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# A Mixed Methods Feasibility Study of Machine-Based Resistance Training With Prefrail Older Adults in Residential Care: The Keeping Active in Residential Elderly Trial II

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Physical activity is an effective, proactive intervention to reduce or reverse frailty and functional decline. However, uncertainty exists about the feasibility and impact of resistance training on multidimensional health in prefrail older adults in residential care. This mixed methods feasibility study assessed practicability with limited efficacy testing on health and functional outcomes. Eleven prefrail older adults participated in a 6-week progressive resistance training protocol three times per week. The intervention and measures were found to be appropriate and acceptable by those who completed the trial, with participants self-reporting improved well-being, mood, and function. Analysis identified several barriers to recruitment, including prior commitments, seasonal impact, and session timing, and offered potential solutions with further recommendations for program refinement prior to a definitive randomized controlled trial. These findings add to our understanding of prefrail older adults' preferences regarding participation in physical activity research and the perceived benefits of resistance training. This trial was registered with ClinicalTrials.gov: NCT03141879.

***Keywords:*** prefrailty, physical function, multidimensional health, resistance exercise, assisted living

**Key Points**

- Maintaining strength is important for all age groups, and we wanted to find out whether resistance training would be acceptable and suitable for prefrail older adults living in residential care.
- We found that a machine-based resistance training trial was possible and appropriate, as were all the measures of multidimensional health that were included.
- Participants reported improvements in their well-being, mood, and function, but we also found important barriers to recruitment and adherence and recommend potential solutions for future studies with older adults.

Frailty is an age-associated multidimensional clinical syndrome characterized by diminished resistance to stressors and decreased reserve, energy, and well-being (Fried et al., 2001; Lyndon, 2015; Rodriguez-Manas et al., 2013). It is typified by weakness and reduced physical resilience and functional capacity (Fried et al., 2021; Morley et al., 2013) and associated with adverse outcomes including disability, falls, hospitalization, and death (Clegg et al., 2013; Vermeiren et al., 2016; Xue, 2011). Even with no consensus definition of frailty (Rockwood & Howlett, 2018; Theou et al., 2015), there is growing acknowledgment that a rising proportion of the world's aging population is affected by this declining later life state (Cesari et al., 2016; Collard et al., 2012; Ofori-Asenso et al., 2019). However, the true scale of the problem is difficult to determine due to differences across measuring tools, countries, and settings (Collard et al., 2012; Gale et al., 2015). Accordingly, studies using physical frailty measures in community-dwelling older adults report European and global prevalence rates of 7.7% (Manfredi et al., 2019) and 12% (O'Caoimh et al., 2021), respectively, whereas pooled estimates of prevalence of frailty in nursing homes were reported as 52.3% (Kojima, 2015). With prevailing research suggesting that increases in lifespan are outpacing healthspan (healthy disease-free years; Partridge et al., 2018; Whittaker et al., 2019), the potential burden of increased levels of frailty on the provision of health and social care, and the associated economic costs, are substantial (Cesari et al., 2016; Pinedo-Villanueva et al., 2019).

However, frailty is not a necessary outcome of aging, and preventative, proactive, and effective management at all points of the frailty continuum has the potential to delay or reverse functional decline (Dent et al., 2019; Morley et al., 2013; Woolford et al., 2020). Identification of frailty status has, thus, become of increasing importance (Alvarez-Bustos et al., 2022; Galluzzo et al., 2018). Fried et al.'s (2001) phenotypical model of frailty is an established



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approach that uses diagnostic criteria to differentiate between earlier or intermediate states (prefrailty) and later stages (frailty) of multisystem dysregulation and decline. The five criteria are weakness (grip strength), slowness, low physical activity, exhaustion (or fatigue), and unintentional weight loss (0, *robust*; 1–2, *prefrail*; ≥3, *frail*; Fried et al., 2021). As a result, prefrailty is now recognized as a multifactorial, dynamic condition increasing vulnerability to, and directly preceding, frailty with increased risk of poor clinical outcomes, such as disability and increased risk of mortality (Sacha et al., 2017; Sezgin et al., 2020).

The prevalence of prefrailty in community-dwelling older adults is higher than that reported for frailty: Rasiah et al. (2020) cited figures between 35% and 60% in large cohort studies using physical frailty measures. An overall population-level estimate of 46% was reported by O'Caoimh et al. (2021), with other global and European studies reporting a weighted average prevalence of 44.2% and an overall prevalence of 42.9%, respectively (Collard et al., 2012; Manfredi et al., 2019). As such, the proportion of older adults living with prefrailty is considerable and important particularly given that a significant proportion of those are at high risk of progression to a future frail state (Fernandez-Garrido et al., 2014; Harrison et al., 2015; Xue, 2011). It is with this in mind that there is increasing interest in multidimensional predictors of physical frailty (Ding et al., 2017), the effectiveness of interventions for prefrail older adults (Apostolo et al., 2018; Rasiah et al., 2020), and their influence on possible trajectories of frailty (Ding et al., 2017; Woolford et al., 2020).

Current evidence suggests that there are several potentially viable interventions to address frailty progression, including physical activity and exercise, nutritional strategies, social support, cognitive training, and multicomponent interventions (Apostolo et al., 2018; Jadczak et al., 2018; Theou et al., 2011; Woolford et al., 2020). There is also growing support for proactive, preventative management (Harrison et al., 2015; Xue, 2011). Although there is still some uncertainty around the optimal approach, it is becoming clear that physical activity may have an important role to play. Recent findings based on the Ageing Trajectories of Health: Longitudinal Opportunities and Synergies project, which harmonized data across 17 international aging studies, suggest that abstinence from any type of physical activity was associated with poor healthy aging trajectories through low baseline scores and fast decline rates (Moreno-Agostino et al., 2020). Healthy aging is defined in line with the World Health Organization as "the process of developing and maintaining the functional ability that enables well-being in older age" (World Health Organization, 2020). Correspondingly, physical activity interventions have been consistently shown to support healthy aging and preserve physical function, with the beneficial effects being well documented and compelling (Bangsbo et al., 2019; Izquierdo et al., 2021; Moreno-Agostino et al., 2020). This is clearly observed by the positive impact of physical activity on muscle and bone strength, balance, and its role in maintaining and promoting functional capacity and quality of life and reducing the risk of falls, fractures, and frailty (Marzetti et al., 2017; Skelton & Mavroeidi, 2018a; Witard et al., 2016).

Physical activity interventions for older adults with prefrailty have typically focused on multicomponent trials, with the inclusion of strength and balance, mobility, and functional movement exercise (Frost et al., 2017; Jadczak et al., 2018). Recent research with community-dwelling older adults in England, including those identified as prefrail, reported significant improvements in lower limb function following a low-cost multimodal exercise and behavioral maintenance intervention designed to improve lower limb muscle strength and balance (Stathi, Greaves, et al., 2022). Other modalities have also included Tai Chi (Ge et al., 2021), seated chair exercise (Furtado et al., 2021), myofascial release (Barrachina-Igual et al., 2021), or functional walking (Faber et al., 2006) or aimed to combine strengthening exercise with components such as diet and education in specific disease groups, such as diabetes (Rodriguez-Manas et al., 2014). However, there is an emerging body of research recognizing resistance exercise training as a primary countermeasure to physical frailty (Fragala et al., 2019; McLeod et al., 2019). Resistance exercise is a specialized form of physical activity that uses a range of resistive loads to enhance health, fitness, and performance (Lloyd & Faigenbaum, 2015). It has been repeatedly shown to improve muscle strength and function, support well-being and quality of life, and counter age-related changes and dysregulation across physiological, neurological, and metabolic systems (Coelho-Junior et al., 2022; Fragala et al., 2019; Maestroni et al., 2020; McLeod et al., 2019; Skelton & Mavroeidi, 2018b). In addition, a growing body of research is recognizing the potential for resistance exercise to reverse the loss of functional capacity and change the trajectory of frailty (Bray et al., 2016; Coelho-Junior et al., 2021; Lopez et al., 2018; Talar et al., 2021). An early, proactive approach is of relevance to prefrail older adults as research suggests that they may respond better than those who have already moved to a frail state (Faber et al., 2006; Kidd et al., 2019; Vermeiren et al., 2016).

Research to date using resistance exercise as the primary focus with community-dwelling prefrail older adults has included a range of methods, such as bodyweight and functional movements (Tou et al., 2021), resistance bands (Tan et al., 2018), weight vests and ankle weights (Coelho-Junior & Uchida, 2021; Lai et al., 2021), free weights (Bray et al., 2020), and resistance machines (Drey et al., 2012; Lee et al., 2021). In contrast, there are few published data on those living in assisted living/residential care facilities (de Souto Barreto et al., 2016; Valenzuela, 2012) despite an acknowledgment that findings cannot be generalized across settings (Arrieta et al., 2019; Lee et al., 2021).

Physical activity research interventions present unique challenges, including recruitment, retention, and adherence (El-Kotob & Giangregorio, 2018), and factors influencing older adults' participation are complex. A recent review paper by Forsat et al. (2020), for example, found that the literature on older adults' willingness to engage with research trials was somewhat contradictory: Some studies identified a declining inclination to participate with age, whereas other studies found higher levels of curiosity and interest in research. Frequently reported barriers influencing recruitment and retention include study eligibility criteria with rigid exclusion conditions and declining participation based on advice from relatives or physician (Forsat et al., 2020). A recent randomized controlled trial (RCT) with community-dwelling older adults, including those with prefrailty, also reported physical health barriers that included mobility issues, pain, discomfort, and tiredness (Stathi, Withall, et al., 2022). There are additional challenges to resistance training interventions in residential care facilities. A pilot study by Fien et al. (2016) examining the feasibility and benefits of group resistance training in residential care facilities using bodyweight and dumbbells noted that some residents declined to participate due to fear of never having done resistance training and not wanting to try. There is limited work addressing recruitment challenges specific to resistance training in residential care homes and an acknowledged need to examine these (Fien et al., 2019). Pilot and feasibility trials may help

investigators better understand issues unique to older adults' participation in exercise, physical activity, and rehabilitation interventions, including barriers to recruitment and retention (El-Kotob & Giangregorio, 2018), and inform future recruitment methods and study design.

In addition to the physical benefits noted earlier, group-based resistance training interventions within assisted living/residential care homes potentially offer opportunities to improve social connectedness, well-being, peer support, and adherence (Dionigi & Cannon, 2009; Finnegan et al., 2015). With recent research highlighting the negative impact of loneliness, isolation, and poor social support on the trajectory of frailty (Davies et al., 2021; Ding et al., 2017), regular group interaction among those living in the same setting may offer a proactive mitigation. Research to date has not clearly established the impact of group resistance exercise on multidimensional health, well-being, and physical function in prefrail older adults in assisted living/residential care. With prefrailty increasingly acknowledged as a potentially reversible, multifactorial, and transitional risk state, research to evaluate the feasibility and impact of this is imperative.

## Aims and Objectives

Consequently, the primary aim of this feasibility study was to assess the feasibility of a definitive RCT using a resistance training intervention with prefrail older adults in an assisted living/residential care setting. The secondary aim was to perform limited efficacy testing on measures of multidimensional health, including physiological, psychological, cognitive, and emotional health measures and functional capacity from pre- to postintervention compared with a wait-list control group. These measures were proposed as the primary dependent variables in a future definitive RCT.

The specific objectives were to: (a) evaluate the experiences of the participants and care home staff (acceptability); (b) determine levels of interest and adherence to the training intervention (demand); (c) evaluate the requirement for organizational change, including perceived cultural fit (integration and adaptation); (d) determine the practicality of the intervention with this population group (practicality); (e) evaluate the suitability and relevance of the selected multidimensional health measures (implementation and expansion); and (f) examine changes in multidimensional health measures using mean differences, effect size, and meaningful change pre- to postintervention compared with the wait-list control (limited efficacy testing). Bowen et al.'s (2009) feasibility framework was used to guide the research design structure, aims, and objectives. Due to the feasibility design, there were no directional hypotheses. This research has been reported in line with Consolidated Standards of Reporting Trials (CONSORT) 2010 guidelines for reporting randomized pilot and feasibility trials (Eldridge et al., 2016), Consensus on Exercise Reporting Template (Slade et al., 2016), and Standard Protocol Items: Recommendations for Interventional Trials Schematic Participant Timeline (Chan et al., 2013). The CONSORT 2010 checklist is included as Supplementary Material S1 (available online).

# Methods

## Participants

The trial site was a residential care home in Birmingham, United Kingdom, which agreed to participate having been involved in previous studies that were aimed at improving health and aging. The residential care home was a unique facility including residential, nursing, and dementia care in one setting, allowing older adults with varying care needs to live together in a supportive community. Participants were recruited by well-being or care staff or by direct volunteering to a member of the research team following an onsite introductory talk by the researcher (July 2019). Eligibility criteria required participants to be: (a) resident in the care home, (b) age ≥65 years, (c) identified as prefrail by scoring one or two on the Fried Frailty Phenotype criteria (adapted from Fried et al. (2001), (d) without severe sensory impairments that would profoundly impact upon their ability to participate, (e) able to speak and read English, (f) currently not taking part in any other clinical trial that could potentially affect the results of this study, and (g) with a predicted life expectancy greater than the length of the trial.

## Recruitment

Potential participants were offered a summary document about the study (a two-page leaflet based on the participant information sheet). This leaflet summarized the purpose and procedures, the benefits and risks of participation, research team contact details, and confidentiality and data protection. Use of a summary document has been previously described in Swales et al. (2021) and was designed to improve accessibility for all potential participants, including those with any cognitive or sight impairment. All potential participants who expressed further interest in the study were given the full participant information sheet and had 10 days to consider whether they wished to take part and to discuss any further queries with a member of the research team. Interested potential participants received an informed consent form. The trial design was inclusive of those who may have lacked capacity to provide informed consent, and documentation was in place for personal or nominated consultees, if required.

All participants had capacity, that is, they did not have a dementia diagnosis and were deemed capable of consent by their care staff, and provided written informed consent before the trial commencement and verbal consent before interviews. They were free to withdraw from the study at any time.

## Sample Size

As this was a mixed methods feasibility trial, a formal sample size calculation was not performed. However, sample size was guided by current recommendations for qualitative and quantitative feasibility studies, which suggest that even small samples of five to 20 individuals may be informative for decisions relating to acceptability and practicality (Hertzog, 2008; O'Cathain et al., 2015) and that it depends on circumstances (Shanyinde et al., 2011). Following the initial level of interest in the trial, and collaboration with the care staff, the researcher aimed for a sample size of 20 participants.

## Trial Design

Ethical approval for this study was provided by London Harrow Research Ethics Committee. REC: 17/LO/1316. Protocol: RG_17-108 IRAS: 219616. The full study protocol has been published elsewhere (Doody et al., 2019); the trial was registered with ClinicalTrials.gov: NCT03141879 on May 5, 2017. Important changes to health and functional outcome assessments, equipment and delivery, and exercise prescription made after the protocol was published are detailed in Swales et al. (2021). Important changes to trial design are detailed later.

The mixed methods feasibility study was conducted between July and December 2019. The participant timeline is shown in Table 1 and represents the overall study duration. All study participants completed eligibility screening (Week 2) and baseline assessments (Weeks 1 and 0) prior to group allocation. The intervention group only participated in scheduled instructor-led group-based resistance training sessions during Weeks 1–6. The wait-list group did not have access to the equipment during this time. Postintervention testing was completed by both groups in Weeks 7–8. The wait-list control group only participated in their scheduled group-based training sessions during Weeks 9–14. Follow-up testing was arranged for Weeks 13–14 and Weeks 15–16 for the intervention and wait-list control groups, respectively. This approach ensured that follow-up testing was carried out 6 weeks after completion of the group exercise sessions. During their designated training weeks, all study participants followed the same program, as detailed in Table 2 "Program Prescription." Participants were advised to avoid any strenuous physical activity for at least 24 hr prior to assessment of strength or functional capacity or blood sampling. Due to the comprehensive test measures, and to minimize participant fatigue, assessments were scheduled over several days/visits (Table 1).

## Randomization

Randomization and allocation were conducted by the principal investigator independent of the identification, consent, screening, and baseline assessments. The researcher enrolled participants, conducted eligibility screening and baseline testing, and informed participants of their group allocation. Permuted block randomization (1:1) was used to randomize participants to either the intervention or the wait-list control group. Randomization was conducted using a computer-generated random number generator (www.randomizer.org). Group allocation was not revealed until after consent, eligibility screening, and baseline assessments had been completed to ensure allocation concealment and minimize selection bias. Further blinding was not possible due to the researcher's dual role (intervention delivery and assessments). The trial participants and care home staff were also aware of group allocation. All postintervention and follow-up tests were completed unblinded by the researcher. Minimization of conscious bias was upheld by exact adherence to standardized assessment measures, timing of tests, and consistency of encouragement across all tests.

## Important Changes to Trial Design After the Protocol Was Published

Eligibility criteria in the published protocol (Doody et al., 2019) stated a requirement for participants to be frail according to the Fried Frailty Phenotype criteria (Fried et al., 2001), having at least three of the five key clinical signs. For this study, eligibility was amended (and given Research Ethics Committee approval of the amendment) to comprise participants classified as prefrail, having one or two of the criteria only (Fried et al., 2001). In addition, the published protocol outlined assignment of individual participants to either the intervention or the control group. However, in response to participant feedback and discussions with care home staff about adaptability and long-term sustainability, this process was modified. Individual participants were assigned as per protocol, and any eligible married couples, who requested to do so, were randomly allocated as a pair and completed the study together. A wait-list control design was used to ensure that all participants could have access to the potential benefits of the intervention and to counter the possible negative psychological impact of expressing interest in a healthy aging initiative and then being randomized to no treatment. As described in Swales et al. (2021), this was a revision from the published protocol and supported by the care home management in terms of inclusivity and sustainability.

## Measures

The primary aim of this study was to evaluate the feasibility of conducting a definitive RCT. The feasibility outcome measures address all principal focus areas for feasibility studies (Bowen et al., 2009).

### *Primary Feasibility Outcomes*

**Qualitative Methods.** Feasibility outcomes related to acceptability, demand, implementation, practicality, integration, adaptation, and expansion were assessed using semistructured interviews and focus groups. The researcher conducted all the participant interviews in a quiet recess of the communal lounge outside of scheduled activities and all staff focus groups and interviews in private staff offices. The researcher had previous interviewing experience and had established professional relationships with the participants and staff during the study. Audio was digitally recorded using an IBM ThinkPad X1 Laptop (Lenovo), Voice Recorder App (Microsoft 2018), and iGOKU USB Microphone (iGOKU). The researcher also kept a reflective diary and written field notes. Full details of the data collection are provided in the published protocol (Doody et al., 2019).

**Quantitative Methods.** Feasibility outcomes related to acceptability and demand included study uptake, retention, attendance, and adherence. Uptake and retention were recorded by the researcher. Measures of attendance and adherence were monitored and recorded by the researcher and tracked by the software log-in data linked to the HUR (HUR Ltd.) exercise equipment. Attendance was reported as a percentage of exercise sessions attended. The adherence to exercise prescription was reported as the percentage of total repetitions completed at the prescribed load. The HUR SmartTouch (HUR Ltd.) software automatically recorded all exercise data (including attendance, exercises performed, sets, repetitions, and load). Any technical issues that compromised accurate electronic record keeping, including issues with Wi-Fi connectivity, log-in, or card recognition, were documented to ensure data integrity.

### *Secondary Outcome Measures*

Multidimensional health and functional measures are summarized in Table 1, and a detailed description is in the published protocol (Doody et al., 2019). These were classified into physiological, psychological, cognitive, and emotional health measures; social support; and functional capacity. The physiological measures were cortisol and dehydroepiandrosterone sulfate from blood serum. Psychological and emotional measures consisted of the Geriatric Depression Scale (Yesavage et al., 1983), the Hospital Anxiety Depression Scale (Zigmond & Snaith, 1983), and the Perceived Stress Scale (Cohen et al., 1983). The Standardized Mini-Mental State Examination (Molloy et al., 1991) and the Interpersonal Support Evaluation List-12 (Cohen et al., 1985) were utilized for measuring cognitive assessment and social support, respectively. Finally, functional capacity was assessed using the Activities of Daily Living scale (Katz et al., 1970), the Short Physical Performance

**Table 1 Participant Timeline (Schedule of Enrollment, Interventions, and Assessments Based on Standard Protocol Items Recommendations for Interventional Trials [2013])**

| | Study period | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Baseline | | | Postintervention | | | Intervention (wait-list control) | Follow-up (intervention group) | | | Follow-up (wait-list control) | | |
| | Enrollment | B1 | B2 | Intervention | P1 | P2 | P3 | | F1 | F2 | F3 | F1 | F2 | F3 |
| Timepoint (weeks) | –2 | –1 | 0 | 1–6 | 7 | 8 | 8 | 9–14 | 13 | 14 | 14 | 15 | 16 | 16 |
| Enrollment | | | | | | | | | | | | | | |
| Eligibility screen | x | | | | | | | | | | | | | |
| Informed consent | x | | | | | | | | | | | | | |
| Fried Frailty Phenotype | x | | | | x | | | | x | | | x | | |
| SMMSE | x | | | | x | | | | x | | | x | | |
| Allocation | | | x | | | | | | | | | | | |
| Study groups | | | | | | | | | | | | | | |
| Intervention | | | | x | | | | | | | | | | |
| Wait-list control | | | | | | | | x | | | | | | |
| Assessments | | | | | | | | | | | | | | |
| SPPB | | x | | | | x | | | | x | | | x | |
| GDS | | x | | | x | | | | x | | | x | | |
| ISEL-12 | | x | | | x | | | | x | | | x | | |
| Sociodemographics | | x | | | | | | | | | | | | |
| MNA | | x | | | | x | | | | x | | | x | |
| Leg strength/RFD | | | x | | x | | | | | x | | | x | |
| HADS | | | x | | | x | | | | x | | | x | |
| PSS | | | x | | | x | | | | x | | | x | |
| Katz ADL | | | x | | | x | | | | x | | | x | |
| Blood measures | | | x | | | | x | | | | x | | | x |
| Semistructured interviews | | | | | | | | | | | x | | | x |
| Focus groups (staff) | | | | | | | | | | | x | | | x |

*Note.* SMMSE = Standardized Mini-Mental State Examination; SPPB = Short Physical Performance Battery; GDS = Geriatric Depression Scale; ISEL = Interpersonal Support Evaluation List; MNA = Mini Nutritional Assessment; RFD = Rate of Force Development; HADS = Hospital Anxiety and Depression Scale; PSS = Perceived Stress Scale; ADL = Activities of Daily Living; B1 = Baseline 1; B2 = Baseline 2; P1 = Postintervention 1; P2 = Postintervention 2; P3 = Postintervention 3; F1 = Follow-up 1; F2 = Follow-up 2; F3 = Follow-up 3.

**Table 2 Program Prescription, Including Sets, Reps, Interset Recovery Interval, and Intensity (Load)**

| Exercise | Sets | Reps | Interset recovery(s) | Speed of movement | Load |
|---|---|---|---|---|---|
| Optimal rhomboid | 2 | 12 | 120 | Concentric: As rapidly as possible while maintaining sound technique<br>Eccentric: Controlled (1–2 s) | Progression from "light–moderate" intensity (RPE 5–6) to "moderate–hard" (RPE 7–8)<br>(Equivalent OMNI-RES 4–6 progressing to 6–8, with 2–4 RIR) |
| Hip adduction | 2 | 12 | 120 | | |
| Hip abduction | 2 | 12 | 120 | | |
| Chest press | 2 | 12 | 120 | | |
| Leg extension | 2 | 12 | 120 | | |
| Leg curl | 2 | 12 | 120 | | |
| Leg press | 2 | 12 | 120 | | |

*Note.* RPE = rating of perceived exertion; reps = repetitions; OMNI-RES = OMNI resistance exercise scale; RIR = repetitions in reserve.

Battery (Guralnik et al., 1994), and maximal isometric leg strength. Maximal isometric strength was tested using the HUR Performance Recorder 9200 (HUR Ltd.) as detailed in Swales et al. (2021). The Fried Frailty Phenotype (Fried et al., 2001) and Standardized Mini-Mental State Examination (Molloy et al., 1991) also comprised part of eligibility screening (Table 1). Each participant's data were recorded on an individual case report form.

## Resistance Training Intervention

### *Equipment*

The resistance training intervention used specialized, pneumatic, strength training equipment from the premium line of HUR SmartTouch (Fourth Generation, HUR Ltd.). The machines were specifically designed for active-aging programs and utilized touch screens, web-based software, and radio-frequency identification (RFID) user log-in systems with smart cards. The touch screens displayed participant name on log in and sign out, the prescribed program, sets, repetitions, and load.

Five independent, standalone machines were used: leg press, leg extension/curl, chest press, hip abduction/adduction, and optimal rhomboid. The leg extension/curl and hip abduction/adduction machines had dual functionality, and all machines (except for hip abduction/adduction) had unilateral and bilateral capability. The program prescription included all seven exercises. The machines were installed in the main communal room (lounge) at the care home with sufficient space between them to support usability and accessibility. All machines were used in accordance with the manufacturer's guidelines. Individual seat heights, lever arm lengths, and range of motion limiters were established, stored on personal RFID cards, and checked prior to each session by the researcher.

Participants were encouraged to perform the full range of movement (unless limited by pain or specific joint or medical problems) with correct form and technique, including body and limb positioning, breathing patterns, and speed. The researcher assisted the participants with any technology issues (including RFID card recognition or Wi-Fi connectivity) and modifications to load or lever arms and offered feedback and encouragement. Participants with hearing, sight, or movement impairments were supported with individual attention as needed. All RFID cards were stored in an index card box next to the machine compressor and only accessed by the participants or researcher.

### *Delivery*

All exercise sessions were scheduled as a group-based activity, supervised by the researcher, and the participants wore their usual day clothes. The researcher was a qualified strength and conditioning coach with previous experience of working with older adults and HUR equipment (including isometric strength testing with Performance Recorder and HUR Labs Performance Recorder software). Additional technical support was available from HUR Ltd. throughout the trial duration. The researcher and care home staff were supportive throughout the intervention, and participants were encouraged to attend all scheduled assessment and exercise sessions. This could include a verbal reminder of the day/time of the session from care staff or researcher. Although attendance was actively championed, no formal motivation strategies were used, and the participants were reassured that involvement was voluntary.

### *Exercise Prescription*

The exercise program prescription was based on published guidelines for strength training for older adults, including American College of Sports Medicine Guidelines for Exercise Testing and Prescription (American College of Sports Medicine, 2018), U.K. Chief Medical Officers Physical Activity Guidelines (Davies et al., 2019), and National Strength and Conditioning Association Resistance Training for Older Adults (Fragala et al., 2019). Special considerations included the session structure, duration, number, frequency, loading, sets, repetitions, total volume load, rest intervals, and progression.

All participants were scheduled to attend 18 sessions in total, with a minimum of a 48-hr recovery between sessions. The sessions were timetabled three times per week for 6 weeks on Monday, Wednesday, and Friday mornings (09:30–10:30). The duration of the first sessions (Week 1) was 45–50 min and allowed additional time for participants to familiarize themselves with warm-up and cooldown exercises, machines and log-in cards, and individual machine setup and to determine appropriate individual loads. After this initial phase, total session duration, including warm-up and cooldown, was 30–35 min.

The warm-up routine (5–10 min) was performed immediately prior to the resistance exercises and comprised a range of low-intensity, movement preparation exercises primarily aimed at increasing blood flow, joint fluid viscosity, and range of movement. It included shoulder circles, reaches, trunk rotations, marching on the spot, and chair sit-to-stands. The exercise sequence was not strictly standardized and could be completed either sitting or standing depending on each participant's ability. The researcher encouraged a focus on movement quality, posture, and technique. Postexercise, the participants performed approximately 5 min of light stretching and mobility work to ensure a gradual reduction in intensity and effort. The warm-up and cooldown sections were often periods of feedback, social interaction, and engagement

between the researcher, the participants, and other care home residents. The researcher supervised all exercise sessions to ensure high levels of consistency for delivery, coaching, and encouragement.

The intervention was delivered as planned, and the program prescription is detailed in Table 2. Although the exercise selection was standardized, practical issues of time to transfer between machines, use by another participant, or individual preference required some flexibility in the order of completion. Any confirmed preferences or sequencing were recorded.

All the participants were beginners with no previous experience of resistance training. To ensure an appropriate primary focus on skill acquisition and movement competency, the initial loads (Week 1) were conservative (Conlon et al., 2018). Subsequent training loads were guided by the participants' subjective feedback using the OMNI resistance exercise scale (Gearhart et al., 2009) and "repetitions in reserve" (Helms et al., 2016). Load progression, although not a condition of the feasibility study, was acknowledged as a key principle of resistance training and a programmable feature of the equipment: Microadjustments (100 g and 1 kg) allowed an automatic intersession increase of 5% for upper limb and 10% for lower limb when >14 technically sound repetitions were completed (Sheppard & Triplett, 2016). The loads were also manually adjustable by the participant or researcher intrasession, if required, and immediate confirmation of volume load (Sets × Repetitions × Load) achieved was given on the SmartTouch screen. The participants were encouraged to achieve their goals and progressively increase load, but the focus was on consistency, movement proficiency, and enjoyment. For the duration of the intervention, all participants were asked to follow the resistance training program as specified and not make any other major physical activity changes. There were no nonexercise components in the study, that is, lifestyle coaching or health education.

## Data Analysis

### *Primary Feasibility Outcomes*

**Qualitative Methods.** All qualitative interview data were manually transcribed verbatim by the researcher into Microsoft Word and uploaded into NVivo (version 12, QSR International Pty Ltd.) for analysis. Supporting data, including the researcher's reflective journal and additional field notes, were also uploaded. Thematic analysis (Braun & Clarke, 2006) was used to identify, interpret, and communicate themes in the qualitative data. The researcher read and reread the text alongside the supporting notes to ensure deep reflection and engagement with the data. Initial themes (codes) were developed deductively based on the feasibility outcomes, key areas of interest, and interview questions. An initial Mind Map framework, based on these, was created in NVivo (version 12, QSR International Pty Ltd.). Subthemes were subsequently refined and developed inductively through purposeful, deliberative, and thorough data coding. The researcher documented this stage of active reflection, development of ideas, and coding decisions to improve trustworthiness of the data (Nowell et al., 2017). Reappraisal and refinement of themes, including any recoding and renaming, were completed by all the authors before the final analysis and write-up.

**Quantitative Methods.** To provide additional insight into feasibility, demand, and acceptability, the attendance and adherence data for both groups were analyzed over the duration of their corresponding 6-week intervention (Weeks 1–6 and Weeks 9–14, as described in Table 1).

### *Secondary Outcome Measures*

**Quantitative Methods.** All quantitative data management and analysis was performed using IBM SPSS Statistics for Windows (version 25.0). Limited efficacy testing was completed on all measures. Descriptive statistics were used to report participant characteristics, recruitment, adherence, participation rates, and pre- and posthealth and functional outcome measures.

# Results

## Participants

Of those who were contacted ($n = 13$), all consented to eligibility screening, giving an uptake of 100% (see Figure 1 CONSORT diagram). Two were excluded through not meeting the Fried Frailty criteria for prefrailty. All the eligible participants ($n = 11$) completed the full baseline assessments. Six participants (54.5%) were randomly allocated to the intervention group and five (45.5%) to the wait-list control group. Two participants in the intervention group withdrew due to unrelated health complications. All remaining participants (81.8%; intervention and wait-list control) were assessed for every feasibility and health and functional outcome.

Just over half the sample (55%) were women with a mean (*SD*) age of 80.73 (4.24) years. All participants were White British in origin. Baseline descriptive characteristics are summarized by intervention and control groups in Table 3. The Fried Frailty mean (*SD*) score was 1.36 (0.50) with short physical performance battery scores ranging from 5 to 10, indicating a risk of developing frailty and functional limitations. The Katz Activities of Daily Living mean (*SD*) score was 6.00 (0.00), representing physical independence. Calculated mean (*SD*) gait speed from the Short Physical Performance Battery walking test suggested increased likelihood of poor health and functional capacity, but the Standardized Mini-Mental State Examination mean (*SD*) score indicated normal cognitive function.

## Primary Feasibility Outcomes

### *Qualitative Findings*

The primary outcomes were concerned with feasability and qualitative findings from the staff, and participant interviews established subthemes for each of the feasibility issues examined. These are outlined in Figure 2 for illustrative purposes. All participants who completed the study (intervention and wait-list control) and care home management staff engaged in interviews. Interview duration ranged from 6 to 18 min.

**Acceptability.** For the feasibility outcome of acceptability, two themes were identified: "Appropriateness of Intervention" and "Participant Experience." As regards "Appropriateness of Intervention," discussions were focused around how "useful," "relevant," and "constructive" it had been and a "positive move" to improve well-being and mobility. Participants reported having confidence in the intervention due to its association with the university and it being "well organized":

> And I think generally, everyone is approving of what's been done here, and to have these machines here is a tremendous thing for a home like this. Especially for the older people who are not so strong that they can get better as well. (James, participant)

Staff echoed this view, commenting that it had been "nice and exciting" to see the intervention in action: "I just think it's been

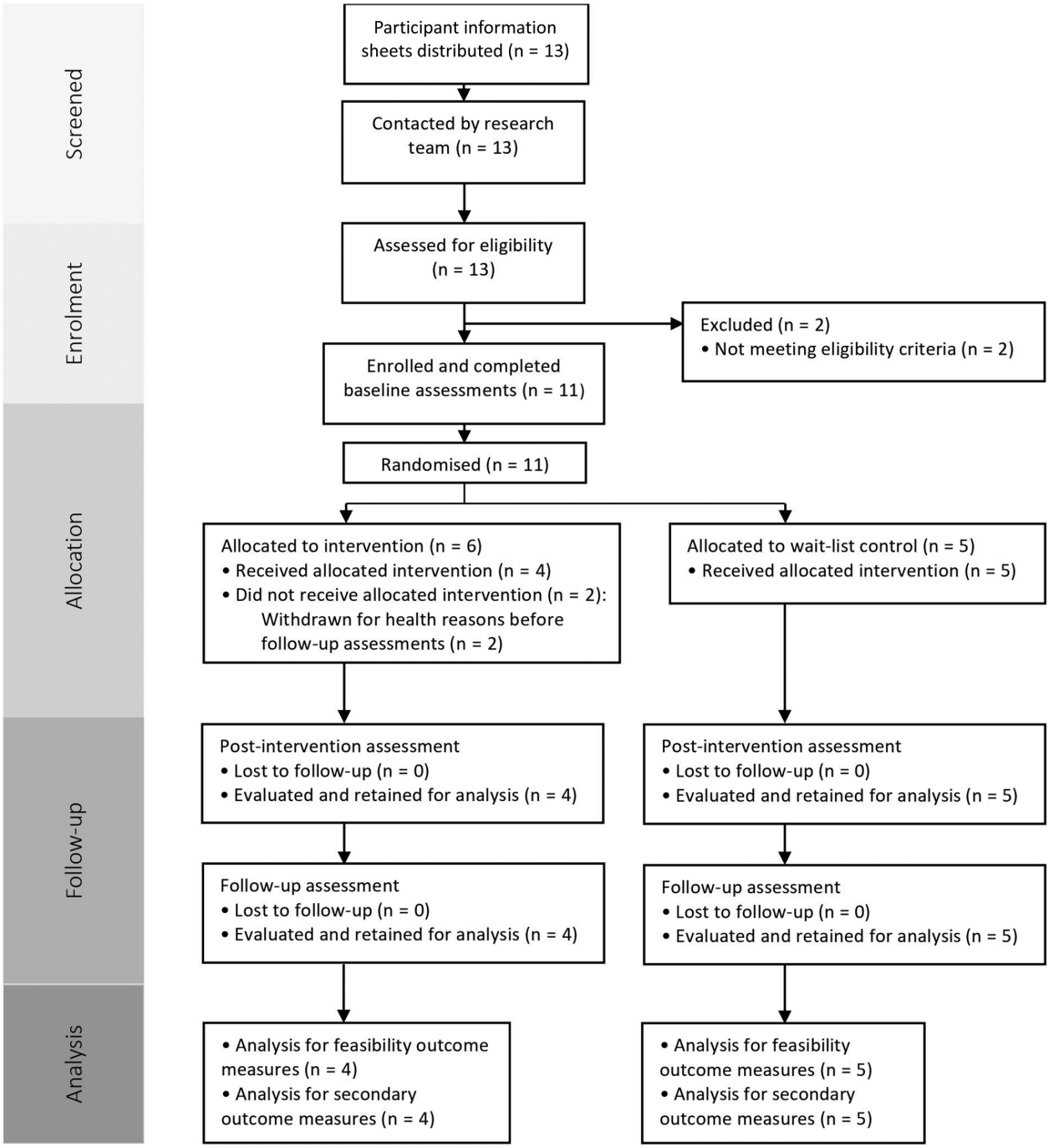


**Figure 1** — CONSORT 2010 participant flow diagram.

> the best thing, we ever took on board. And I wouldn't hesitate to do anything like this again." (Linda, staff member)

In terms of "Participant Experience," all participants described it as having been a positive experience, were pleased to have taken part, and would do so again. Participants commented that it had been "enjoyable," "beneficial," "very good," and that it had "really been worth it." Even those who had been initially skeptical were upbeat when reflecting on their involvement: "I just thought I didn't need these exercises, but you don't realise how much you did need them, and how it's helped me" (Richard, participant).

**Demand.** The feasibility outcome of demand generated a theme of "Consistent Use," with study participants referring to it as an "opportunity to exercise" and an "investment in well-being." Participants reported that attending three times per week had been "very doable" and linked improvements in quality of life to regular and consistent adherence. Several participants exercised more often than the prescribed schedule while actively encouraging other residents, family, and friends to join them. As one male participant confirmed, "Yeah, yeah I do. I come on a Thursday, I come on a Tuesday sometimes. Most days. I think it's excellent" (James, participant). In addition, some residents who had been involved in a previous study at the care home were continuing to exercise regularly and make use of the resistance equipment at similar times. This created not only a level of interest, energy, and social activity in the lounge area but also some friendly challenge around attendance and training loads. As noted by a staff member, "I think the second study has gone very, very well and it's caused a

social engagement and a competition between a lot of the flat members, to be honest" (Linda, staff member).

**Implementation.** Two themes were developed within the feasibility focus area of "Implementation": "Session Time Flexibility" and "Applicability of Assessments and Measures." Regarding "Session Time Flexibility," some participants reported finding the scheduled session time as restrictive in relation to their established personal schedules and would have preferred more flexibility. Although all participants committed to complete the prescribed number of sessions, there was a clear preference for greater autonomy, and often a different pattern of attendance emerged across the intervention duration. Participants explained several different reasons for this including a busy, social life outside of the care home (pre-COVID), caring or other external commitments, a preference to exercise outside of busy times, and a dislike of early morning starts. As one participant explained, "Yes, we're well into retirement mode and not getting up too early, or to a timetable and then, you know, we had to get up to a timetable" (Nancy, participant).

In terms of "Applicability of Assessments and Measures," participants spoke positively about the physical and functional assessments, including grip strength and walking speed, stating that they were "very good and simple to do." Despite the novel experience of maximal strength testing, this was well received, and participants commented that they could understand how the physical tests related to the study. When asked about possible improvements to the study, one participant even proposed more strength testing:

> What I would like, which I know would take an awful long time, but I would like to test on all of them. I think if I could have seen that from what I tested in beginning, and then after to do them all for so long, to be able to be tested on each one to see if I'd improved, I'd have liked that. (Helen, participant)

The questionnaires were less well received by participants and described as seeming "a bit banal," time-consuming, and requiring careful reading due to their structure. However, most participants said that they had been content to complete them as part of the study and were interested to understand how they related to the assessment of multidimensional health:

> I think especially the depression, I hadn't thought about that. I know I've been depressed just lately because I'm not doing what I was doing, but that's all. But I don't think on the whole that we are depressed people but it's interesting to know that it can help depression. (Helen, participant)

**Practicality.** The feasibility outcome of "Practicality" established a theme of "Equipment Suitability and Accessibility." Participants were clear and enthusiastic in their praise for the exercise equipment and, despite some initial concerns about not understanding machines and technology, had embraced the

**Table 3 Baseline Sociodemographic, Anthropometric, and Health-Related Characteristics of Sample**

| | Mean (*SD*)/*n* (%) | |
|---|---|---|
| **Variable** | **Intervention (*n* = 6)** | **Control (*n* = 5)** |
| Age (years) | 83.50 (3.21) | 77.40 (2.61) |
| Range (years) | 80–88 | 75–81 |
| Sex (female) | 3 (50.0) | 3 (60.0) |
| BMI ($kg \cdot m^{-2}$) | 27.43 (3.02) | 32.93 (4.09) |
| Medical conditions | 1.83 (1.47) | 1.80 (1.48) |
| Education | | |
| Secondary | 5 (83.3) | 4 (80.0) |
| Degree/diploma | 1 (16.7) | 1 (20.0) |
| Education years | 10.00 (0.0) | 11.00 (1.00) |
| Occupational category (manual) | 2 (33.3) | 0 (0.0) |
| Marital status | | |
| Married | 4 (66.7) | 4 (80.0) |
| Separated/divorced | 0 (0.0) | 1 (20.0) |
| Widowed | 2 (33.3) | 0 (0.0) |
| Length of stay (months) | 112.33 (64.09) | 61.20 (23.29) |
| Fried Frailty score | 1.33 (0.52) | 1.40 (0.55) |
| SPPB score | 7.33 (1.63) | 7.80 (1.30) |
| SPPB gait speed (m/s) | 0.67 (0.19) | 0.75 (0.07) |
| Katz ADL | 6.00 (0.00) | 6.00 (0.00) |
| SMMSE | 28.83 (1.17) | 29.40 (0.89) |

*Note.* ADL = Activities of Daily Living; BMI = body mass index; SMMSE = Standardized Mini-Mental State Examination; SPPB = Short Physical Performance Battery.

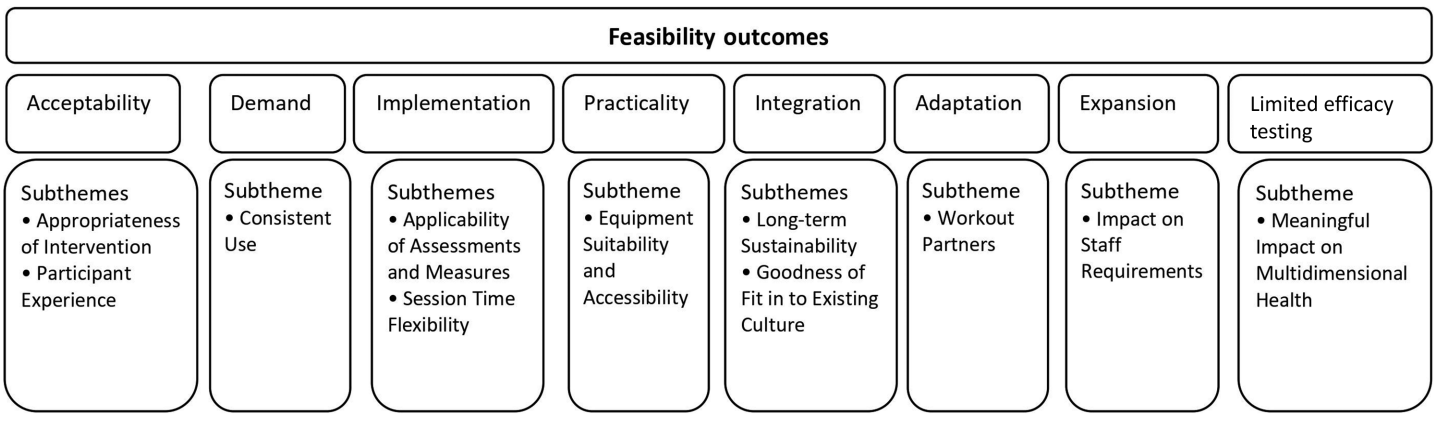


**Figure 2** — Thematic tree identified from participant experiences.

challenges. As one participant explained, "At first, I was not going to do it because I thought I couldn't do it, it would be too much, but I find it's excellent" (Mary, participant). Several participants remarked that they had liked the technology and found the ability to track progress, especially extra repetitions, as "encouraging" and that it had given them "motivation" to continue:

> And I think with it being computerized, that's the thing as well. So, you can tell us how we're doing better and that is important. If I thought I was doing this and there was no improvement . . . but this would seem that there is. (William, participant)

**Integration.** Two themes established from the feasibility outcome of "Integration" were "Long-term Sustainability" and "Goodness of Fit into Existing Culture." As regards "Long-term Sustainability," care home staff were clear in their support of the resistance exercise and equipment and discussed future investment to ensure that all residents could benefit. As one staff member explained, "It's [investment] got to be there, I'm afraid, it's got to be there. It's the way forwards and I think it's possibly the best thing to do and put [the equipment and investment] into a care home anywhere" (Linda, staff member). Participants also stated an interest in continuing to keep the equipment on site and supported longer term use:

> I've enjoyed what I've done and as far as the future's concerned I would like to feel that the machines were here and I would be able to use them at my own time, my own pace and continue to enjoy them. (Joan, participant)

In terms of "Goodness of Fit into Existing Culture," staff were clear that the resistance exercise sessions had become an accepted part of the care home's investment in well-being and quality of life. Initial concerns about disruption to existing activities, demands on staff time, and it not being appropriate for some of the older female residents were swiftly rebuked:

> No, I think that the participants actually did it all themselves, and it didn't interfere with any other activities that were going on. It's worked out in between, and we thought it was going to maybe, stop activities but it didn't, and people were still using it while activities were going on anyway. So, from that point of view, it's been great, and it's just become part of the norm. (Linda, staff member)

**Adaptation.** The feasibility outcome of "Adaptation" generated a theme of "Workout Partners." From the initial recruitment stage, participants who were married had expressed a strong wish to be able to attend screenings, assessments, and exercise sessions together. This was both from a logistical standpoint (i.e., timetabling their days) and from a desire to share the experience and offer support and encouragement. As one participant explained, "Yes, we do like to work together, and we do go together quite a bit, so we just enjoy it. I'd never say I'm going down on my own, it's always together" (Mary, participant). Although participants noted the benefits of having a specific workout partner for those occasions when they needed to be "spurred on," the overall group social interaction was also praised as "nice," "good," and an opportunity to interact with other people. As one participant explained, "And they help, and we're all helping each other" (James, participant).

**Expansion.** The feasibility outcome of "Expansion" generated a theme of "Impact on Staff Requirements and Support." Participants and staff discussed the need for an "enthusiastic person" to run the intervention and provide coaching expertise and guidance. Participants noted how they had appreciated the encouragement, the supervision and support, and the pre- and postsession interaction:

> I think the talk with B helps before we even go on the machines, you know, the warming up and getting ready to go on the machines, and then after the machines, she asks you what you think about it, and I think that's good. (James, participant)

Several participants commented that it had made a big difference to have a consistent contact who "has explained things" and "been with us":

> And you being here, and not giving us an instructor or whatever you are [laughter], and if we'd have had different ones, it wouldn't have worked. You've got to have the continuity, with the same person. That gives us confidence. (Helen, participant)

**Limited Efficacy Testing.** Regarding the feasibility outcome of "Limited Efficacy Testing," a theme of "Meaningful Impact on Multi-dimensional Health" was generated. Participants reported improvements in physical function, including reduction in pain levels in specific joints, feeling stronger, and improvements in balance and walking speed. Participants talked about having more movement "confidence," including going up and down stairs and standing up: "But it is, you know, but I feel that strength in my legs that I'm not going to fall whereas before you had the fear of falling, now that isn't so apparent" (Richard, participant).

Participants were also enthusiastic about the mental health benefits, reporting that they had enjoyed the socializing, felt that they now wanted to "get out and do more, go for a walk," and were feeling "more alive." One participant explained, "I think I'm eating better, sleeping better, my outlook is much better because of it. I think it's beneficial in so many ways" (James, participant). And another simply stated, "I can improve my life by adopting a pretty consistent approach to these machines. Positive and consistent" (William, participant). Care home staff also reported seeing a difference in mental health and mood:

> Yeah, they're so much happier in themselves and they feel that they've got a purpose. They feel more energetic. They can see themselves that they're feeling stronger and more confidence. They exude happiness when they've done their session, they really do. I think it's been good from that point of view. (Linda, staff member)

### *Quantitative Findings*

The feasibility outcomes of acceptability and demand also included an evaluation of recruitment, retention, and adherence rates and analysis of uptake rates. Overall study uptake was 100% with retention rates over 65%. Attendance and adherence were consistent with previous findings (Martin & Sinden, 2001) and exceeded 70% in all cases.

The CONSORT (2010) Participant Flow Diagram (Figure 1) details the number of participants screened, assessed for eligibility, and subsequently enrolled. Although the number of participants recruited was only 65% of the sample size target, 100% of those invited to attend screening did so, and 85% of those screened were found to be eligible.

### Secondary Outcome Measures

Pre- to postintervention health and functional outcomes are presented in Table 4. Effect sizes and 95% confidence intervals can be found in the Supplementary Material S2 (available online) version of this table.

### Harms

There were two separate reported adverse events in the intervention group during the feasibility trial, at Weeks 1 and 3. The adverse events were reported immediately, indicating causality and severity, in liaison with a medical expert and submitted to the Research Ethics Committee and study sponsor within 24 hr. Both adverse events were assessed to be unrelated to the intervention. Both participants subsequently withdrew from the study.

## Discussion

This study broadly supports the feasibility of a resistance training intervention designed to improve the multidimensional health and functional capacity of prefrail older adults in residential care. The findings suggest that future development of a definitive RCT should be informed by the qualitative data, which provided important feedback in terms of acceptability, demand, implementation, practicality, integration, adaptation, and expansion. In addition, the challenges of recruitment and possible refinement of methods need further consideration. Regarding the secondary aim of performing limited efficacy testing on measures of multidimensional health, the generalizability of these findings is limited, and they need to be interpreted with considerable caution due to the small sample size.

### Acceptability

Staff and participants offered positive and encouraging feedback on the relevance, usefulness, and appropriateness of the intervention design and equipment. Levels of interest and uptake were higher than previous resistance training studies with older adults in residential care (Hassan et al., 2016; Johnen & Schott, 2018) potentially due to the established on-site presence of the researcher and the equipment. However, despite an initial enthusiasm and support for the training study and the use of tried and tested recruitment strategies (Swales et al., 2021), the actual number of potential participants recruited was lower than anticipated. This may have been due to a number of different barriers and challenges. First, the study was scheduled to run from July until December, and several of those living in the residential care facility who had expressed an early interest in participation had already scheduled summer holidays in August and September and/or were keen to attend other outdoor activities run by the well-being team during the summer months. It is possible that there was a seasonal effect and that participation in an indoor physical activity study was more appealing in the winter months. Second, some of the potential participants who lived in supported living accommodation as part of the residential care community had multiple other outside interests, family, established routines, and commitments, including caring for a less able spouse. The flexibility in exercise times and equipment use that evolved throughout the study may have helped resolve this barrier if it had been openly suggested up front as an option, although this would, then, have reduced social interactions between members of the intervention group. Third, a broader inclusion policy involving family and friends may have been helpful for recruitment. The study protocol was changed, based on participant and staff feedback, to allow any married couples who wished to complete the study together to be randomized as a pair. This could have been expanded to include any eligible participant who may have liked to have exercised with a training buddy, family member, or friend who did not need to meet the criteria or undertake the assessments. These documented changes to the protocol and observed barriers also raise the prospect of using a more formal coproduction process. This would give those with lived experience a key role in ensuring the intervention was relevant and fit for purpose (Smith et al., 2022)

A further consideration for future recruitment would be to more proactively involve previous study participants, if they were willing to share their experiences, as intervention supporters/advocates. There were residents living in the care home who had participated in previous research trials and were vocal about their positive experiences engaging with resistance training research, several of whom continued to use the equipment. Their voices, opinions, and shared experiences at an informal prerecruitment social event could have given a unique perspective to other older adults who may have been considering getting involved. Finally, a unique feature of this study was the location of the exercise equipment in the communal lounge area. Although this alleviated some of the commonly cited barriers to participation in trials, including transport and location (Forsat et al., 2020), the full and inclusive access to the equipment for all residents may have disinclined potential study participants who already had the benefits of regular strength training without the required commitment for assessments. To explain, from an ethical perspective, we had actively encouraged and supported all residents who expressed interest to use the equipment while the previous study was underway (Swales et al., 2021). However, this level of access may have influenced engagement in this present trial. Overall study retention rate and reasons for withdrawal were consistent with those reported for resistance training interventions with older adults in care homes (Valenzuela, 2012) and with frail older adults' participation in research trials in others' (Provencher et al., 2014) and our own work (Swales et al., 2021).

Participants also reported high levels of enjoyment and satisfaction, and despite some initial misconceptions that it could be boring, they were vocal about the benefits of participation in resistance exercise. These findings agree with previous research that found that although some older adults may doubt the potential benefits of resistance training, perceived improvements in capability, movement confidence, and functional capacity are highly valued (Dionigi & Cannon, 2009; Henwood et al., 2011).

### Demand

Levels of attendance and adherence were similar to or greater than previously reported figures for older adults in residential care (Fien et al., 2019; Hassan et al., 2016), and the three times weekly exercise prescription was considered achievable and suitable, as was found previously in frail individuals (Swales et al., 2021). This is in line with current U.K. and NSCA resistance exercise guidelines and position statements for older adults (Davies et al., 2019; Fragala et al., 2019), which recommend strengthening exercises on at least 2 days per week and two to three times per week, respectively, and recent recommendations for resistance and power training to prevent frailty in community-dwelling older adults (Coelho-Junior et al., 2021). Recent research from Stathi, Greaves, et al. (2022) has brought further support to these

**Table 4 Effects Table: Within-Group Changes From Baseline to Follow-Up**

| | Intervention | | | | Control | | | |
|---|---|---|---|---|---|---|---|---|
| Outcome measure | *n* | Baseline mean (*SD*) | Post mean (*SD*) | Mean difference [95% CI] | *n* | Baseline mean (*SD*) | Post mean (*SD*) | Mean difference [95% CI] |
| Knee extension left, peak torque (N·m) | 4 | 72.21 (19.26) | 98.85 (5.27) | 26.64 [−3.24, 56.52] | 5 | 82.63 (41.80) | 90.62 (38.30) | 7.99 [−22.64, 10.98] |
| Knee extension right, peak torque (N·m) | 4 | 80.56 (12.58) | 103.82 (15.05) | 23.26 [−6.66, 53.17] | 5 | 83.85 (28.04) | 81.25 (28.52) | −2.60 (−17.11, 11.92] |
| Knee flexion left, peak torque (N·m) | 4 | 39.27 (9.26) | 38.82 (14.09) | −0.44 [−16.48, 15.59] | 5 | 39.85 (15.74) | 46.98 (11.10) | 7.13 [−0.23, 14.49] |
| Knee flexion right, peak torque N·m) | 4 | 39.96 (13.96) | 39.91 (12.40) | −0.05 [−9.81, 9.70] | 5 | 47.93 (24.54) | 50.02 (18.38) | 2.09 [−3.86, 8.04] |
| Hip adduction, peak torque (N·m) | 4 | 112.65 (21.30) | 116.00 (21.76) | 3.35 [2.62, 4.08] | 5 | 114.97 (35.15) | 124.46 (41.27) | 9.49 [0.90, 18.08] |
| Hip abduction, peak torque (N·m) | 4 | 75.11 (31.28) | 79.04 (32.22) | 3.93 [−9.51, 17.37] | 5 | 113.62 (41.91) | 107.21 (31.24) | −6.41 [−17.21, 4.40] |
| SPPB balance test (0–4) | 4 | 3.75 (0.50) | 4.00 (0.00) | 0.25 [−16.48, 15.59] | 5 | 3.60 (0.55) | 3.40 (0.55) | −0.20 [−0.63, 0.23] |
| SPPB gait speed test (0–4) | 4 | 2.50 (1.29) | 3.50 (0.58) | 1.00 [−0.30, 2.30] | 5 | 3.20 (0.45) | 3.40 (0.89) | 0.20 [−0.64, 1.04] |
| SPPB gait speed (m/s) | 4 | 0.66 (0.24) | 0.85 (0.16) | 0.19 [0.02, 0.36] | 5 | 0.75 (0.07) | 0.79 (0.09) | 0.03 [−0.07, 0.14] |
| SPPB chair stand test (0–4) | 4 | 1.25 (0.50) | 1.75 (0.96) | 0.50 [−0.42, 1.42] | 5 | 1.00 (0.71) | 1.00 (0.00) | 0.00 [−0.62, 0.62] |
| SPPB total points (0–12) | 4 | 7.50 (1.91) | 9.50 (1.29) | 2.00 [0.70, 3.30] | 5 | 7.80 (1.30) | 7.80 (1.30) | 0.00 [−1.14, 1.14] |
| Katz ADL (0–6) | 4 | 6.00 (0.00) | 6.00 (0.00) | 0.00 [0.00,0.00] | 5 | 6.00 (0.00) | 6.00 (0.00) | 0.00 [0.00, 0.00] |
| Fried Frailty, weight loss (0–1) | 4 | 0.00 (0.00) | 0.00 (0.00) | 0.00 [0.00, 0.00] | 5 | 0.00 (0.00) | 0.00 (0.00) | 0.00 [0.00, 0.00] |
| Fried Frailty 2a, depression (0–3) | 4 | 0.50 (0.58) | 0.00 (0.00) | −0.50 [−1.42, 0.42] | 5 | 1.00 (1.22) | 0.60 (0.89) | −0.40 [−1.26, 0.46] |
| Fried Frailty 2b, depression (0–3) | 4 | 0.50 (0.58) | 0.00 (0.00) | −0.50 [−1.42, 0.42] | 5 | 0.40 (0.55) | 0.20 (0.45) | −0.20 [−0.69, 0.29] |
| Fried Frailty, grip strength (kg) | 4 | 28.43 (8.62) | 27.35 (7.23) | −1.08 [−3.51, 1.36] | 5 | 28.56 (8.84) | 27.46 (9.86) | −1.10 [−2.69, 0.49] |
| Fried Frailty, walk test (s) | 4 | 7.42 (2.86) | 5.14 (1.46) | −2.29 [−4.73, 0.16] | 5 | 5.84 (0.51) | 5.35 (0.92) | −0.49 [−1.83, 0.85] |
| Fried Frailty, walk test speed (m/s) | 4 | 0.69 (0.27) | 0.95 (0.27) | 0.26 [0.18, 0.34] | 5 | 0.79 (0.07) | 0.87 (0.14) | 0.08 [−0.04, 0.21] |
| Fried MLTAQ (kcal/week) | 4 | 511.98 (572.77) | 410.20 (456.92) | −101.78 [−289.13, 85.57] | 5 | 255.62 (251.97) | 153.85 (118.95) | −101.77 [−260.89, 57.35] |
| Fried Frailty total (0–5) | 4 | 1.25 (0.50) | 0.75 (0.50) | −0.50 [−1.42, 0.42] | 5 | 1.40 (0.55) | 1.60 (0.55) | 0.20 [−0.49, 0.89] |
| GDS (0–30) | 4 | 2.50 (1.29) | 1.50 (0.58) | −1.00 [−2.30, 0.30] | 5 | 4.60 (2.19) | 5.80 (1.92) | 1.20 [0.13, 2.27] |
| HADS anxiety (0–21) | 4 | 0.75 (0.50) | 2.50 (1.29) | 1.75 [−0.64, 4.14] | 5 | 5.40 (4.28) | 5.40 (6.19) | 0.00 [−2.76, 2.76] |
| HADS depression (0–21) | 4 | 0.75 (1.50) | 2.25 (1.71) | 1.50 [−0.55, 3.55] | 5 | 3.00 (1.22) | 3.80 (2.59) | 0.90 [−0.66, 2.26] |
| PSS total (0–40) | 4 | 3.75 (2.22) | 4.75 (3.20) | 1.00 [−1.60, 3.60] | 5 | 5.80 (3.56) | 12.80 (9.88) | 7.00 [1.96, 12.04] |
| SMMSE total (0–30) | 4 | 29.00 (1.41) | 28.50 (1.00) | −0.50 [−3.26, 2.26] | 5 | 29.40 (0.89) | 29.60 (0.89) | 0.20 [−0.97, 1.37] |
| ISEL appraisal (0–12) | 4 | 11.50 (0.58) | 11.75 (0.50) | 0.25 [−1.27,1.77] | 5 | 11.80 (0.45) | 11.80 (0.45) | 0.00 [−0.57, 0.57] |
| ISEL belonging (0–12) | 4 | 11.00 (1.41) | 11.75 (0.50) | 0.75 [−0.77, 2.27] | 5 | 10.00 (3.39) | 10.20 (3.49) | 0.20 [−0.50, 0.90] |
| ISEL tangible (0–12) | 4 | 11.50 (1.00) | 12.00 (0.00) | 0.50 [−1.09, 2.09] | 5 | 11.40 (1.34) | 11.20 (1.79) | −0.20 [−0.89, 0.49] |
| MNA total (0–14) | 4 | 13.25 (1.50) | 13.75 (0.50) | 0.50 [−1.09, 2.09] | 5 | 13.20 (1.30) | 13.40 (0.55) | 0.20 [−0.76, 1.16] |
| Cortisol (ng/ml) | 4 | 128.03 (39.02) | 124.61 (36.72) | −3.42 [−54.02, 47.18] | 5 | 116.60 (40.42) | 130.19 (67.22) | 13.58 [−23.65, 50.82] |
| DHEAs (ng/ml) | 4 | 665.08 (347.50) | 647.10 (297.52) | −17.98 [−106.42, 70.47] | 5 | 580.63 (409.90) | 624.32 (399.67) | 43.69 [−26.34, 113.72] |
| Cortisol:DHEAs | 4 | 0.24 (0.17) | 0.24 (0.18) | 0.00 [−0.04, 0.04] | 5 | 0.55 (0.76) | 0.44 (0.55) | −0.11 [−0.27, 0.04] |

*Note.* ADL = Activities of Daily Living; DHEAS = dehydroepiandrosterone sulfate; GDS = Geriatric Depression Scale; HADS = Hospital Anxiety and Depression Scale; ISEL = Interpersonal Support Evaluation List; MLTAQ = Minnesota Leisure-Time Activity Questionnaire Shortened Version; MNA = Mini Nutritional Assessment; PSS = Perceived Stress Scale; SMMSE = Standardized Mini-Mental State Examination; SPPB = Short Physical Performance Battery; TNFa = tumor necrosis factor alpha; CI = confidence interval.

recommendations and found that a twice-weekly multimodal, group-based physical activity session (reduced to once weekly after 12 weeks) for community-dwelling older adults was an effective way to maintain good physical function.

It is interesting to note that there was additional demand for the exercise equipment from the study participants, staff, and other care home residents, and similarly to the RCT by Stathi, Withall, et al. (2022), many attendees did not want the sessions to end. A possible explanation for this might be the enduring impact of the prior, successful on-site resistance training study (Swales et al., 2021). Likely factors include increased awareness of the equipment in the communal lounge area and the benefits of engaging in resistance training, positive feedback from previous participants, and growing levels of support from staff. It may also be related to the emergence of "peer-leaders" who boosted social interaction, encouraged other residents to try the equipment, and prompted friendly competitive banter around training loads and attendance. Previous research has highlighted the influence of "exercise champions" for older adults (Barras et al., 2021) and the importance of the social aspect of group exercise in residential care settings (de Souto Barreto et al., 2016; Franco et al., 2015). Given the impact of these findings, and the feedback from participants, use of peer leaders in the recruitment and delivery stages of the future intervention should be considered.

## Implementation

Participants displayed a high level of commitment to the study, and several of them made changes to their established routines to ensure full attendance and adherence at the designated exercise times. This agrees with Fiordelli et al.'s (2021) findings that older adults display a sense of duty and responsibility to contribute to research, particularly around well-being and health. In addition, some participants quickly developed the confidence and ability to use the resistance equipment independently and subsequently expressed a desire for greater overall autonomy, for example, the ability to complete sessions on different days or at different times and/or complete additional sessions with family and friends. This finding was unexpected given their inexperience with resistance exercise; however, there are several possible explanations. First, it is possible that this was due to participants pairing up with spouses, friends, and "workout partners," greater engagement by family members and staff, and a cultural shift at the care home to support resistance exercise for all residents. Second, it is also likely that the need for exercise sessions to fit into their established routines became increasingly important. Third, it is possible that the simple, smart touch preprogrammed digital nature of the machines gave participants more confidence about independent use than traditional equipment; this is discussed further later under practicality. Given this feedback, and the decision to pair up spouses within the trial protocol, greater flexibility to incorporate training time preference and training partners should be considered in the definitive trial.

Implementation of all multidimensional measures was manageable, with participants willing to prioritize these and schedule them in advance. Most of the participants displayed a particular interest in the maximal strength and functional assessments, including the protocols, rationale for inclusion, expected changes, and normative data. However, several participants queried the relevance and viability of multiple, time-consuming questionnaires. This was in line with previous research findings (Ferrucci et al., 2004; Swales et al., 2021) and suggests that this may negatively impact participation in a future definitive RCT. Potentially a future trial wishing to incorporate measurement of psychosocial health and well-being should consider fewer and shorter validated measures.

## Practicality

The specialized resistance exercise equipment was widely praised by participants and staff, many of whom had been initially unsure of computerized equipment and touchscreen technology. Several participants expressed delight at their ability to engage with technology, learn new skills, and track their own progress. These results reflect those of Valenzuela et al. (2018), who suggested that the provision of automatically recorded exercise sessions, load progression, and real-time feedback is an underutilized benefit of technology-based exercise programs with older adults. In association with the ease of use reported by participants, this may lend support to the initial financial outlay for aging-specialized pneumatic exercise equipment in residential care facilities.

## Integration

Care home staff and participants were united in their support of a longer term commitment to resistance training, continued investment in equipment, and wider accessibility for all care home residents. Care staff voiced a clear opinion that the inclusion of resistance exercise equipment into future residential care developments should be a key consideration. Moreover, this should sit within a wider responsibility toward multidimensional well-being, quality of life, and proactive health care. These findings are very encouraging and support the work of Baldelli et al. (2021) in relation to well-being of older adults in care facilities. They also lend support to investment in proactive approaches to reduce health care costs, including resistance training to mitigate frailty trajectories (Angulo et al., 2020; Pinedo-Villanueva et al., 2019) and access to rehabilitation support and digital enhancement of care (British Geriatrics Society, 2021).

## Adaptation

Possible modifications to the existing intervention were discussed, and although there was no clearly identified need for amendments, there was firm support for the protocol amendment that granted random group allocation as couples, with spouses, if requested. This finding reflects those of others who identified spousal support as a key motivator for consistent attendance and longer term participation (Gellert et al., 2011). High levels of social interaction and camaraderie were also established more broadly, both within the participant groups and between other care home residents who either accessed the equipment independently of the study or were attending other activities in the community lounge. These promising results reinforce the documented benefits of group resistance exercise programs for older adults in residential care (de Souto Barreto et al., 2016) and the impact of peer support to nurture social interaction, guarding against loneliness and isolation (Barras et al., 2021; Franco et al., 2015).

## Expansion

Future expansion of the program raised queries about staffing requirements. There was collective acknowledgment that the success of any future intervention would be heavily dependent on enthusiasm and encouragement from a suitably qualified individual. Participants and staff noted that consistency of delivery

was vital to build trust, confidence, and rapport. Although previous studies have identified staffing as a barrier to provision of physical activity in long-term care homes (Baert et al., 2016; Benjamin et al., 2009), this was not regarded to be a substantial obstacle in this instance. However, in line with previous findings, the person delivering an intervention can make all the difference between success and failure (Harvey & Griffin, 2020). This suggests that a future trial of this specific training program would need to evaluate the effectiveness of a care staff-delivered intervention wherein care staff are trained to utilize the equipment and deliver the exercise program. Unless care homes invest substantial funding to support the input of trained exercise program deliverers, it is likely that local staff delivery of the intervention would be essential for wider roll-out and uptake. Training would need to be comprehensive as physical activity interventions for older adults have been shown to be more effective when delivered by a medical or exercise professional (Shvedko et al., 2018) and can improve adherence (Hawley-Hague et al., 2016), although the impact of the support of professionals on intervention success has received little attention according to a recent review of meta-analyses (Di Lorito et al., 2021).

### Limited Efficacy Testing

Limited efficacy testing on measures of multidimensional health and functional capacity was completed with both groups for thoroughness. However, it should be noted that the small sample size restricts the value of interpreting treatment effects beyond the actual groups measured, and as indicated by Sim (2019), formal decision making about proceeding to a full RCT should not be based on this. Although it was disappointing that the small sample size limited the trustworthiness of the quantitative data trends, specifically in relation to measures of strength, functional capacity, and frailty status, there was still value in completing the full assessment protocol and subsequent analysis. Important qualitative feedback from participants relating to test burden and timings, and future consideration of the importance of clinically important change (Kwon et al., 2009), may help refine changes to the potential future RCT and ensure that it is informed by both participant perspectives and clinical judgment (Sim, 2019),

Interestingly, the qualitative analysis did identify a positive meaningful impact on self-reported movement confidence, strength levels, and functional capacity. These positive improvements also extended to self-rated energy levels, happiness, mood, and well-being. These findings corroborate those of Dionigi and Cannon (2009) and Rydeskog et al. (2009), which reported enhanced enthusiasm for life, joy, and physical confidence. Qualitative interviews with older adults engaged in a group multimodal physical activity intervention also reported improved mental and social well-being, higher physical confidence, and improved motivation (Stathi, Greaves, et al., 2022). It is interesting to note that the extent of resistance training benefits on physical function has also been shown to relate to the amount of improvement in self-reported health-related quality of life (Geirsdottir et al., 2012). This might suggest the value of including measures of self-efficacy in a future trial but should be considered carefully alongside the issue of questionnaire burden discussed earlier.

## Limitations

This feasibility study had some limitations. First, the small sample size prohibited any statistical analysis; however, with the primary aim identified as feasibility, a small sample was deliberate, and decisions to move to a full RCT were to be based on feasibility objectives and not the exploratory secondary outcome measures. Recruitment challenges further limited the sample size, and practical issues relating to these need to be considered and addressed. Second, the short duration of the resistance training intervention may have affected levels of participant uptake and attendance and may not be representative of levels of dropout and adherence over a longer duration RCT; however, again, as this was a feasibility study, a shorter duration was deemed appropriate to test feasibility as the primary outcome. Third, broader expansion may be limited due to the affordability and accessibility of the specialized resistance equipment used in this trial and regular access to a qualified instructor. However, as noted earlier, the care home involved thought it a worthwhile continuing investment in this equipment due to its accessibility, technology, and design. It would be beneficial to test whether care staff trained by qualified resistance exercise instructors could successfully deliver the intervention given the relative ease of setup and use of this specialized equipment. An important limitation is the lack of behavior change techniques, which can be successfully used to increase self-efficacy, enhance participant motivation, and support maintenance of physical activity in older adults. This would be a beneficial addition to the RCT and ensure that longer term change mechanisms were integrated into the intervention. The lack of a behavior change theoretical basis to the trial is a key limitation and should be a primary consideration for inclusion in any expansion of this preliminary study.

## Recommendations and Future Directions

Progression to a future definitive RCT would benefit from several recommended changes: first, revision of the study design to include a theoretical framework and behavior change elements to increase intervention effectiveness and support adoption and longer term maintenance of resistance training in residential care homes, and second, revision of recruitment strategies to address the identified barriers and potential solutions. This could be supported by further discussion and emphasis on coproduction with care home staff and residents and include offering greater flexibility in scheduling exercise sessions and encouraging engagement of family and friends. Third, all assessments should be carried out by a researcher who is blinded to group allocation to reduce potential bias. Fourth, the exercise prescription should be extended to at least 12 weeks, with fewer and/or more sensitive questionnaire measures and greater emphasis on self-reported changes in overall well-being and movement competency. Longer duration studies have been shown to lead to better physical function outcomes and would offer an important insight into the longer term maintenance of a resistance training intervention in the care home setting. With further regard to exercise prescription, it is also important to note that recent research with community-dwelling older adults indicated a dose–response relationship supportive of group, multimodal physical activity once a week in the initial stage and once per fortnight in the maintenance phase for achieving meaningful clinical change in functional measures (Stathi, Greaves, et al., 2022). It may be that a lower level of commitment is required to achieve health and functional benefits in this population group, and this has important implications for broader health messaging and engagement. Fifth, pairing of workout partners and proactive recruitment of peer leaders should be encouraged. In addition, to ensure continuity of delivery and support, an enthusiastic, experienced instructor

should be present at all sessions and actively encourage equipment use by other care home residents.

Further research in residential care facilities is timely and important, particularly with older adults at risk of physical function and mobility limitations. In future investigations, it could be possible to include more social interaction and intergenerational support from peers, family, and friends. It may also be feasible to link more closely with allied professionals, including doctors and physiotherapists already supporting older adults' care, to provide a clearer pathway of proactive muscle strengthening exercise supported by behavior change techniques. Longer term involvement could also be supported and embedded into the daily activities of the care facility, with the opportunity to involve activity coordinators and work in tandem with existing programs for community-based older adults. To ensure cost-effectiveness of future interventions, they may need to be delivered by suitably trained in-house care staff and activity coordinators with an interest in physical activity. In addition to the future RCT, future research could usefully address the impact of peer leaders and workout partners on attendance and adherence as well as broader care home resident use of the resistance exercise equipment over a longer term follow-up. This would also help give some indication of economic viability of equivalent programs and equipment.

## Conclusions

Taken together, these findings offer preliminary support for the feasibility of a definitive RCT using a resistance training intervention with prefrail older adults in residential care. The study findings add to our understanding of resistance training interventions, with important insights into older adults' preferences concerning participation in exercise trials, barriers to recruitment and possible solutions, and perceived changes in strength, well-being, and physical competence.

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