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Research Article

Power training in older adults: A pilot and feasibility study

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Abstract

Background: Previous research shows that power training can increase power output in older adults and may also improve physical performance, physical functioning, and independence. However, power training interventions have not been optimized for older adults. The aim of this study was to assess the feasibility and preliminary effectiveness of a power training program called *Powerful Ageing* in older adults.

Methods: A total of 28 older adults participated in a 12-week power training intervention at an intensity of 20-30% 1RM. The primary outcome, feasibility, was assessed through intervention retention, adherence (attendance and compliance), and safety. Secondary outcomes were measured in health domains of the ICF. In the function domain, muscle power and anaerobic power were assessed using a weighted squat and Wingate test, respectively. In the activities domain, physical performance was measured using the 6-minute walk test, and in the participation domain, physical activity in daily life and health status were evaluated using an accelerometer and the SF-36 questionnaire, respectively.

Results: With intervention retention and adherence at 100%, and 0% drop-out due to injuries, *Powerful Ageing* was considered feasible and safe for older adults. Power training significantly improved muscle power, anaerobic power, and physical performance in older adults, but did not have a significant effect on physical activity in daily life or health status.

Conclusions: Preliminary results suggest that *Powerful Ageing* is a feasible and safe intervention that may improve muscle power, anaerobic power, and physical performance in older adults. Randomized clinical trials are necessary to fully assess the potential of power training as an exercise intervention for older adults.

Keywords: Power training, Older adults, Feasibility, Muscle power, Physical performance, Physical functioning in daily life, Health status, Accelerometer

Introduction

Global aging has led to a greater proportion of older adults and is one of the factors contributing to the increase in annual healthcare expenditure. People live longer despite the presence of chronic health conditions [1]. To offset rising healthcare costs, it is expected that older adults continue to live independently at home for as long as possible [2]. However, older adults must maintain their physical performance and physical functioning to facilitate independent living.

Aging is associated with a decrease in both muscle strength and muscle power [3-8], causing daily tasks, such as rising from a chair or climbing a flight of stairs, to become more difficult. Muscle power, the product of contraction force and velocity, is best trained through targeted power training, which is a form of exercise that involves moving resistance at higher velocities than traditional strength training [4,5,9,10]. Studies have shown that power training generates high power output even in older adults [10-12], allowing for older adults to maintain or regain the ability to perform everyday activities, which may lead to increased independence and improved quality of life. Despite this, power training is rarely used as an intervention in practice as little is known about the exercise physiology and effectiveness of power training in older adults [9,12,13], and some consider explosive muscular contractions a risk for injuries. Information on how power training should be implemented in older adults is lacking [9,12,14], making it unsurprising that current exercise guidelines do not include recommendations for power training.

Therefore, the aim of this study was to assess the feasibility of a power training intervention called *Powerful Ageing* in older adults. In addition, we performed a preliminary evaluation of the effectiveness of *Powerful Ageing* within the function, activities, and participation domains of the International Classification of Functioning, Disability, and Health (ICF).

Methods

Setting and study design

A cohort of older adults participated in a 12-week power training intervention called *Powerful Ageing*. Training, testing, and data collection occurred at the physical therapy practice and fitness center Sports & Science located in Lochem, the Netherlands. The study was longitudinal in design, with measurements obtained at baseline (week 0) and following the completion of the intervention (week 12).

Participant selection

Study participants were recruited from an open population in the municipality of Lochem, the Netherlands, from October through December 2015. The recruitment process was aimed at older adults and consisted of flyers distributed by local healthcare services, newspaper ads, social media, and information available on the website of the Sports & Science Center. To be eligible to participate in the study, participants had to be >55 years of age, live at home, and experience difficulties in participating in activities of daily life. It was required that participants spoke the Dutch language and had the ability to come to the training location independently. Participants were excluded from the study if they had been diagnosed with a condition that would prohibit full participation in testing or training (e.g. Alzheimer's disease, neurological disorders, musculoskeletal injuries, or complications associated with acute cardiovascular disease). Participants with a body mass index (BMI) <19 or >35 kg/m^2 or blood pressure >150/90 mmHg were also excluded in view of participant safety. Lastly, older adults who had participated in a different exercise or training intervention 3 months prior to the start of the current training intervention were also excluded. Individuals who did not meet eligibility criteria were offered an alternative exercise intervention.

Following inclusion, participants were informed of the study's purpose, procedures, and potential risks and benefits verbally during a group gathering and in writing. Informed consent was obtained from each participant prior to testing. This study had been approved by the Ethical Commission of Research at the University of Applied Sciences Utrecht.

Training protocol

Based on our previous work, a power training program called *Powerful Ageing* was created based on the theoretical concepts and practical requirements of a power training intervention [15, submitted manuscript by el Hadouchi et al; manuscript under review by el Hadouchi et al]. The rationale behind *Powerful Ageing* is largely based on the velocity component of muscle power, as the ability to move with a sufficiently large speed is more often the limiting factor than the ability to produce sufficient muscle force [10,16]. To train high contraction velocity, the resistance used in power exercises should be lower so that the movement speed can be higher. Therefore, *Powerful Ageing* uses a training load of 20-30% of the 1-repetition maximum (1RM), which has been proposed as the ideal power training load for older adults [17-19] and was also chosen for feasibility and safety. Training sessions were led by an experienced professional trainer and supervised by a sport's physical therapist, both of whom ensured correct technique, intensity, and number of sets. To allow personal instruction, participants were divided into two training groups of 15 individuals.

Participants completed a 45-minute power training session twice a week for 12 weeks. Each session began with an explanation of the training goal and instructions on what was expected from participants (e.g. emphasis on movement speed). A 10-minute warmup consisted of movements and functional exercises with either no weight or a minimal load, which offered participants familiarization with the exercises, and provided trainers a chance to verify each participant's technique. The exercises used in the intervention were chosen based on their ability to generate a high power output [20]. Each training session consisted of three components: (1) Olympic weightlifting, such as deadlift high pulls, clean and press, back squats, and snatches; (2) sprint and agility training; and (3) functional movement training, including step-up lunges, burpees, and stair climbing.

During the training session, participants were instructed to perform 3 sets of 5-7 repetitions within a specific period of time, e.g. 10 seconds (s). Exercises were performed at a controlled tempo, concentrating on a fast explosive concentric phase and a slow and steady eccentric phase (the movement speed followed a <1s–0s–3s–0s pattern). The instruction for the power exercises was to be "as fast as possible". In between exercises, participants took a 2-5 minute break as needed, ensuring that each participant was able to complete the exercise using their maximum movement velocity. The training load gradually increased in both the number of sets and the 1RM load. Participants were instructed to add greater resistance when they could easily perform the number of repetitions of an exercise in the predetermined time (e.g. 5 hang cleans in 10 seconds). **Table 1** summarizes the test protocol using criteria from the Template for Intervention Description and Replication Checklist (TIDieR) checklist [21].

Feasibility

Feasibility was used as an umbrella term encompassing retention, adherence (attendance and compliance), and safety [22]. We defined retention as the proportion of participants who completed all follow-up assessments compared to the number of participants who completed baseline assessments. Adherence was defined using the World Health Organization definition as the extent to which a person's behavior corresponds with agreed recommendations [23] and incorporates both the number of training sessions attended as well as the compliance with the prescribed power training program. Compliance was determined through training records of a participant's progression, duration of the exercise, intensity, and level of difficulty of the exercises. The safety of the intervention was monitored through structured weekly screenings that aimed to assess any new physical complaints lasting longer than 48 hours related to the intervention, and adverse events that occurred during the intervention. The intervention was considered feasible if retention and adherence (attendance and compliance) were at least 90%, and drop-out due to injuries was below 15% [22].

Table 1. Training protocol.

#	Criteria	Power training intervention
1	Intervention	Powerful Ageing
2	Rationale	Aging causes muscle power, the product of force and velocity, to deteriorate. Specifically, older adults often miss the velocity component of muscle power. Therefore, power training interventions that use the high velocity and low force approach would be expected to be optimal for older adults (20-30% 1RM).
3	Materials	Various exercise equipment commonly available at fitness centers
4	Procedure	Each session began with a 10-minute warm-up consisting of movements and functional exercises that were featured in that day's training with either no weight or a minimal load. The power training consisted of 3 components: Olympic weightlifting, sprint and agility training, and functional movement training.
5	Person	The intervention was administered by an experienced professional trainer and under supervision of a sport's physical therapist.
6	Modes	In-person group training of 15 participants
7	Location	Indoor sports facility
8a	Sessions	24 sessions
8b	Frequency	2x per week
8c	Duration	45 minutes
8d	Intensity	30% of 1RM
8e	Type of exercises	The exercises used were explosive strength exercises. Each session consisted of Olympic weightlifting (including deadlifts, high pulls, clean and press, back squats), sprint and agility training, and functional movement training (including step-up lunges, burpees, and stair climbing).
8f	Level	Participants were instructed to concentrate on a fast explosive concentric phase and a slow and steady eccentric phase. The movement speed followed a <1s–0s–3s–0s pattern.
8g	Combination	N/A
9	Tailoring	Participants were instructed to add greater resistance when they could easily perform the number of repetitions of an exercise in the predetermined time (e.g. 5 hang cleans in 10 seconds).
10	Modification	None
11	Adherence	Acceptable intervention adherence was set at 90% for both attendance and compliance.
12	Deliverance	The intervention was delivered as planned.

1RM: 1-Repetition Maximum.

Preliminary effectiveness

Secondary outcomes were measured in the health domains of the ICF, as shown in **Table 2**. Within the function domain, muscle power was assessed using weighted squat and anaerobic power was assessed using the Wingate test. Within the activies domain, physical performance was measured using the 6-minute walk test (6-MWT), and within the participation domain, physical activity in daily life and health status were evaluated using an accelerometer and the SF-36 questionnaire, respectively.

Muscle power: The weighted squat was assessed using a GymAware device (Kinetic Performance Technology, Canberra, Australia), a portable Linear Positional Transducter (LPT with

Table 2. Primary outcomes and their ICF domains.

ICF domain	Outcome	Test
Function	Muscle power	Weighted squat
	Anaerobic power	Wingate Test
Activities	Physical performance	6-minute walk test
Participation	Physical activity in daily life	Accelerometer
	Health status	SF-36

ICF: International Classification of Functioning, Disability, and Health; SF-36: 36-item Short Form Survey angle measurement), which can be attached to free weights [24-26]. Participants were instructed to sit on a box and rise to stand at a controlled tempo, while simultaneously holding two 6 kg dumbbells at shoulder height. The assessed outcome variables were peak and mean power (Watt) and peak and mean velocity (m/s).

Anaerobic power: The Wingate test consisted of a 5-minute warm-up, a 30-second sprint, and a 2-minute cool down performed on a Wattbike Pro/Trainer (Wattbike, Nottingham, United Kingdom). Participants were instructed to try to reach their maximum cycling speed early in the sprint and to try to maintain this speed for 30-seconds. Outcome variables were average power (Watt), peak power (Watt), cadence (revolutions per minute), and fatigue factor (%).

Physical performance: The 6-MWT was conducted in a training facility on a flat surface of 12 meters long. Participants were instructed to walk as far as possible during the 6 minutes and were told to be able to take breaks as needed but to continue walking again as soon as they deemed this possible. Outcome variables were the total distance covered in 6 minutes and the BORG scale for exhaustion conducted following the 6MWT [27-29].

Physical activity in daily life: Participants were instructed to wear a MoveMonitor (McRoberts, the Hague, the Netherlands) around their waist for 7 consecutive days, removing the device only when bathing/showering/swimming, or sleeping. The MoveMonitor is an accelerometer that records physical activity by measuring movement parameters, such as the duration of movement and the number of long and short episodes of movement. A walking bout ranging between 1 to 24 seconds was considered a short walking bout, while walking bouts >24 seconds were considered long walking bouts. A daily journal was also kept in which participants noted their daily activities and any special circumstances throughout the day. Outcome variables were gait activity, the total time a participant wore the accelerometer, total number of walking bouts, and total number of short and long walking bouts. Gait activity is an expression use by McRoberts for the duration of activity and number of walking bouts measured in 24 hours.

Health status: The health status of participants was evaluated using the SF-36, a widely used and validated instrument that assesses the health and well-being of individuals through a self-administered questionnaire [30]. Although the complete SF-36 questionnaire was administered, our primary focus lies on five specific domains: physical functioning, energy/fatigue, emotional well-being, social functioning, and general health.

Additional baseline measurements: The following demographic, anthropometric, and clinical variables were also obtained from participants: age, sex, level of education, smoking status, cholesterol, presence of chronic disease, medication use, blood pressure, resting heart rate, weight, fat index (%), fat and muscle mass (kg), BMI, working status, participation in sports, and whether there were any injuries/functional limitations.

Statistical analyses

Participant data obtained at baseline (week 0) and following the intervention (week 12) were entered manually into Excel (Microsoft, Redmond, USA), and cleaned prior to data analysis using SPSS (IBM, Chicago, USA). Continuous variables are presented as mean (standard deviation) or median (interquartile range), whereas categorical variables are presented as frequency (percentage per category). The preliminary effectiveness of *Powerful Ageing* was evaluated by testing the differences between measurements at baseline (week 0) and following the intervention (week 12) using a paired samples t-test or Wilcoxon signed rank test. The level of significance was set at $p \leq 0.05$.

Results

Participant characteristics

A total of 110 visitors to the Sport & Science Center were eligible to participate in the study. Thirty individuals were invited at random to participate in the study and all of them accepted. Two participants were excluded from analyses evaluating preliminary effectiveness due to an error in the registration of accelerometers, leaving 28 participants for which these outcome data were available. However, the two participants were included in the analyses evaluating feasibility. Participant characteristics at baseline are shown in **Table 3.**

Table 3. Study population at baseline.

Variable	Summary	N
Age (years)	68.3 (6.2)	28
Sex (male)	16 (57.1%)	28
Level of education		26
Primary	3 (11.5%)	
Secondary	7 (26.9%)	
Post-secondary	16 (61.6%)	
Smoker	1 (3.8%)	26
Cholesterol (mg/dL)	4.7 (0.7)	25
Presence of chronic disease	5 (20%)	25
Medication use	12 (46.2%)	26
Systolic blood pressure (mmHg)	159.4 (21.7)	26
Diastolic blood pressure (mmHg)	95.3 (15)	26

Resting heart rate (bpm)	77.9 (14.1)	26
Weight (kg)*	84 (23.5)	28
Fat index (%)	32.1 (10)	28
Fat mass (kg)*	25.7 (17.8)	28
Muscle mass (kg)*	58.9 (24.1)	28
BMI*	26.9 (8.5)	28
Currently working	3 (11.5%)	26
Participation in sports	10 (32.3%)	26
Injuries/ functional limitations	5 (17.9%)	28
Continuous variables are expressed as mean (SD) unless indicated by an asterisk*, in which case median (IQR) range are reported and categorical variables are expressed as frequency (% per category).		

Feasibility

Feasibility results are summarized in **Table 4.** The retention rate throughout the full trial period was 100%, as all 28 participants whom completed baseline assessment also completed the power training intervention. The attendance of training sessions was 100%, and a review of training records indicated that all 30 participants were able to complete the prescribed exercises within the 45-minute training sessions, making the compliance rate also 100%. Throughout the study period, there were no reports of new injuries, physical complaints lasting longer than 48 hours, or adverse events related to power training. The drop-out rate due to injury was 0%.

Preliminary effectiveness

Results for the preliminary effectiveness of *Powerful Ageing* are summarized in **Table 5**. Within the function domain, significant improvement was measured in all outcome variables for muscle power and anaerobic power. Within the activities domain, the total distance walked during the 6-MWT improved significantly ($p<0.001$) while there was no change in the BORG test. Regarding physical activity in daily life in the participation domain, gait activity, total walking bouts, total short walking bouts, and total long walking bouts increased slightly, but not enough to reach statistical significance. For health status, a trend showing improvement in the

Table 4. Feasibility of power training in older adults.

Feasibility outcome	Value
Retention	100%
Adherence	
Training attendance	100%
Compliance	100%
Safety (drop-out)	0%
N=30.	

Table 5. Preliminary effectiveness of power training in older adults.

ICF domain	Outcome	Test	Variable	Week 0	Week 12	Significance
Function	Muscle power	Weighted squat	Concentric mean power (Watt)	91.5 (32.2)	117.8 (51.6)*	<0.001*
			Concentric peak power (Watt)	172.4 (72.6)	232.2 (118.7)*	<0.001*
			Eccentric peak power (Watt)	145.5 (61.8)	317.6 (60.4)*	<0.001*
			Concentric mean velocity (m/s)	0.5 (0.1)	0.6 (0.2)	<0.001
			Concentric peak velocity (m/s)	0.8 (0.3)*	1.1 (0.3)	<0.001*
	Anaerobic power	Wingate	Average power (Watt)	322.5 (114)*	368.4 (97.6)	0.001*
			Peak power (Watt)	396 (143)*	447 (147)*	<0.001*
			Cadence (rpm)	82.9 (10.3)	87.1 (11.1)	0.001
			Fatigue factor (%)	29 (25)*	40 (22)*	0.007*
Activities	Physical performance	6-MWT	Distance (meters)	436.5 (64)*	600 (117)*	<0.001*
			Borg test	11 (1)*	11 (3)*	0.947*

Participation	Physical activity in daily life	McRoberts MoveMonitor	Gait activity	54.4 (25.6)*	60.4 (30.1)	0.904*
			Measuring period (days)	6.7 (0.1)*	6.25 (0.1)*	<0.001*
			Total walking bouts	1208.3 (479.2)	1377.8 (550.2)	0.206
			Total short walkings bouts	1101.7 (446.6)	1253.7 (501.7)	0.214
			Total long walking bouts	99 (75)*	103 (137.3)	0.696*
	QoL	SF-36	Physical functioning	90 (10)*	90 (6.3)*	0.929
			Energy/fatigue	74.8 (14)	80 (11.3)*	0.372
			Emotional well-being	84.1 (10)	86 (16)*	0.806
			Social functioning	100 (25)*	100 (12.5)*	0.424
			General health	69.2 (16.3)	80 (35)*	0.093

Summary measures are expressed as mean (SD), and differences are tested using a paired samples t-test unless indicated by an asterisk*, in which case median (IQR) range are reported and differences are tested using Wilcoxon signed rank test. Abbreviations: 6-MWT: 6-minute Walk Test; QoL: Quality of Life; SF-36: 36-item Short Form Survey.

energy/fatigue, emotional well-being, and general health domains of the SF-36 was found, but not enough to reach statistical significance. Scores for the physical functioning and social functioning domain of the SF-36 remained the same, and approached the maximum score of 100 points both at baseline and at week 12.

Discussion

Results indicate that *Powerful Ageing* was highly feasible among older adults, as intervention retention, training attendance, and compliance rates were very high and the drop-out rate due to injuries was 0%. Furthermore, preliminary results with regards to the effectiveness suggest that *Powerful Ageing* may improve muscle power and anaerobic power (function domain), and physical performance (activities domain) in older adults. However, no significant effect was found for physical activity in daily life or health status (participation domain).

These results are in line with other studies evaluating the effects or feasibility of power training in older adults [12,31-33]. However, the present study has several additional strengths that add to the current literature. Previous studies assessed their training protocol using tests that focused solely on the strength or velocity component of muscle power [manuscript under review by el Hadouchi et al.]. The sit-to-stand test is commonly used to measure muscle power, but this test predominantly measures the velocity component of muscle power and does not take the contraction force at which the motion is performed into account. In the present study, a weighted squat was performed using GymAware equipment to capture the strength and velocity components of muscle power simultaneously. Similarly, assessing anaerobic power in an older adult population is often done in brief and using measures that provide only an indication of their anaerobic capacity, such as ergometer or treadmill activities and post-exercise measurement of blood lactate levels [34,35]. In contrast, the current study used the Wingate Test, which is considered a widely accepted standard and offers a more accurate reflection of an individual's anaerobic capacity.

It is crucial that power training interventions are tailored towards older adults, including special considerations for the intensity of training, risk of injury, and safety of the participant [20]. Health practitioners and professionals might assume that performing skeletal muscle contractions "as fast as possible" may be dangerous and unsafe for older adults, particularly if clinical conditions are associated with advanced age. However, injuries caused by training in older adults occur most often when individuals exert themselves at or near maximal muscular force, or perform a combination of heavy and repetitive workloads until exhaustion [36]. Therefore, an exercise training aimed at increasing muscle power using lower external loads (20-30% 1RM) than strength training and performed without muscle exhaustion, can be expected to reduce the risk of injury. Additionally, it is of high importance to also take the individual's health status and physical limitations into account and modify or tailor the exercises accordingly. Proper supervision and guidance throughout the intervention are crucial for ensuring safety and effectiveness.

Our results suggest that an increase in muscle power (function domain) and physical performance (activities domain) may not necessarily translate to heightened levels of physical activity in daily life (participation domain). These findings underscore the significance of additional factors, such as motivation, environmental barriers, and individual habits, which are likely to substantially contribute to individuals' engagement in physical activity and their overall health outcomes. Consequently, a singular emphasis on enhancing muscle power and physical performance may prove insufficient to effect substantial changes in daily physical activity among older adults.

Limitations to this study are the small sample size, short duration of the study, and the fact that the study was limited to one geographical area, which are characteristics of a pilot study. Future research in the form of a randomized controlled trial containing a larger sample size and longer follow-up period would be valuable in further investigating the effects of power training in older adults. A more extensive list of covariates should also be obtained, including diet, personal medical history, genetic history, and lifestyle factor, as such factors may influence results. Additionally, the ceiling effect observed in the SF-36 was a limitation to the present study, as this influenced our ability to measure an improvement in health status following the Powerful Ageing. At baseline, mean scores for SF-36 domains ranged between 69-100 points, suggesting that our study population may have been 'too fit' in certain domains of the SF-36 to capture a significant improvement. Future studies evaluating change health status following a power training intervention may need to use a different instrument or should aim specifically at participants of lower health status. We assumed that study participants had experienced age-related decreases in muscle power prior to the start of the intervention, however, it would have been better if measurements prior to baseline were taken to verify the assumed reduction in muscle power.

Conclusion

Powerful Ageing was feasible in older adults, with high rates of intervention retention, adherence, and safety. The intervention may also improve muscle power, anaerobic power, and physical performance in older adults, but appears not to affect physical activity in daily life and health status. Further research in the form of a randomized controlled trial using a validated measurement set is needed to evaluate the effects of power training in older adults.

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Author Contributions Statement

Mohamed el Hadouchi: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Original Draft, Project administration; **Henri Kiers:** Conceptualization, Writing – Review & Editing, Supervision, Funding acquisition; **Brittany A. Boerstra:** Formal analysis, Writing – Review & Editing, Visualization; **Roos Pijpers:** Investigation, Project administration; **Cindy Veenhof:** Conceptualization, Writing – Review & Editing, Supervision, Funding acquisition; **Jaap van Dieën:** Conceptualization, Writing – Review & Editing, Supervision, Funding acquisition.

Conflict of Interest Statement

None declared.

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