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COMPARISON OF POWER TRAINING USING PLATE-LOADED VS. PNEUMATIC MACHINES ON STRENGTH, POWER, AND PHYSICAL FUNCTION IN OLDER ADULTS

By

Anoop Thozhuthungal Balachandran

A DISSERTATION

Submitted to the Faculty
of University of Miami
in partial fulfillment of the requirements for
the degree of Doctor of Philosophy

Coral Gables, Florida

August 2016

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COMPARISON OF POWER TRAINING USING PLATE-LOADED VS. PNEUMATIC MACHINES ON STRENGTH, POWER, AND PHYSICAL FUNCTION IN OLDER ADULTS

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(August 2016)

Comparison of Power Training Using
Plate-Loaded vs. Pneumatic Machines
on Strength, Power, and Physical Function in Older Adults

Abstract of a dissertation at the University of Miami.

Dissertation supervised by Professor Joseph F. Signorile.
No. of pages in text. (33)

Background: In randomized controlled trials, power training has been shown to be more effective than conventional resistance training for improving physical function in older adults; however, most of these trials used pneumatic machines for power training. Considering that the majority of the people only have access to plate-loaded machines, it is important to examine the benefits and adverse effects of power training using plate-loaded machines compared to pneumatic machines to determine the feasibility of their use.

Objective: The purpose of this investigation was to compare high-velocity training using pneumatic machines and standard plate-loaded machines on power, physical function, strength and adverse effects.

Methods: A total of 36 independently-living older adults, 65 years or older, were randomized into two groups: pneumatic machine (Pn, n=19) and plate-loaded machine (PL, n=17). After 12 weeks of high-velocity training twice per week, groups were compared using an intention-to-treat approach. The primary outcome was lower body power measured using a linear transducer and upper body power using medicine ball throw. Secondary outcomes were lower and upper body strength, the Physical Performance Battery (PPB), gallon jug test and get up and go test, and self-reported function using Patient Reported Outcomes Measurement Information System (PROMIS) and an online video questionnaire. The outcome assessor was blinded to group membership.

Results: Lower body power significantly improved in both groups (Pn: 19%, PL: 31%), but there was no significant difference between the groups (d=0.4, 95% CI (−1.1, 0.3). Upper body power significantly improved only in the PL group, but showed no significant difference between the groups (Pn: 3%, PL: 6%). For secondary outcome of balance, the Pn group showed a significant difference between the groups and favored the Pn group (d=0.7, 95% CI (0.1, 1.4). There were no statistically significant differences between the groups for PPB, gallon jug transfer, strength, get up and go or self-reported function. No intervention-related or serious adverse events were reported in either of the groups.

Conclusions: Pneumatic machines were not superior to plate-loaded machines in improving power in older adults. Pneumatic and plate-loaded machines were both effective in improving lower body power and physical function in older adults. The results suggest that power training can be effectively and safely performed using plate-loaded machines among older adults.

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CHAPTER 1: INTRODUCTION

It is well established that normal aging, even in the absence of overt disease, leads to a gradual decline in muscle mass and strength[1]. This progressive decline can lead to the loss of physical independence, increased fall probability, poor quality of life, increased health care costs and lowered life expectancy[2-45]. It has been estimated that 20-30% of community-dwelling older adults report poor mobility and impairments in instrumental (IADL) and basic activities of daily living (BADL)[6].

Resistance, cardiovascular, balance, and flexibility training modalities are currently recommended to improve physical function in older adults[7-9]. Among all the exercise strategies, resistance training has been shown to have the greatest impact on increasing muscle strength and mass in young and old participants[7,8].

Muscle power is an important determinant of physical function in the aging population[10]. During the aging process, muscle power declines two to three times faster than muscle strength and it is more strongly related to physical function than muscle strength or muscle mass[11-13]. Power-training is typically characterized by a rapid concentric phase (muscle shortening) followed by a slower eccentric phase (muscle lengthening) performed at moderate to high loads, and is often termed high-velocity training. Multiple systematic reviews and meta-analyses have now shown that high-velocity training may be more beneficial in improving older persons' power and function than conventional resistance training[14,1516]. Recent power training trials in special populations, such as those with Parkinson’s disease, osteoarthritis and knee arthroplasty further demonstrate the positive role of power in physical function[17-19]. However, the majority of power training studies were conducted using pneumatic machines that are specifically designed for power or high-velocity training[20-26]. Pneumatic machines, due to their high cost and reliance on special support equipment, such as a dedicated compressor and pneumatic lines, are generally limited to research facilities. Although power training studies using conventional plate-loaded machines have increased in the past few years [27-29], the benefits and safety of power training using plate-loaded machines compared to pneumatic machines remains uncertain.

Acute exercise conditions have shown pneumatic machines to be superior to standard plate-loaded machines on certain neuromuscular variables. For example, Napoli et al.,[30] showed using EMG wavelet analysis that pneumatic machines evoked greater temporal intensity during eccentric and concentric contractions than high-speed plate-loaded machines during a leg extension exercise. In another study, Peltonen et al., [31] showed that compared to standard plate-loaded machines, pneumatic machines generated lower levels of peripheral fatigue during hypertrophic loading and lower central fatigue during power and strength training. These acute results potentially indicate that pneumatic machines could be better than plate-loaded machines in improving performance variables in older adults. However, to our knowledge, no long-term study has compared the effects of high-velocity training using pneumatic machines and standard resistance training machines on power, physical function and adverse effects in older adults.

In light of the benefits of power training in older adults and the paucity of studies comparing power training using pneumatic and plate-loaded machines, the purpose of the current study was to assess upper and lower body power, physical function, and adverse effects of high-velocity training using plate-loaded compared to pneumatic machines.

We hypothesized that pneumatic machine training would be superior to plate-loaded machine training for increasing power, physical function, activities of daily living and self-reported function while the plate-loaded machine training would produce greater improvements in strength.

CHAPTER 2: METHODS

Participants

The study was a 12-week randomized, controlled, single-blind study to assess neuromuscular performance, body composition and IADL function in older persons. A CONSORT flow diagram of the study is presented in Figure 1.

Participants were recruited from the local South Miami community using flyers, posters, and advertisements in newsletters. We also used an internal database that contained names of older adults interested in participating in research. Additionally, participants were recruited by posting an advertisement in the local newspaper. The criteria for inclusion were that volunteers should be between 60 and 90 years of age, live independently in the community, not have lifted weights regularly in the past six months, be planning to reside in the area for the duration of the study, and be able to communicate and read in English. Exclusion criteria included neurological impairments that would affect balance, severe cognitive impairment (Mini-Mental State Examination score of 19 or below), severe musculoskeletal impairment, unstable chronic disease state, major depression, severe vestibular problems, severe orthostatic hypotension, simultaneous use of cardiovascular, psychotropic and antidepressant drugs as reported by the subjects, and active participation in a resistance or balance training program. The protocol was approved by the University's Institutional Review Board and all participants signed an informed consent.

Participants were stratified based on the lower body power they produced (<800 W and ≥800W) during the pre-test using a 1:1 allocation with a random block size of 2, 4 or 6. Following stratification, participants were randomized into either the PL or Pn group using a computer-generated randomization list. To ensure concealment of group allocation, randomization and group allocation were implemented by personnel not involved in the study or the recruitment of subjects.

Interventions

The duration of the intervention was 12 weeks and the participants engaged in a full-body workout twice per week. After randomization and prior to the start of training, training loads were determined by finding the 10-repetition load reported to be at a moderate intensity for each subject and exercise using a rating of perceived exertion (RPE) of 5-6. Within the 12-week training period, participants went through a 2-week preparatory phase during which the volume was gradually increased from 1 set to 3 sets. Subsequently, each training session began with 1 set of warm-up at 50% of the set workload for 8–10 repetitions on two multi-joint upper body and lower body machines. The intensity, volume, and progression were based on the current resistance training guidelines recommended by the American College of Sports Medicine [9] including:

- the intensity ranging from a moderate intensity (5-6) on an RPE scale of 0-10;
- a volume of 3 sets of 12 repetitions;
- participants performing the concentric phases of each exercise as fast as possible and the eccentric phase in 2 s;.
- a load increase of 5 to 10% based on the specific exercise when participants could perform 3 sets of 10 repetitions with proper form while reporting an RPE of less than 6;
- the repetition range being reduced to 8 repetitions rather than 10 after eight weeks;

- periodization of load (increase in intensity and decrease in volume) during the final weeks to ensure progression throughout the duration of the study[32];
- a one minute recovery between sets; and,
- both groups performing five lower body and six upper body exercises targeting the major muscle groups as shown in Appendix A.

The PL group performed all the exercises seated using conventional resistance machines (VR2: Cybex International, Inc., Medway, MA, USA), while the pneumatic group performed all exercises using pneumatic machines (Keiser A420, Keiser Sports Health Equipment, Fresno, CA). Both groups performed exercises targeting similar muscle groups. Each session ended with a 5 minute cool down involving stretching exercises and light calisthenics. The training sessions were supervised by a minimum of two trainers. All trainers were exercise physiology majors who received comprehensive preparation prior to the start of the study.

Primary Outcomes

Subjects and trainers were not aware of the hypotheses being tested; hence, participants were partially blinded. Tester for post-testing was blind to group assignments.

Upper Body and Lower Body Power Testing

Chair stands using a linear transducer (TENDO Sports Machines; Trencin, Slovak Republic) were used to assess lower body peak power. Chair stand power using a Tendo Weight Lifting Analyzer has been shown to be valid, reliable and sensitive to change due to training[27,33,34]. The highest peak power across five chair stands with one minute of rest between stands was used for statistical analysis.

The seated medicine ball throw test was used to assess upper body power. The test has been shown to be valid, reliable, and safe for measuring upper body power in older adults[35]. The score is the horizontal distance participants can propel a 3 kg ball without any trunk flexion. The chair stand and medicine ball throw were chosen as tests for upper body and lower body power instead of the pneumatic or plate-loaded chest or leg press machines, since improvements seen on either machine might be biased in favor of the machine used during training.

Secondary Outcomes

Physical Function Measure

The Physical Performance Battery (PPB) was chosen to detect performance changes since it is specifically designed for well-functioning older adults. The battery includes balance (tandem stance, semi-tandem and single leg stance), five chair stand, normal gait speed, and narrow walk. The PPB modifies an established performance battery, namely the Short Physical Performance Battery (SPPB), by adding more challenging tasks, the single leg stance and narrow walk[36,37]. In addition, estimates of meaningful or clinically significant changes in PPB have been previously reported[38].

Upper Body and Lower Body Strength

The 30 s Arm Curl is a general measure of upper body strength. The score is the total number of arm curls (5 lb dumbbell for women, 8 lb dumbbell for men) performed through a full range of motion in 30 s. A moderate to high correlation (0.84 for men and 0.79 for women) was observed between the arm curl test and a composite measure of upper body strength that included the one-repetition maximum (1RM) for bicep, chest, and upper back strength [39] .

The 30 s Chair Stand test was used to measure lower body strength. Studies have shown that chair stand performance correlates well with other indicators of lower body strength (knee extensor, knee flexor and 1RM leg press strength) and functional measures such as stair climb, walking speed, and risk of falling; and can also detect age-related functional decline[40,41]. The 30 s chair stand exhibits a moderate to high correlation of 0.78 in men and 0.71 in women compared to the 1RM leg press.[41] The score is the total number of times that an individual can rise from a seated position to a full stand without pushing off with their arms.

Activities of Daily Living

The timed up and go (TUG) is a test to assess dynamic balance, fall risk and agility. It has been shown to be well correlated to the Berg balance score (r=0.81), gait speed (r=0.6), and the Barthel index of ADL's (r=0.78)[42]. A TUG score of 14 s is sensitive (87%) and specific (87%) for identifying elderly individuals who are at risk for falls [43]. Two trials were performed with the lower score used for statistical analysis.

The gallon-jug shelf-transfer test is designed to mimic an important activity of daily living, the transfer of a moderately heavy object. The test has been shown to be valid, reliable, and responsive in elderly population[44]. Each participant was asked to sequentially transfer five 1-gallon jugs as quickly as possible from a lower shelf, aligned with the participant's patella, to a higher shelf placed at the level of the top of the participant's shoulder. Two trials were provided with a 1-minute recovery between trials.

Self-Reported Physical Function Questionnaire

It is now known that self-report assessment and performance assessment of physical function are distinct, yet complementary concepts and both have their own advantages and disadvantages [45]. The PROMIS physical function questionnaire uses item response theory (IRT) and computer-aided testing (CAT) to improve precision and quality and has been shown to be reliable and valid in a large sample of the general population[46]. In addition, a novel online video questionnaire was used to assess physical function in the participants. The test has been shown to be valid and reliable in community living older adults[47]. The questionnaires were administered using our laboratory computers.

Ratings of Perceived Exertion (RPE)

Ratings of perceived exertion (RPE) have been assessed for the total body and the active muscles to track resistance training progressions and prescribe training intensities[48]. OMNI (omnibus) scales include mode specific pictorials, numerical ratings, and corresponding verbal descriptions that are distributed along an increasing intensity gradient thus making the scale easier to interpret [49]. The session RPE were recorded for each participant after their cool down (5 min after the workout session). Also, RPE was recorded after each exercise to track weight progressions.

Adverse Effects

Reporting of adverse events was based on the four types of events (falls, cardiovascular-related episodes, musculoskeletal-related events, and health care) suggested by the Behavior Change Consortium (BCC) of the NIH when reporting trial results for physical activity interventions[50]. Since most adverse events in resistance training studies are musculoskeletal in nature, we chose to further refine the classification of severity of musculoskeletal events as reported by the BCC. The form and the classification of adverse events are shown in Appendix 1.

Statistical Analysis

An analysis of covariance (ANCOVA) was used to examine between group differences using baseline values as a covariate. All significance tests were two-tailed and an alpha level of .05 was required for significance. An intention-to-treat approach (ITT) in which participants were grouped according to randomization assignment and primary outcome data was used. Adjusted means and pooled SD as a standardizer were used to calculate Cohen's *d*. All statistical analyses were performed with SPSS, version 22 statistical package (IBM SPSS Statistics, Armonk, NY).

For the primary outcome of lower body power, a large effect size of 0.8 was chosen to calculate sample size. Taking into account the cost and special requirements of pneumatic machines, at least a large effect size difference was determined to be warranted between groups to adequately demonstrate differences. Thus based on a 5% two-sided significance level and power of 80%, a sample size of 26 was required in each group. Using a correlation of 0.80 obtained between pretest and post-test during comparisons of functional variables in our previous studies, we applied the ‘design factor (correction factor)’ for ANCOVA [51]. The sample size was therefore reduced to 16 per group. Accounting for a 10% drop out rate, a conservative estimate for this type of study in our laboratory, the final sample size calculated was 18 per group.

CHAPTER 3: RESULTS

As shown in Figure 1, 36 subjects were recruited and randomized into two groups: 19 in the pneumatic group (Pn) and 17 in the plate-loaded group (PL). Baseline characteristics were similar in the groups and are shown in Table 3.1.

Adherence to Intervention

Intervention adherence (the number of sessions attended / total session * 100) for the Pn group was 84% (SD, 16%) and for the PL group was 87% (SD, 10%).

Adverse Events

As shown in Appendix B, there were no serious adverse events in any of the categories. All events were reported as either possibly related or not related to the intervention, and musculoskeletal events were the most common. The classifications for the adverse events are also shown in Appendix B.

Primary Outcomes

Results for chair stand peak power and medicine ball throw are shown in Table 3.2. The chair stand peak power showed no significant difference between the groups (MD = 113.7 W, 95% CI (-293, 65); p = .21); however, there was a small effect size (g = 0.4, 95% CI (− 1.1, .3) favoring the PL group. Analysis of unadjusted means for peak power did not change the outcomes, once again showing a small effect size (g = 0.4, 95% CI (− 1.0, 0.3), p = .46). Per protocol analysis did not change the outcomes. Both the Pn group (d = 0.7, p = .007) and the PL group (d = 0.9, p = .001) showed improvements. Pn showed a 174 W (19%) increase in peak power, while PL showed a 287 W (31%) increase.

For the medicine ball throw, there was no significant difference between the groups (MD = 0.1, 95% CI (-0.3, 0.1); $p = .35$). For within-group changes, PN ($d = 0.1$, $p = .18$) showed no significant improvement, while PL ($d = 0.2$, $p = .001$) did improve significantly. SC showed a 0.1 m (3%) increase; while PL showed a 0.2 m (6%) increase. Using per protocol analysis to estimate the effect of received treatment did not change the outcomes as shown in Appendix C.

Secondary Outcomes

Strength

Results for secondary outcomes are also presented in Table 3.2. Upper body and lower body strength assessed using the 30 s arm curl and 30 s chair stand tests, respectively, showed no significant difference between groups. However, both arm curls (d=0.3, 95% CI (-0.9, 0.4), $p = .33$) and chair stand d=0.2, 95% CI (-0.8, 0.5), $p = .5$ showed a small effect size favoring the PL group. For within-group improvements in arm curls, both Pn (d=0.9, $p < .001$ and PL (d=1.4, $p < .001$) showed significant improvements. For 30 s chair stand, both Pn (d=0.9, $p < .001$) and PL (d= 0.9, $p < .001$) showed significant improvements.

PPB

PPB showed no significant difference between the groups, For within-group changes, both Pn (d = 1.2, $p < .001$) and PL (d= 0.8, $p < .001$) showed significant improvements. For the components of the PPB, total balance showed a statistically significant and moderate effect size (d = 0.7, 95% CI (-0.6, 1.4), $p = .004$) in favor of Pn compared to PL. Normal, narrow walk and 5 chair stands showed no significant differences between the groups. While there was no improvement seen for either group in narrow walk performance, both Pn (d = 0.8, $p < .001$) and PL (d = 0.7, $p < .001$) improved significantly in chair stand performance ($p = .05$). On the contrary, for normal walk, only Pn showed a significant improvement (d =0.5, $p < .01$)

Activities of Daily Living

For ADL, there were no significant between-group differences. For within-group changes, the gallon jug transfer for Pn (d=0.5, $p = .001$) and PL (d= 0.7, $p < .001$) and TUG Pn (d=0.5, $p < .001$) and PL (d= 0.8, p =.001) showed significant improvements. For self-reported function analysis using PROMIS and online video questionnaire no significant differences between the groups were seen. For within-group changes, only the PL group showed a significant improvement in the video questionnaire (d= 0.7, $p = .02$)

Training Changes in Strength and Power

Between-group analyses, revealed no significant differences across the training period for chest press (MD=1.0, 95% CI (-8, 10) and for leg press (MD =5.0, 95% CI (-28, 38). Changes in power for the Pn group are shown in Appendix D. The average increase in power from week 3 to week 12 for the leg press and chest press were 228 W ± 80.8, $p < .001$ and 48 W ± 20.3, $p =.01$, respectively. The average RPE tracked for leg press (Pn: 5.67 ± 0.31; PL: 5.68 ± 0.23) and for chest press (Pn: 5.9 ± 0.31; PL: 5.79 ± 0.36) for the duration of 12 weeks suggests a moderate level of effort as intended and corresponds to a load of 50 -70% for both PL and Pn. In addition, session RPE showed no significant difference between the groups.

CHAPTER 4: DISCUSSION

This study showed that after 12 weeks of power, or high-velocity, training there was no significant difference in power increases produced using Pn and PL machines. To our knowledge, this is the first trial to compare the effectiveness of Pn to traditional PL machines in improving power and physical function.

For the primary outcome of lower body peak power, chair stand time, the Pn group showed a significant 19% increase, while the PL showed a significant 31% increase. These results are consistent with those reported in other power training studies. Studies lasting 16 weeks or more showed large increases in power, which ranged from 50 to 98%[21,25,55,56]. However, similar to the current study , majority of the short term (12-15 weeks) studies showed power change between 10 and 41%[22-24, 28, 29, 52-54,57]. These studies used both pneumatic and plate-loaded machines for training. Notably, most of these power training studies measured power using the same leg press or leg extension machine used during the training intervention[22-24,52-54]. Consistent with specificity theory, studies that showed the least improvements in power, ranging from 8% to 22%, used tests that were not part of the training intervention. For example, studies using counter movement jump (CMJ) as a measure of lower body power, while using plate loaded machines for the intervention, reported increases in power of 17.5% to 22%[28,29,57]. Similarly, a study that used chair stands to measure power and plate-loaded machines for training showed a 10% increase in power[27]. The current study used machines for training and tested power using exercises that were not part of the intervention. So the power improvement observed in the current study is similar and in the upper range of studies using a comparable modality of training and testing.

A 9-10% increase in leg press power is considered to be clinically meaningful improvement, while an 18-19% is considered a substantial improvement in mobility-limited older adults. Our study showed a 19-30% improvement in power. However, these improvements were in healthy older adults and used a functional test of leg power rather than leg press.

For upper body power measured by the medicine ball throw, the Pn showed a non-significant 3% increase, while the PL groups showed a significant 6% increase. Two studies reported increases in medicine ball throw ranging from 15% to 21% [2928]. However, these studies included medicine ball throws as part of the intervention, bringing into question whether this large increase may have been the result of utilizing a training exercise as a testing tool. As shown in Appendix D, the training improvement in power at 10 weeks was 228 W for leg press and 48 W for chest press. This is similar to a previous study conducted in our lab across a10-week training period (Leg press: 205 W, Chest Press: 37 W)[47]. Likewise, Feilding et al.[25] showed a similar increase in leg press training power of 277 W in 10 weeks.

Strength, as measured by 30 s chair stand and arm curl tests, showed no statistically significant differences between the groups; but significant within-group improvements were seen for both 30s chair stand (Pn = 17.4%; PL = 21.4%) and arm curl (Pn = 17.7%, PL = 24.1%). Ramírez-Campillo et al.[28] reported a 21% increase in chair stands after a 12 week study while Correa et al. [29]showed an 8% improvement in a 6 week intervention. For PPB, both groups showed statically significant and clinically meaningful improvements (CMI) of 0.3 points (CMI for PPB = 0.23 points). For the components of PPB, however, balance showed a statistically significant between-group difference and a moderate effect size in favor the Pn group. Studies have shown lower loads emphasizing velocity have a greater influence on low force tasks such as walking and balance, than on strength-dependent tasks such as stair climbing or rising from a chair[58-60]. Consistent with this hypothesis, despite similar improvements in power for 20, 40 and 80% 1RM, balance showed the greatest improvement using low loads [59]. The greater improvement observed in chair stand and arm curl strength in the PL group suggest that the greater improvement in chair stand power in the PL group could be largely due to increase in the force rather than the velocity component of the power equation.

Activities of daily living measured by gallon jug transfer and TUG, showed significant improvements of 10-15% in both groups, while other power training studies have shown an 11-18% improvement in TUG after power training[28,54,61]. For example, one study showed an 18% improvement after 12 weeks in TUG, but the training involved countermovement jumps[28]. Self-reported measures assessed by PROMIS and video questionnaire showed no significant difference between the groups. PROMIS showed 1-2% and the video questionnaire showed a 7-11% improvement. Few studies have assessed changes in self-reported function in response to power training. They showed a modest 4-14% improvement in mobility-limited older adults[24,62]. PROMIS assesses global physical function and includes improvements in strength and cardiovascular components. To our knowledge, the sensitivity of PROMIS to exercise has yet to be assessed. In the ADL video questionnaire, the questions evaluate daily living tasks that are limited by strength and coordination, such as weighted pan carry and getting up the from the floor. Once again, the sensitivity of this tool to change has not yet been determined.

Overall intensity was maintained at approximately 5-6 RPE in both groups as shown by the session RPE. Further, session RPE showed no significant difference between the groups and the leg press and chest press RPE tracked over the training duration also showed no differences. These results imply that any differences in power, physical function and ADL's between groups were not related to a difference in effort or intensity between groups.

Adverse events self-reported by the subjects were either 'possibly related' or 'not related' to the intervention. None of the events were reported as 'definitely related'. In addition, there were no serious adverse events reported for any of the categories. Most of the musculoskeletal events reported were due to existing injuries, like shoulder and knee pain. The lack of any major events could be due to the moderate effort maintained during the program as indicated by the session and exercise RPE. In addition, the subjects went through a 2-week preparatory phase during which volume and intensity were gradually increased and detailed instructions on proper and safe technique were provided. Intervention adherence was approximately 85% for both groups, showing that the program was well tolerated by both groups.

Strength and Limitations

The strengths of the study included using a blinded assessor for post-testing for all outcomes including adverse events and analysis using an intention-to-treat approach. Blinding is a widely recommended strategy to reduce bias in scientific trials, particularly when assessing subjective outcomes[63]. Trials that used blinded assessors tend to report smaller effect sizes than do those that used un-blinded assessors[64]. An ITT analysis was used since an intention-to-treat approach is considered the best analysis for a superiority trial[65]. To our knowledge, this is the first power training trial to use an ITT approach. Second, the study used a pragmatic approach by employing RPE for selecting training loads and also by progressing weights using both RPE and repetitions completed while most studies either tested 1RM every 2-4 weeks or progressed weights based on repetitions completed. Also, progressing weights using both a subjective scale like RPE and an objective criteria of repetitions completed could be beneficial in improving adherence in a population prone to frequent joint discomfort and muscle pain.

The study also has some limitations. First, the intervention period was only 12 weeks and involved healthy community-living individuals. The benefits and adverse effects of power training beyond this training duration, or in older adults with compromised function, remains undetermined. Second, although we showed similar improvements compared to other studies and used a blinded assessor, the study lacked a control group. Studies, with similar duration and population to the current study, which used a sedentary, control showed very small and negative changes in the control group. For example, two studies employing a control group showed power changes in the range of -2% to 1.4% for lower body power using CMJ , -0.8% to -5.6% for upper body power using chest press and medicine ball throw, -1.6% for chair stands, and 1.2% for TUG [28, 57].

Conclusion

Contrary to our hypothesis, power training using pneumatic machines was not superior to plate-loaded machines for improving power and physical function. Both groups showed similar improvements in lower body power and activities of daily living. Considering the availability of plate-loaded machines, the lack of adverse events related to the intervention, and the improvements seen in power and physical function, the study shows that high-velocity training using plate-loaded machines can be performed safely and effectively in healthy older adults. Also, since the only modification required to perform power training is to move the weight faster in the concentric portion compared to conventional resistance training, power training can be easily implemented into an existing strength training routine without any expert supervision or guidance.

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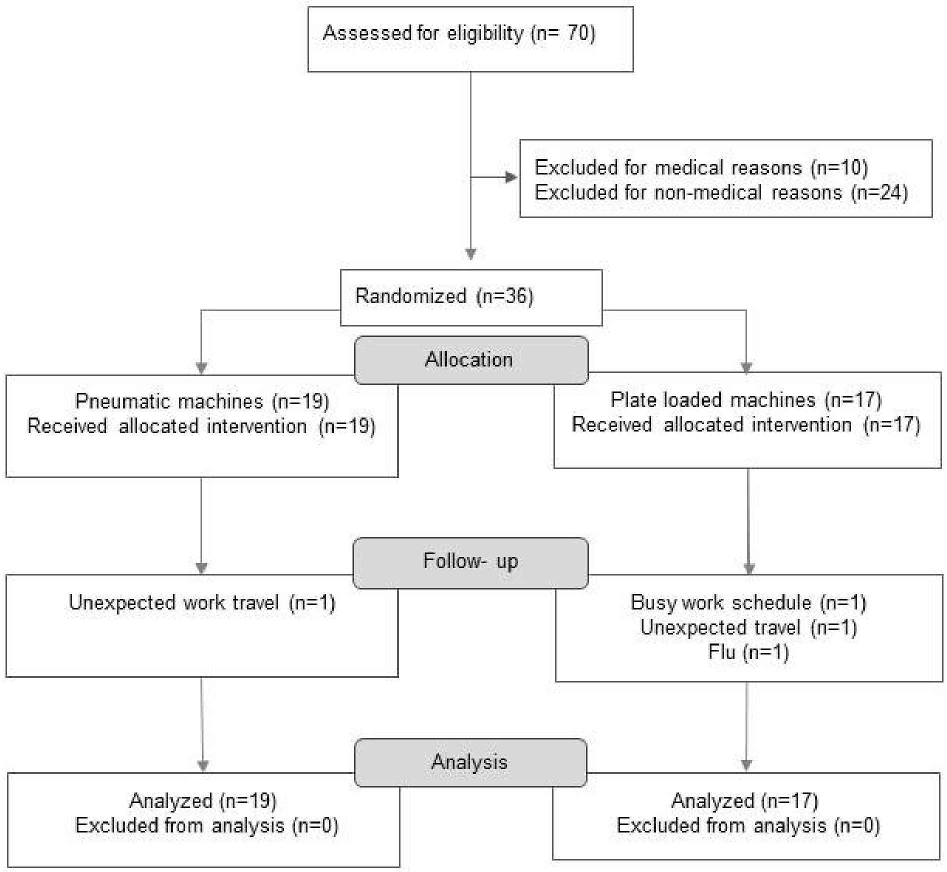
FIGURES

Figure 2.1 CONSORT participant flow diagram



TABLES

Table 3.1 Baseline characteristics

Characteristics	Pneumatic (n = 19)	Plate-Loaded (n=17)
Age, y	68.9 ± 4.9	68.8 ± 5.0
Gender	12F (63%)	8F (47%)
Body Composition		
Weight, kg	79.1 ± 19.0	75.6 ± 10.3
Height, cm	165.7 ± 9.1	168.2 ± 9.2
BMI, m/kg^2	27.9 ± 6.5	27.6 + 3.5
Body fat, %	35.7 ± 8.8	34.7 ± 7.6
Power		
Medicine ball throw, m	3.2 ± 0.9	3.2 ± 1.0
Chair stand peak power, W	935.9 ± 240.8	927.1 ± 313.3
PPB	2.6 ± 0.3	2.4 ± 0.4
Self-Reported Function		
PROMIS	51.6 ± 7.7	50.8 ± 6.0
Video questionnaire	271.2 ± 54.4	280.0 ± 44.5
MMSE (0-30)	29.6 ± 1.2	29.7 ± 1.2

Notes: Values are mean ± SD unless noted otherwise. PPB: Physical performance battery; MMSE: Mini–Mental Status Examination

Table 3.2 Raw, adjusted means and effect sizes

	Pneumatic (n=19) Mean (*SD*)		Plate (n=17) Mean (*SD*)		Adjusted Mean at 12 wk (*SE*)		Adjusted Mean Difference 95% CI	*P*	Effect Size Cohen's *d* 95% CI
	Baseline	12 wk	Baseline	12 wk	pneumatic	Plate			
Power									
Peak power, W	926.4 (244.1)	1110.7(333.4)*	927.1 (313.2)	1214.1 (493.2)*	1105.8 (60.5)	1219.6 (64.0)	-113.7 (-293, 65)	.21	0.4 (-1.1, 0.3)
Ball throw, m	3.2 (1.0)	3.3 (1.0)	3.2 (1.0)	3.4(1.1)*	3.27 (0.1)	3.36 (0.1)	-0.1 (-0.3,0.1)	.35	
Strength									
Arm curls	20.4 (4.0)	24.0 (5.3)*	17.6 (3.0)	21.8 (4.1)*	22.47 (0.7)	23.43 (0.7)	-1.0 (-.2.9, 1.0)	.33	0.3 (-0.9, 0.4)
30s chair stand	14.6 (2.8)	17.2 (4.1)*	14.3 (3.4)	17.4 (4.5)*	16.98 (0.6)	17.54 (0.6)	-0.6 (-2.2, 1.1)	.50	0.2 (-0.8, 0.5)
PPB	2.6 (0.3)	2.9 (0.4)*	2.4 (0.4)	2.7 (0.4)*	2.85 (0.1)	2.81 (0.1)	0.05 (-0.1, 0.2)	.60	
Normal walk, s	5.3 (1.1)	4.7 (1.1)*	4.9 (0.5)	4.6 (0.7)	4.6 (0.2)	4.7 (0.2)	-0.1 (-.60, 0.47)	.80	
Narrow walk, s	5.3 (2.1)	4.8 (1.3)	4.8 (1.9)	4.6 (0.7)	4.8 (0.3)	4.6 (0.3)	0.2 (-0.6, 0.9)	.60	
Chair stand, s	10.3 (1.9)	8.7 (1.7)*	10.9 (2.8)	8.9 (2.9)*	8.9 (0.3)	8.7 (0.3)	0.2 (-0.6, 1.0)		
Balance, s	75.9 (13.4)	85.9 (7.7)*	77.6 (17.9)	75.9 (17.9)	86.4 (2.4)	75.4 (2.5)	10.9 (3.8, 18.1)	.004	0.7 (0.1, 1.4)
Activities of daily living									
Jug transfer, s	9.1 (1.3)	8.4 (1.4)*	9.0 (1.2)	8.1 (1.2)*	8.34 (0.2)	8.17 (0.2)	0.2 (0.3, 0.6)	.43	
Get up & go, s	5.8 (0.9)	5.3 (0.9)*	5.5 (0.7)	5.0 (0.9)*	5.17 (0.1)	5.09 (0.1)	0.1 (-0.3, 0.4)	.64	
Self-reported measures									
PROMIS	51.6 (7.7)	52.4 (6.6)	50.1 (6.0)	51.1 (5.7)	52.1 (0.8)	51.4 (0.9)	0.7 (-1.7, 3.2)	.54	
Video Questionnaire	274.4 (54.5)	290.8 (63.4)	280.0 (44.5)	311.0 (56.3)*	294.4 (11.0)	308.3 (10.8)	-12.5 (-43.2, 18.1)	.41	0.3 (-0.9, 0.4)
Session RPE		5.9 (0.4)		5.7 (0.3)			0.1 (-0.1, 0.4)	.30	0.4 (1.1, 0.5)

Notes: Values are mean ± SD unless noted otherwise. PPB: Physical performance battery; RPE: Rate of perceived exertions; PROMIS: Patient reported outcome measures information system. Absolute between-group differences, cohen's *d*, p values and 95% confidence interval (CI) are derived from analysis of covariance, adjusted for baseline level. Effect size of $d = 0.80$ or greater is considered large, 0.50 to 0.79 is considered medium, and 0.20 to .49 is considered small. Only effect size equal or greater than 0.2 reported. *$p < 0.05$

APPENDIX A

LIST OF EXERCISES

Upper Body	Lower Body
Chest Press	Leg Press
Seated Rows	Leg Curl
Shoulder Press	Calf Raises
Lat Pulldowns	Hip Abduction
Biceps curl	Hip Adduction
Triceps Pushdowns	

APPENDIX B

ADVERSE EVENTS CLASSIFICATION

Musculoskeletal adverse event classification

- Mild event is any event that requires the participant to lower the exercise volume for the specific muscle group for at least 2 weeks.
- Moderate event is any event that requires discontinuing the exercise for the specific muscle for at least 2 weeks.
- Severe event is any event that requires the participant to withdraw from the study.

	Pneumatic (n=19) Mean (*SD*)			Plate (n=17) Mean (*SD*)		
	Severe	Moderate	Mild	Severe	Moderate	Mild
Musculoskeletal		3	3		1	1
Cardiovascular			1			
Falls					1	2
Health care utilization		1	2			1
Total		4	6		2	4

All adverse events listed were self-reported as ‘related’ or ‘not related’ to the intervention.

APPENDIX C

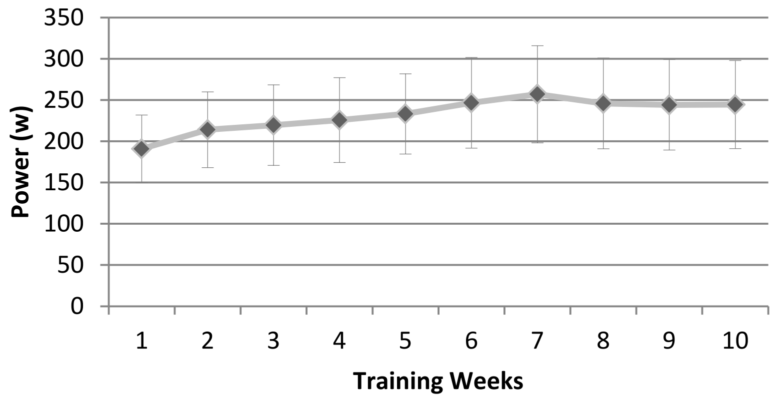
PER PROTOCOL ANALYSIS TABLE

	Pneumatic (n=16) Mean (*SD*)		Plate (n=12) Mean (*SD*)		Adjusted Mean at 12 wk. (*SE*)		Adjusted Mean Difference 95% CI	*P*	Effect Size Cohen's *d* 95% CI
	Baseline	12 wk	Baseline	12 wk	pneumatic	Plate			
Power									
Peak power, W	971.8 (217.1)	1180.4 (287.8)*	947.2 (327.4)	1216.6 (468.7)*	1170.1 (68.1)	1230.4 (78.6)*	-60.3 (-275.0, 154.0)	.56	0.2 (-1, 0.5)
Ball throw, m	3.3 (1.0)	3.5 (1.0)	3.2 (1.1)	3.4 (1.1)*	3.4 (0.1)	3.5 (0.1)*	-0.60 (-0.3, 0.2)	.61	

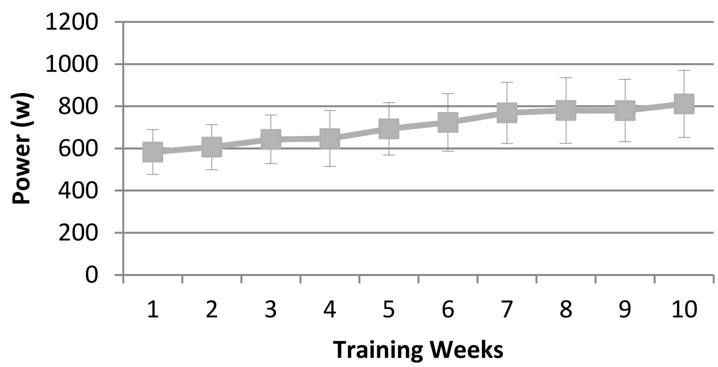
Notes: Values are mean ± SD unless noted otherwise. Absolute between-group differences, Cohen's *d*, p values and 95% confidence interval (CI) are derived from analysis of covariance, adjusted for baseline level. Effect size of $d = 0.80$ or greater is considered large, 0.50 to 0.79 is considered medium, and 0.20 to .49 is considered small. Only effect size equal or greater than 0.2 reported. *$p < 0.05$. Excluded drop outs and subjects who missed more than 25% of the sessions.

APPENDIX D

WEEKLY CHANGES IN POWER



Chest press power changes (week 3 - week 12) with 95% CI for the pneumatic group (n =17)



Leg press power changes (week 3 - week 12) with 95% CI for the pneumatic group (n=17)