulty with turning. Therefore, for future studies we will conduct the 6MWT using the recommended 30m walkway.

Future directions

The next step is a larger feasibility study with a larger (e.g., n=60, thirty in each arm, as recommended[67]), more diverse sample (in terms of activity levels). We aim to review and test more behavioural change techniques aligned to exercise knowledge, preferences and motivations. A longer follow-up period will allow for power calculations. We will aim to recruit a sex balanced sample to further explore the relationship with sex differences and exercise preferences. The activity diary will be altered in line with the participants' feedback, embedding goals within the diary, refining the headings to streamline its completion, providing videos of the exercises and demonstrating to the family members to ensure correct technique is completed at home. The WhatsApp group will be discontinued. The APDM would not be used as it did not provide any further data, and generic measures such as the EQ5D and the exercise self-regulation questionnaire will replace the PDQ-39 and ESES to overcome their ceiling effect.

Conclusion

Falls and frailty are of major concern in PD, with an urgent need for interventions that promote long-term adherence to physical activity. Given the heightened fall risk in PD, interventions must account for motivation, self-efficacy, and perceived barriers. The amalgamation of behaviour change techniques with the PEEP programme was deemed to be feasible and acceptable among PwPD. The addition of the BC techniques showed promise of improvements in physical activity, and feedback was positive. Identifying the participants' type of motivation, and their baseline knowledge about exercise are important when considering BC preferences. The activity diary was deemed the most important activity but requires careful redrafting. The WhatsApp peer support group was considered the least helpful. The participants' suggestions will help refine the intervention, including adaptations to the activity diary, encompassing goal setting, providing videos of the exercises, involving family members more, reducing the number of education sessions, and including information about available support services. The group dynamic and knowledge acquisition were reported as key motivators, suggesting that social and educational components should be emphasized in future interventions.

Ethics approval

The study was approved by the Clinical Research Ethics Committee of the Cork Teaching Hospitals [ECM 5 (4) 06/07/2023] and conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and its later amendments.

Consent to participate

Written informed consent was obtained from all participants involved in the study before inclusion.

Consent to publish

Written informed consent has been obtained from the participants to publish this paper.

Authors' contributions

Conceptualization, L.A., S.T., S.L. and R.McC.; methodology L.A., S.T., S.L. and R.McC., formal analysis, L.A. and R. McC.; writing—original draft preparation, L.A.; writing—review and editing, R.McC. S.T. and S.L.; supervision, S.T., R.McC. and S.L.; project administration,

L.A. and R.McC. L.A and R.McC accept responsibility for the integrity of the data analysis. All authors have read and given final approval to the published version of the manuscript and agree to be accountable for all aspects of the work.

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Supplementary material 1. 7 - Day Activity Diary (Week 1-12).

SAMPLE DIARY

Day	What Activity? (group or alone)	Where?	How Long?	Difficulty Level Light/ Moderate/ Hard	How did it make you feel?	If you had trouble exercising what are the reasons? What stopped you from exercising?
Monday	Walking (with friends) Swimming (alone)	Local Park Local Pool	20 mins 45 mins	Light Moderate	Energised, by body feels less stiff, improved my mood. Felt tired, but in a good way. I did an extra length of the pool today and I feel amazing. Very tired now – but I am delighted with myself.	No trouble exercising today – felt good, felt empowered.
Tuesday	Exercises at home (alone)	Home	5 mins	Hard	Sore, tired, no energy	Feeling sore and tired today, maybe I over did it yesterday. I did not finish my exercises. I wanted to do more but my body is saying no. I am a little disappointed, but today I am going to listen to my body and rest and start again tomorrow or the next day
Wednesday						
Thursday						
Friday						
Saturday						
Sunday						

Behaviour Change Template

Name ..... **ID Code** .....

Group Chat ***(Peer support)***	Did they use the group chat? If so, did they find it helpful? What about it was helpful?
Family/friend encouragement (Social influences/recruiting supports)	Are their family/friends encouraging them to exercise? If yes, do they find it beneficial? How do the family members encourage exercise (e.g. exercising with them (as buddies) or providing prompts, nudges to exercise alone) If not, do they think it would help to exercise more (if their family/friends encouraged them). If yes, as the weeks progress are they doing more themselves (without requiring the encouragement)
Activity Diary What motivated them to exercise?	Did they struggle to exercise this week? If yes, what were the reasons? How could they overcome this?
(Barrier Identification, goal setting, self-monitoring, belief about capabilities)	Do they fill out the diary themselves or does someone help them? If no, why aren't they doing it themselves? Could they try fill it out themselves next week? Are they meeting the WHO guidelines – 150 mins per week, 2-3 strength session and 1-2 flexibility sessions? Do they have any goals they would like to set for themselves for next week? Encourage them to plan an exercise schedule.
Education ***(Enhancing knowledge)***	Discuss the importance of exercises: - Strength - Balance - Improve mental health - Sleep Slow down the progression of symptoms of Parkinson's disease Adverse Effects - Fatigue - Muscle Soreness - Exacerbation of pain
Reflect on their progress to date.	Ask them to reflect on their progress? Do they feel there is a change (improvement, dis-improvement, the same)? Explain

(Positive reinforcement, belief about capabilities, empowerment)	Has their ability to set goals changed (improvement, disimprovement, the same)? Explain Do they find they are more motivated to exercise, without others encouraging them? Explain Mention how well they are doing. - Acknowledge the participants' progress in the group classes. - Encourage peer support within and outside the classes. - Encourage participants to explore exercises that may be meaningful or of interest to them (outside the programme).

Parkinson's disease Exercise and Education Programme Feedback Survey

Thank you very much for participating in the programme. I would be grateful if you would complete this survey. Please be as open and honest as possible. Your feedback helps plan future programmes.

Please tick one of the following boxes:
I am a **Class participant** ☐ **Family member** ☐
How many classes did you attend? (Total: 24 for participant; 12 for family member)
Exercise classes ☐ **Education sessions** ☐

Do you believe you benefitted from the programme? Can you explain why?

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.....

Family members, please write N/A for the following two questions.
What did you enjoy most about the exercise classes?

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.....
.....

What did you enjoy least about the exercise classes? What would you change?

.....
.....
.....
.....

How do you feel about continuing to exercise? What plans have you?

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What did you enjoy most about the education classes?

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.....

What did you enjoy least about the education classes? What would you change?

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.....

Were all the education sessions helpful? Would you drop/change any sessions?

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.....

How can we improve this programme? Can you give suggestions?

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.....
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.....

Is there any other guest speakers/topics that you would have liked to hear from/learn about?

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.....

Thank you for your feedback. I hope you enjoyed the program.

Topic Guide: Qualitative interview to explore the patients' experience and acceptability of the Behaviour Change Techniques with Exercise

Activity Diary (TDF Domain 14: Behaviour Regulation, TDF Domain 4: Belief about capabilities)

1. What are your opinions on using the **activity diary**? [probe its impact on self-efficacy and exercise adherence]
2. Will you continue to use the activity diary, why?
3. [the research physiotherapist] tried to get you to lead the classes as the weeks progressed. How do you feel that went? [probe further about self-efficacy and self-management
4. Is there a better way of doing this/ delivering this?
5. Or a better way of getting you confident about exercising with less guidance?
6. When we are running the programme again, do you think this element should be included or changed?

Peer Support (TDF Domain 12: Social Influences)

1. What are your opinions about the group dynamics within the class?
2. What are your opinions/experience on using the WhatsApp group? [probe its impact on self- efficacy and exercise adherence]
3. Will you continue to use the WhatsApp group, why?
4. Is there a better way to deliver this?
5. When we are to run the programme again do you think this element should be included?

Education (TDF Domain 1: Knowledge, Domain 6: Belief about consequences)

1. What are your thoughts on the education/advice give about the benefits of exercise, pacing, muscle soreness, fatigue, and exercise intensity level? [probe its impact on self-efficacy and exercise adherence]
2. Is there a better way to deliver this?
3. When we are to run the programme again do you think this element should be included or changed?

Goal Setting (TDF Domain 9: Goals, Domain 11: Environmental context and Resources)

1. Do you think your confidence to set your own goals has changed with the programme? completing the programme? [probe its impact on exercise adherence]
2. Will you continue to set goals, why?
3. Is there a better way to deliver this?
4. When we are to run the programme again do you think this element should be included or changed?

Acceptability and feasibility

1. Which of the four BC techniques that you like the most? [Probe the reasons behind their choice, and how it made a difference].
2. Which of the four BC techniques that you like the least? [probe the reasons behind your choice and discuss why they felt it was of less value].
3. Would you recommend this programme to someone you else? [probe why]

Process of change

1. What did you learn from this programme? [probe its impact on self-efficacy and exercise adherence, overall impact on wellbeing].
2. Are there any changes in your thoughts on exercise/intensity of exercise. If yes, what are they? What brought about these changes.
3. Have you noticed any differences in your life because of taking part in the 'Parkinson's disease Exercise and Education' programme? If 'yes', what are these differences? Probe further on why they think it worked.
4. What was the reason you continued to attend the classes/sessions each week?

Barriers

1. What were the difficulties in taking part? [Probe solutions.]

Implementing change

1. Do you think you will continue to use what you have learned going forward (goal setting, barrier identification, RPE scale, exercises log (reps and sets).
2. What would help you to keep exercising now, as the programme is now finished. [probe the perceived need for support now].

Suggestions for further improvement

1. What do you think could be improved?
2. If [the research physiotherapist] was to start over again, what advice would you give them?
3. Is there anything else that you would like to mention that we have not discussed?

Supplementary Table 1. APDM Data: TUG and 2-minute walk test data.

		PEEP + BC				PEEP	
		ID 6		ID 8		ID 15	
		Post-intervention	Δ	Post-intervention	Δ	Post-intervention	Δ
TUG Outcomes	TUG Duration (seconds)	8.76	-2.44	12.4	-2.04	8.85	-1.5
	Sit to Stand Duration (seconds)	0.87	-0.54	1.05	-0.29	1.12	-0.01
	Stand to Sit duration (seconds)	0.94	-0.2	0.9	-0.25	0.97	-0.09
	Turn velocity (degree/seconds)	175.3	15.4	107.1	-10.1	160.6	13.35
	Turn duration (seconds)	2.13	-0.27	3.53	0.76	2.45	-0.81
2MWT Outcomes	Cadence (steps/minute)	120.8	6.9	109	2.7	101.8	1.2
	Gait speed (metre/second)	1.1	0.1	1.1	0.2	1	-0.04
	Stride Length (metre)	1.1	0.1	1.2	0.2	1.2	-0.1
	Step duration (seconds)	0.52	-0.04	0.55	-0.01	0.6	-0.01
	Turn velocity (degree/second)	170.5	41.3	94	8.8	116.6	1.2
	Turn Duration (seconds)	2.3	-0.6	3.6	-0.1	3	-0.4