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ORIGINAL RESEARCH

The Impact of Power Training on Muscle Power, Physical Performance, and Physical Functioning in Older Adults: A Descriptive Case Series

Mohamed El Hadouchi[1–4], Henri Kiers[1,2], Cindy Veenhof[2,5], Jaap Van Dieën[3]

[1]Institute for Human Movement Studies, University of Applied Sciences Utrecht, Utrecht, the Netherlands; [2]Research Group Innovation of Human Movement Care, University of Applied Sciences Utrecht, Utrecht, the Netherlands; [3]Department of Human Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Amsterdam, the Netherlands; [4]Health Research Consultancy, Sports & Science, Lochem, the Netherlands; [5]Department of Rehabilitation, Physical Therapy Science and Sport, Brain Center, University Medical Center Utrecht, Utrecht, the Netherlands

Correspondence: Mohamed El Hadouchi, Email Mohamed.elhadouchi@hu.nl

Purpose: Powerful Ageing is a power training intervention offered by Dutch municipalities to improve the physical functioning of its older residents, thereby reducing their reliance on assistive living devices and social support services. This study aimed to investigate the effects of Powerful Ageing on muscle power, physical performance, and physical functioning in older adults immediately following the intervention and at 1-year follow-up.

Patients and methods: The study design was a prospective longitudinal case series. Eligible older adults requesting social support services from their municipality participated in a 14-week power training intervention. Primary outcomes were categorized according to ICF health domains: within the function domain, muscle power was measured with a Power Squat Test and a Lifting Test; within the activities domain, physical performance was assessed using the Star Agility Run and Timed Up-and-Go Test; and within the participation domain, physical functioning was assessed using a patient-specific complaints questionnaire. Participant motivation, a secondary outcome, was assessed using a short questionnaire.

Results: Participants showed statistically significant improvements performing the Power Squat Test ($p<0.001$; effect sizes: 0.52–1.00), the Lifting Test ($p<0.001$; effect sizes: 0.64–0.82), the Star Agility Run ($p<0.001$; effect size: 0.61), and the Timed Up-and-Go Test ($p<0.001$; effect size: 0.74) immediately following Powerful Ageing. Additionally, activities of daily life became significantly less difficult to perform (p-value <0.001, effect sizes: 0.60–0.78). Among participants who continued power training following the intervention, these improvements were even greater at 1-year follow up. Participant motivation was high throughout the duration of the study.

Conclusion: Powerful Ageing led to significant improvements in muscle power, physical performance, and physical functioning in older adults. Among participants who continued power training in the year following the intervention, improvements progressed even further, suggesting long-term benefits. Further research is needed to confirm the sustainability of the effects of power training in older adults.

Keywords: exercise intervention, elderly, power squat test, timed up-and-go test, motivation

Introduction

The global population is ageing rapidly, with projections estimating that by 2050, there will be more than two billion individuals aged 60 years or older.[1] Successful aging involves maintaining an active lifestyle, independent functionality, and societal engagement, yet unfortunately, aging is characterized by a decline in muscle power, muscle mass, and muscle strength,[2–4] negatively affecting physical functioning and the ability to perform activities of daily life. With the proportion of older adults increasing, addressing age-related declines in physical functioning becomes crucial. The preservation of physical performance and functioning, both important for maintaining physical independence, are closely linked to muscle power. Muscle power, defined as the product of muscle force and contraction velocity,[5,6] is vital for

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tasks requiring rapid muscle contractions, such as standing up from a chair, climbing stairs, and reacting to balance perturbations. Research has shown that muscle power can be improved by power training, a form of resistance training with the emphasis on the ability to generate muscle force rapidly.[7–10] Therefore, power training appears to be a promising way to maintain or restore muscle power and physical performance in older adults.[11]

Powerful Ageing is a power training intervention offered by Dutch municipalities to improve the physical functioning of its residents, thereby reducing their reliance on assistive living devices and social support services. By increasing older residents' ability to live independently at home longer, healthcare costs can be reduced and quality of life can be increased. Over the past five years, the implementation of Powerful Ageing across the Netherlands shows the program's scalability and potential impact, while the adaptability to various settings and its integration into existing healthcare systems highlight its potential for promoting active aging. A recent pilot study demonstrated that Powerful Ageing is safe, feasible, and replicable in older adult,[12] and prior to conducting this study, it was confirmed that Powerful Ageing was therapeutically valid and met the proposed criteria for power training (Supplemental information 1 and 2). However, further research is needed to investigate the effectiveness of Powerful Ageing, preferably in a larger, older, and more heterogenous study population and using a wider range of outcome measurements. Therefore, the aim of this descriptive case series was to assess the effects of Powerful Ageing on muscle power, physical performance, and physical functioning in older adults immediately following the intervention and one year following the intervention.

Methods

Study Design

This study followed older adults who participated in Powerful Ageing, a 14-week power training intervention conducted at various primary care physiotherapy centers across the Netherlands. The design of the study was a prospective longitudinal case series, with measurements obtained as baseline (T0), immediately following Powerful Ageing (T1), and one year following Powerful Ageing during which participants continued to practice power training (T2). Ethical approval for this study was obtained from the Ethical Commission of Research at the University of Applied Sciences Utrecht. Additionally, this study complies with the Declaration of Helsinki.

Participant Selection

The Social Support Act is a Dutch government initiative that provides support to residents in the form of domestic help, a mobility scooter, or a chair lift to allow residents to continue to live independently. Since 2019, Powerful Ageing has been integrated into the Social Support Act, giving residents the opportunity to improve their physical functioning before requesting additional support. Older adults requesting support via the Social Support Act between October 2020 and April 2023 and who met eligibility criteria were invited to participate, and participant recruitment was facilitated by municipality consultants. A total of 17 municipalities participated: Almelo, Boxtel, Coevorden, Delft, Eemsdelta, Het Hogeland, Hoogeveen, Maassluis, Midden Delfland, Rheden, Schiedam, Smallingerland, Valkenswaard, Vlaardingen, Westland, Weststellingerwerf, and Zoetermeer.

To qualify for the study, participants had to be >55 years of age, reside at home, and be capable of independently traveling to the training facility. Individuals with chronic mental disorders or physical ailments that would hinder full participation in testing or training (e.g. Alzheimer's disease, neurological disorders, or acute cardiovascular disease) were not included in the study. Additionally, a fall risk assessment was conducted to determine participant eligibility for group training. The Fall Risk Assessment tool, comprising of three key questions, was utilized to rapidly identify individuals at increased fall risk.[13] Questions addressed recent fall history, concern about falling, and mobility difficulties. Participants responding negatively to all questions were classified as low risk, while an affirmative response to any question indicated increased risk. Those categorized as having increased fall risk were excluded from the study to ensure participant safety during group exercises.

Once eligibility was confirmed, participants were verbally briefed on study procedures and received written information about the purpose, procedures, as well as potential risks and benefits during a group session. Written informed consent was then obtained from each participant before baseline testing commenced.

Training Protocol

The training protocol for Powerful Ageing has been described elsewhere using criteria from the Template for Intervention Description and Replication Checklist (TIDieR).[12] The included older adults participated in a 45-minute power training session, twice a week, for 14 weeks under the guidance of an experienced physical therapist. Prior to leading the power training intervention, physical therapists completed a 3-day course which covered the Powerful Ageing training protocol, working with older adults, and integrating exercises into activities of daily life. Training groups were limited to eight participants to ensure individualized instruction and supervision such that proper technique, intensity, and set numbers were achieved. Following completion of the 14-week power training, some municipalities offered participants the opportunity to continue training, however, in most municipalities, this was not feasible to organizational factors and a lack of resources. Each training session began with an overview of the objectives and detailed instructions emphasizing movement speed. The 10-minute warm-up included movements and functional exercises from the day's training with minimal or no weight, allowing participants to become familiar with the exercises, while enabling the physical therapist to assess their technique. Each training session involved three components: (1) Olympic weight lifting, such as deadlift high pulls, clean and press, back squats, and snatches; (2) sprint and agility training; and (3) functional movement routines like step-up lunges, burpees, and stair climbing. Throughout the training sessions, individuals were directed to complete 3 sets of 5–7 repetitions within a designated timeframe (e.g. 10 seconds). The exercises were executed with deliberate control, focusing on rapid explosive muscle contraction and gradual relaxation (the movement rhythm followed a pattern with 1 second concentric contractions and 3 second eccentric contractions without rest in between). Between exercises, participants had the option to take a 2 to 5 minutes rest as required, ensuring they could perform at their peak velocity for each exercise.

The exercise load ranged from 20–30% of 1-repetition maximum (1RM). The training load was gradually increased when a participant could comfortably complete the prescribed number of repetitions within the specified time frame (e.g. 5 hang-cleans in 10 seconds) by increasing the weight or the number of sets performed.

Outcome Measurements

Primary outcomes were categorized according to the health domains of the International Classification of Functioning, Disability and Health (ICF).[14] Additionally, participant level of motivation was assessed as a secondary outcome using 6 questions scored on a 5-point Likert scale. The maximum score was 30 points, and participants were considered "motivated" if their score exceeded 18 points (Supplemental information 3).

Muscle Power (Function Domain of the ICF)

Power Squat Test

A Power Squat Test was performed and measured with a GymAware device (Kinetic Performance Technologies, Canberra, Australia), which is a Linear Power Transducer used for measuring sport and performance.[15] Participants were directed to maintain a controlled tempo moving from squatting to standing, holding a 6 kg dumbbell at shoulder height. During the Power Squat Test, participants were instructed to perform a rapid and explosive squat movement, aiming for maximal power output. Outcome variables were the velocity (m/s) of movement and power output (Watt).

Lifting Test (Deadlift)

The lifting test required participants to lift a 6 kg dumbbell at a controlled pace, extending their arms until the dumbbell reached hip height. Participants were instructed to push through their heels, simultaneously extend their knees and hips, and lift the dumbbell close to their bodies along the shins and thighs. It was emphasized to keep the arms straight and maintain a neutral back position, using the legs and hips to generate the lifting force. The test utilized the GymAware for data collection.

Physical Performance (Activities Domain of the ICF)

Star Agility Run

The star agility run test requires participants to move through a series of low training cones arranged in a square, with one cone positioned at the center. The goal was for the participant to tap each cone as they moved through the star-patterned course. We recorded the number of cones touched in 30 seconds.

Timed Up-and-Go Test

The Timed Up and Go assessment involved walking to a cone placed 3 meters away, circling around it, and returning to the chair. The time taken was recorded from when the participant began until they touched the chair again at the end of the test.

Physical Functioning (Participation Domain of the ICF)

PSK Questionnaire

The PSK questionnaire is a patient-specific complaint survey that asks respondents to identify and rate 3 activities of daily life they find difficult to perform. Participants rated the difficulty of the activity on a scale of 0–100, where 0 represents no difficulty and 100 signifies the activity is impossible for them. The first part of the PSK focuses on measuring these difficulties at the activity level. However, in this study, we used the second part to draw conclusions about participation in daily life activities at home, using the difficulty rating to make inferences about problems with participation in activities of daily life.

Statistical Analysis

Usual care data were collected at baseline (T0) and at 14-weeks following the intervention (T1). In the municipalities that offered continued power training following the intervention, measurements were also taken at 1-year follow-up (T2). The quality of the data was checked in Excel (Microsoft, Redmond, United States) prior to analysis in SPSS (IBM, Chicago, United States). Continuous variables were expressed as mean (standard deviation) or median (interquartile range), while categorical variables were presented as frequency (percentage per category). A paired *t*-test or Wilcoxon matched-pair signed rank test of complete cases was used to test differences in measurements taken at baseline (T0) and immediately following the intervention (T1). Additionally, effect sizes were calculated using Cohen's d formula as a measure of the importance of observed differences: 0.2 was considered a small difference; 0.5 was considered a medium difference, and 0.8 was considered a large difference.[16]

Fewer participants were measured 1-year following the intervention (T2) as a result of organizational factors, such as the inability for some municipalities to continue providing power training to a growing group of older adults. As a result, the effect of Powerful Ageing at 1-year follow-up was not tested for statistical significance, and instead, data measured at 1-year follow were used to make observations about longitudinal trends and about program retention.

Results

Study Participants

Baseline data were available for a total of 484 older adults across 17 municipalities in the Netherlands (Table 1). Participants were mostly female (34%), averaged nearly 79 years of age, with a body mass index (BMI) of 28.97 kg/m^2. The majority of patients had self-reported injuries and/or chronic diseases.

Muscle Power (Function Domain of the ICF)

For the 5x Power Squat Test, both mean power and peak power increased significantly from 353.91 and 592.30 Watt (W) at baseline to 427.10 and 761.21 W, respectively, immediately following Powerful Ageing (Table 2). Both mean and peak power were considered to have a medium effect size (0.52 and 0.58, respectively), indicating reasonable differences between pre- and post-measurements. Among participants who continued power training following the intervention, mean and peak muscle power increased to 502 and 945.4 W at 1-year follow-up (Supplemental information 4). Mean and peak velocity increased similarly, from 0.41 and 0.72 m/s at baseline to 0.51 and 0.87 m/s immediately following the intervention. The overall time it took to perform 5x Power Squat Test also improved, from 19.97s at baseline to 14.79s. Among participants who continued power training, one year later, the time it took to complete 5x Power Squat Test was

Table 1 Participant Characteristics

Variable	Baseline Value	Number of Patient Records Available
Men, N (%)	170 (34.4%)	479
Age in years, mean (SD)	78.8 (8.2)	484
BMI in kg/m2, mean (SD)	29.0 (5.0)	122
Muscle mass %, mean (SD)	49.5 (12.5%)	122
Fat mass %, mean (SD)	30.1 (11.0)	121
SBP in mmHg, mean (SD)	149.5 (20.6)	224
DBP in mmHg, mean (SD)	88.1 (13.8)	221
Resting HR in bpm, mean (SD)	72.8 (12.0)	214
Current smoker, N (%)	29 (5.9%)	303
Current medication use, N (%)	362 (73.1%)	412
Presence of injuries/chronic diseases,* N (%)		408
Hip and lower limb conditions	143 (35.0%)	
Spinal and lower back Conditions	99 (24.3%)	
Upper limb conditions	60 (14.7%)	
General musculoskeletal conditions	49 (12.0%)	
Neurological conditions	41 (10.0%)	
Conditions related to chronic diseases	266 (65.2%)	
Specific conditions	25 (6.1%)	
Post-traumatic/surgical conditions	21 (5.1%)	
Non-specific symptoms	36 (8.8%)	
Currently working, N (%)	11 (2.2%)	350
Municipality region, N (%)		495
North	122 (24.7%)	
East	113 (22.9%)	
South	59 (11.9%)	
West	200 (40.5%)	
Living situation, N (%)		402
Independent without stairs	155 (38.6%)	
Independent with stairs	247 (61.4%)	

Notes: Due to the pragmatic nature of the study, not all baseline measurements were available for all participants, leading to varying degrees of patient records available. * = self-reported injuries/chronic diseases.
Abbreviations: SD, standard deviation; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

11.10 seconds. The effect size for mean and peak velocity, and the time to complete 5x Power Squat Test, was considered large, ranging from 0.76–1.00.

For the deadlift, mean and peak power increased from 38.93 and 70.68 W at baseline to 52.54 and 101.77 W immediately following the intervention. Among participants who continued power training, mean and peak power were 56.3 and 114.4 W at 1-year follow-up. Similarly, deadlift mean and peak velocity showed comparable improvements, from 0.68 and 1.06 at baseline to 0.94 and 1.39 following Powerful Ageing. The effect size for mean power (0.82), peak power, and mean velocity (both 0.78) was considered large, while the effect size for peak velocity was in between medium and large (0.64).

Table 2 Primary and Secondary Outcomes

Level	Outcome	Measurement Instrument	Variable	Baseline (T0)	Immediately Following Powerful Ageing (T1)	p-value	Effect Size	N
Primary	Muscle power	5x Power Squat Test	*Time, (s)	20.0 (10.5)	14.8 (6.7)	<0.001	0.830	252
			Mean muscle power, (W)	353.9 (132.5)	427.1 (150.8)	<0.001	0.516	201
			*Peak muscle power, (W)	592.3 (356.3)	761.2 (402.9)	<0.001	0.584	207
			*Mean velocity, (m/s)	0.4 (0.2)	0.5 (0.2)	<0.001	0.760	202
			Peak velocity, (m/s)	0.7 (0.2)	0.9 (0.2)	<0.001	1.000	207
		Lifting Test (deadlift)	*Mean power, Watt	38.9 (19.7)	52.5 (23.7)	<0.001	0.818	203
			*Peak power, Watt	70.7 (40.9)	101.8 (63.2)	<0.001	0.775	204
			Mean velocity, (m/s)	0.7 (0.2)	0.9 (0.3)	<0.001	0.784	206
			*Peak velocity, (m/s)	1.1 (0.5)	1.4 (0.6)	<0.001	0.641	205
	Physical performance	Star Agility Run	*Number of cones touched	4.0 (2.7)	5.7 (3.0)	<0.001	0.606	317
		Timed Up-and-Go Test	*Time, seconds	10.2 (4.6)	7.8 (3.5)	<0.001	0.740	351
	Physical functioning	PSK questionnaire	*Activity 1 (0–100)	80.0 (20.0)	60.0 (40.0)	<0.001	0.779	324
			*Activity 2 (0–100)	80.0 (30.0)	60.0 (40.0)	<0.001	0.664	317
			*Activity 3 (0–100)	75.0 (30.0)	60.0 (40.0)	<0.001	0.604	243
Secondary	Motivation	Short survey	*Score (0–25)	27.0 (6.0)	30.0 (6.0)	<0.001	0.132	137

Notes: Analysis reflects complete cases only. * = non-parametric variable: median (IQR) are reported and Wilcoxon matched-pairs signed ranks test was performed.
Abbreviations: m, meter; s, seconds; W, watt.

Physical Performance (Activities Domain of the ICF)

The number of cones touched in the Star agility run increased from 4.00 at baseline to 5.67 immediately following the intervention, indicating a medium effect size of 0.6. This further increased to 9 at 1-year follow-up for participants who continued power training following intervention. For the Timed Up-and-Go test, the time to complete the task decreased from 10.18s at baseline to 7.81s following the intervention, and decreased to 6.8s one year after the intervention among participants who continued power training. The effect size for the Timed Up-and-Go test was close to being considered large (0.7).

Physical Functioning (Participation Domain of the ICF)

Scores on the PSK questionnaire for the three most challenging daily activities showed significant improvements: the difficulty scores for activities 1 and 2 both decreased from 80 to 60, and the difficulty score for activity 3 decreased from 75 to 60. One year after the intervention, PSK scores continued to decrease among participants who continued power training. The effect sizes ranged from 0.78 in activity 1 to 0.60 in activity 3, indicating medium to large differences.

Motivation

Participants were considered motivated to participate in *Powerful* Ageing, as was reflected by motivation scores, with a mean of 27 at baseline and 30 following the intervention. The effect size for motivation was 0.13, indicating small differences.

Discussion

Summary of Main results

This study aimed to investigate the effects of Powerful Ageing on muscle power, physical performance, and physical functioning in older adults immediately following Powerful Ageing and at 1-year follow-up. Our results demonstrate significant improvements with medium to large effect sizes in muscle power, physical performance, and physical functioning following Powerful Ageing. These improvements appear to be maintained or further enhanced one year after the intervention in participants who continued to train, suggesting the impact of power training on the physical capabilities of older adults was durable. The high motivation scores increased over the training period, indicating high participant engagement and satisfaction with the intervention, while also mirroring the results of the previously-conducted feasibility study.[12]

The benefits of power training rely on both consistent participation and the implementation of a well-structured protocol. The program described in this study, Powerful Ageing, has been tested for its therapeutic validity and reproducibility, likely contributing to the positive results found in the present study. The study also supports the feasibility and acceptability of the Powerful Ageing intervention, as evidenced by high motivation scores and participant retention rates. These strengths underscore the potential of power training as a viable strategy to enhance physical function and independence among older adults.

Comparison with Previous Literature

The magnitude of improvement in our study corroborates and extends previous longitudinal studies on power training in older adults. Ramírez-Campillo et al (2014) documented significant improvements in functional performance metrics after a 12-week power training intervention,[9] and Henwood et al's (2018) 24-week follow-up study after an 8-week high-velocity resistance training intervention showed maintained improvements in muscle strength and power relative to baseline, despite some performance decline.[17] Similarly, Pereira et al (2012) reported significant functional performance improvements immediately after a 12-week power training program, with partial retention after 12 months of detraining.[18] Our study suggests not only maintenance, but improvements in muscle power and physical functioning over the course of one year in people who continued to train.

Strengths and Limitations

This study has several notable strengths. The multi-center design across multiple municipalities in the Netherlands enhances the generalizability of findings to a broader population of older adults. Additionally, it shows that power training interventions are able to be implemented in a practical community setting. Our use of objective measures for muscle power and physical performance in usual care provides robust data to support the observed improvements. Moreover, the follow-up at 1-year post-intervention offers a better understanding into the potential durability of the effects of power training, however, further research is needed to confirm the sustainability of these effects and compare these with a control group.

Several limitations should be considered when interpreting the results of this study. First, the study design was a descriptive case series without a control group, limiting the strength of evidence considering the effectiveness of the intervention. Second, the study partially relied on self-reported outcomes measures, such as the PSK questionnaire, which could be subject to response bias. However, the use of such measures also allows for inclusion of patient-reported outcomes. Third, due to the pragmatic nature of the study, we encountered large differences in the availability of data between measuring points. This is a common limitation in usual care research, where a greater emphasis is placed on the intervention rather than research proceedings. However, this did limit our ability to assess the long-term effects of Powerful Ageing. It is possible that the trend observed one year following the intervention is an overestimation, as it is likely that the "healthiest" and "fittest" participants will continue power training following the intervention.

Clinical Implications and Future Research

Care for older adults is shifting away from traditional forms of support, such as household assistance or providing aids, and instead, is actively promoting self-reliance in physical abilities. The significant improvements in muscle power, physical performance, and physical functioning observed following Powerful Ageing suggest that power training can be an effective component of rehabilitation and preventive care for older adults. Incorporating power training into standard physiotherapy practice or existing interventions for older adults could enhance the ability of older adults to maintain their independence, perform daily activities more efficiently, and potentially reduce the need for assistive devices or social support services. The improvements observed one year post-intervention suggest long-term benefits, which could be an important addition to regular care plans.

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The high levels of motivation and participant satisfaction suggest that power training is a well-accepted and engaging form of exercise for older adults. This is critical for adherence and long-term success in maintaining physical activity levels. We should consider recommending power training as a key component of comprehensive care for older adults, especially for those who are at risk of functional decline. While these results are promising, they highlight the necessity for further research to confirm that power training is an effective intervention for improving and maintaining physical functioning in older adults, and if this is the case for all sub-groups as well (e.g. oldest old, those with specific injuries or disorders). To do so, a randomized controlled trial is needed to compare the efficacy of power training, traditional strength training, general conditioning exercises, and usual care provided by physiotherapy. Such a study would provide robust evidence to determine which approach best supports the physical independence and quality of life of older adults. By addressing this research gap, we can better inform clinical practice and optimize intervention strategies to support successful aging. Future research should also aim to exploring the underlying mechanisms through which power training exerts its effects could provide valuable insights for optimizing exercise protocols. Investigating factors such as neuromuscular adaptations, changes in muscle architecture, and improvements in balance and coordination could help refine and enhance the effectiveness of power training interventions.

Conclusions

The findings of this study demonstrate that the Powerful Ageing intervention leads to significant improvements with medium to large effect sizes in muscle power, physical performance, and physical functioning among older adults. These improvements were not only found immediately following the intervention, but also seemed to be sustained one year later among participants who continued power training, indicating long-term benefits of power training. Furthermore, the increase in motivation scores suggests high levels of participant engagement and satisfaction with the intervention. Further research is needed to confirm both the short- and long-term effectiveness of power training in older adults, preferably in the form of a randomized controlled trial.

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Disclosure

The first author (MeH) holds a dual role as researcher and entrepreneur. To safeguard the independence of research, MeH was not involved in the data collection process and all data were anonymized prior to data analysis. The data were used exclusively for scientific purposes. The authors report no other conflicts of interest in this work.

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