Increased Velocity Exercise Specific to Task (InVEST) Training: A Pilot Study Exploring Effects on Leg Power, Balance, and Mobility in Community-Dwelling Older Women

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OBJECTIVES: To evaluate a dynamic form of weighted vest exercise suitable for home use and designed to enhance muscle power, balance, and mobility.

DESIGN: A single-blind, randomized, controlled trial.

SETTING: Outpatient exercise research facility situated within an academic long-term care center.

PARTICIPANTS: Twenty-one community-dwelling women aged 70 and older with a Short Physical Performance Battery (SPPB) score between 4 and 10 (out of 12).

INTERVENTIONS: Subjects were randomized into a progressive resistance-training program using weighted vests for resistance with exercises designed to be specific to mobility tasks and have a component performed at the fastest possible velocity (Increased Velocity Exercise Specific to Task (InVEST), n = 11) or a control exercise group (control, n = 10), which performed slow-velocity, low-resistance exercise. Both groups exercised three times a week for 12 weeks.

MEASUREMENTS: Changes in muscle power, balance, and physical performance were compared.

RESULTS: In comparison to control group, InVEST group manifested significant improvements ($P < .05$) in leg power across measurements obtained at 75% to 90% of the one-repetition maximum. Both groups demonstrated significant improvements in chair stand and SPPB score from baseline, and the InVEST group showed significant improvements in gait speed and chair stand from baseline ($P < .05$). InVEST produced significantly greater changes in chair stand time than control ($P < .05$).

CONCLUSION: InVEST training appears be an effective means of enhancing leg power and chair rise in this population and is worthy of further investigation as a means of enhancing balance and mobility. **J Am Geriatr Soc 52:799–804, 2004.**

Key words: muscle power; mobility; balance; exercise

Impairments in muscle power are important factors underlying mobility limitations in community-dwelling older women.[1–3] Leg muscle power, both distally[3] and proximally,[1] is associated with mobility tasks predictive of disability and self-reported disability.[2] Muscle power is a different attribute from strength declining more precipitously after the fifth decade of life.[4] Strength refers to the ability to generate maximal muscle force. Power is defined as the product of force and velocity. In direct comparisons of muscle power and strength, muscle power was found to consistently describe more of the variance in mobility function in mobility-limited elders.[1]

In healthy and mobility-limited community-dwelling older women, enhancement of muscle power has been achieved with training programs using exercise machines in which repetitions are performed at high velocity.[5,6] A direct comparison with slow-velocity progressive resistance training indicated that high-velocity training produced similar improvements in strength and over twofold greater improvements in leg muscle power.[6] Although safe and efficacious in enhancing muscle power, the superiority of this form of training in terms of mobility enhancement has yet to be demonstrated.[5,7] It has been suggested that this shortcoming may, in part, be related to insufficient similarity (specificity) between the mode of training and desired mobility tasks.[7] Furthermore, such exercise programs using expensive exercise equipment may not be sufficiently simple, inexpensive, or accessible to be applicable to large numbers of community-dwelling women.

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Other more suitable forms of power training should be developed that could be used in a home or community setting.

Weighted vest exercise may be a potential home-based means of improving muscle power and mobility. A form of weighted vest exercise has been effective at improving leg muscle power in healthy older women.[8] In community-dwelling elders with mobility limitations, stair-climbing exercise using weighted vests and designed specifically to enhance muscle power not only produced improvements in leg power, but also influenced mobility function.[9] Although effective in this cohort with mild to moderate mobility limitations, stair-climbing exercise may not be suitable for frailer older women with more significant mobility and balance problems. Other types of training should be explored. Therefore, the authors sought to evaluate the efficacy of another form of weighted vest exercise appropriate for frail women for whom stair climbing would be too challenging and designed to improve muscle power and mobility function. This training would involve exercises with a component performed as quickly as possible to enhance muscle power and include exercises highly specific to common mobility tasks. It was hypothesized that this dynamic form of weighted vest exercise would enhance leg power and performance-based measures of balance and mobility when compared with a low-intensity, slow-velocity control intervention.

METHODS

Recruitment of subjects ($n = 21$) was conducted in the greater Boston metropolitan area and facilitated through the Harvard Cooperative Program on Aging and advertising in local newspapers. One hundred forty-five inquiries were solicited. At the initial screening visit, consent was obtained, a screening physical performance test was conducted, a comprehensive medical history was documented, and a physical examination was performed. Inclusion criteria were female sex, age of 70 and older, and a score between 4 and 10 on the Short Physical Performance Battery (SPPB).[6,10] Exclusion criteria included unstable acute or chronic medical conditions, a score less than 23 on the Folstein Mini-Mental State Examination, or a neuromusculoskeletal condition interfering with exercise participation. Subjects with certain specific conditions such as severe osteoarthritis, severe degenerative joint disease, symptomatic hernia, or abdominal aortic aneurysm were automatically excluded. If eligible, subjects returned to the laboratory for two subsequent visits to complete baseline testing. All subjects lived independently in the community.

After initial screening via telephone and eliminating subjects who were not eligible or were unable to commit to the study, 37 potential subjects were invited to participate in a screening assessment. Of these, 13 were excluded for medical reasons and two chose not to commit to the study. Therefore, 21 subjects were eligible and randomized, representing 57% of the eligible subjects.

Exercise Programs

Ten subjects were randomized to a progressive resistance program using a weighted vest. This training, which emphasizes *in*creased *v*elocity *e*xercises *s*pecific to *t*ask, is designated by the acronym InVEST. Eleven subjects were randomized to a control group performing slow-velocity, low-resistance exercises using body or limb weight for resistance (control). InVEST and control were conducted three times per week for 12 weeks at the Hebrew Rehabilitation Center for Aged under the direct supervision and training of the research coordinator. Both programs were initiated with identical 5- to 10-minute warm-up and cool-down activities consisting of stretching and breathing exercises. The duration of exercise sessions for both groups was approximately 30 minutes.

InVEST subjects performed dynamic progressive resistance exercises, which included chair stands, toe raises, pelvic raises (standing on a 2-inch block of wood on one leg with knee straight and raising the pelvis to a horizontal position, which effectively raises other foot off ground), step ups (performed on an 8" step, bilaterally), seated triceps dips, and chest press. These exercises were based on normal functional tasks, to optimize specificity of training and focus on important muscle groups associated with balance and mobility. The exercises were divided into three sets of 10 repetitions with a 1- to 2-minute rest between each set. Perceived exertion as measured by the Borg Scale[11] was recorded for each set. To accentuate power production, all repetitions were performed with the concentric component (rising) of the repetition performed as quickly as possible while maintaining good form. This was followed by a 1-second pause and then lowering of the body over 2 seconds. During the initial session of the 12-week training program, subjects wore only the vest with no added weight. Once a subject was capable of completing all three sets, the weight of the vest was increased by 2% of the subject's baseline body mass at the next training session. If a subject consistently exceeded 16 on the Borg Scale or was unable to complete the exercises with the added resistance, resistance was reduced by 1% body weight, the subsequent session. Successful completion of each week was defined by a subject's ability to complete three sets of the chair stand or triceps dip exercises without exceeding 16 on the Borg Scale.

Exercises were designed to optimize improvements in lower extremity power and mobility performance. To optimize power training, a high-velocity component of the repetition was incorporated during the concentric portion of each exercise. To optimize the translation of power improvements into enhanced functional performance, exercises were designed to simulate common mobility tasks, thereby accentuating specificity of training.

The control exercise program consisted of chair-based exercises that involved upper and lower body muscle groups (unilateral knee extension and hip flexion, chair stands, plantar flexion, unilateral knee flexion, shoulder press (overhead, lateral, and posterior), biceps curls, chest press, and triceps extension). All exercises were performed in a seated position except for chair rise, in which participants went from a seated position to standing. The exercises were divided into three sets of 10 repetitions, with minimal rest between each set. All exercises were performed slowly with the concentric (raising) component being performed over 2 seconds, followed by a 1-second pause and then lowering. This group served as a standardized training control group for the purposes of this pilot study. They performed training commonly advocated for frail elders and provided within home- or community-based settings. The exercises are characterized as being low resistance (no added weight other than body or limb weight) and slow velocity. By performing chair rises, this control exercise program also had a component of task specificity, aiding in between-group comparisons.

Power and Strength Measures

Leg power and leg strength measurements were assessed using a customized recumbent pneumatic resistance machine (Keiser Sports Health Equipment Inc., Fresno, CA). Details regarding these testing procedures are described elsewhere.[9] To determine strength, the leg press one-repetition maximum (1RM) was measured. Subjects performed the concentric phase, maintained full extension, and performed the eccentric phase of each repetition over 2, 1, and 2 seconds, respectively. The examiner progressively increased the resistance for each repetition until the subject could no longer move the lever arm one time through the full range of motion. Testing was performed at baseline and 12 weeks.

After measurement of the leg press 1RM, assessment of bilateral leg press muscle power was performed using the same pneumatic resistance machine. Performance of power tests using the pneumatic resistance machines as summarized below has previously been described and validated.[6,10] Power (watts) was computed in sequence at eight relative intensities (40%, 50%, 60%, 70%, 75%, 80%, 85%, and 90%) of the 1RM. Beginning with 40%, subjects performed the lift at each established percentage of their 1RM as fast as possible through the full range of motion. Power measures were recorded at baseline and 12 weeks in coordination with 1RM measures. A research assistant blinded to exercise program conducted all strength and power measurements.

Functional Measures of Mobility and Balance

The SPPB is a reliable and valid measure of lower extremity performance.[12,13] Testing was done as previously described and involved an assessment of standing balance, a timed 2.4-meter walk, and a timed test of 5 repetitions of rising from a chair and sitting down (chair-5 time).[12,13] Each of the three tests was scored, based on performance between 0 and 4, leaving a maximum score of 12 for those individuals performing at the highest levels. Times, measured to the nearest 0.1 second using a stopwatch, for the 2.4-meter walk and chair stand were used to calculate gait speed and chair-5 time. Balance was assessed using unilateral stance and was performed as described elsewhere.[14] Briefly, subjects are instructed to stand unsupported on the leg of their choice. Time that the leg is off the ground was recorded. Testing was terminated if a subject's standing foot shifted or when any part of their lifted leg touched the ground. This test of balance has been recognized as a predictor of injurious falls in community-dwelling older adults.[15]

Questionnaires

To assess baseline health status, subjects completed a questionnaire providing demographic and medical history information, the Medical Outcomes Survey (short-form health survey, 36 items (SF-36)), and the Geriatric Depression Scale (GDS). The SF-36 and GDS are well-established, reliable, valid measures in older adults.[16–18]

Statistical Analysis

Descriptive statistics were calculated for specific baseline resident characteristics by exercise protocol. *T* tests (two-sample) were performed on continuous variables to determine whether their mean baseline values were significantly different by exercise group. Sample size, means, standard deviations, and *P*-values are provided. *T* tests (one-sample) were performed for each group separately to evaluate changes for each variable from baseline to 12 weeks. The mean change value was calculated for each variable by exercise group. The percentage change (defined as the difference between the baseline and 12-week assessment value, divided by the baseline value) was calculated to provide an estimate of the magnitude of change for each variable by exercise group. Two-sided *t* tests were used to determine whether the difference (change) between assessments (baseline and 12 weeks) for specific variables differed significantly by exercise group. All analyses were performed using SAS, and an alpha level of 0.05 was used to determine statistical significance (SAS Institute, Inc., Cary, NC).

RESULTS

Baseline characteristics of the subjects are presented in Table 1. No significant differences between groups were identified. On average, subjects were in their late 70 s, had just under five chronic active medical conditions for which they were followed by their physician, and took approximately six prescription medications per day. They had no evidence of significant cognitive problems or symptoms of depression. Their SPPB scores, gait speed, and chair-5 times were consistent with moderate to severe mobility limitations,[12] and their baseline measures of leg power and leg strength were consistent with those of mobility-limited women of this age.[1,2,6] Exercise compliance was excellent: between 88% and 90% for both groups. One subject in the control group dropped out before initiation of training because of logistical difficulties in arranging transportation. No significant adverse events occurred in either group. All subjects completed InVEST exercises without need for modification. Two subjects in the control group had their arm exercises modified because of the onset of intermittent shoulder pain. The physical and mental components of the SF-36 and the GDS revealed no differences between groups and were consistent with the sex, morbidity, and functional levels of the participants (data not shown).[16]

Changes in double leg press power from baseline for InVEST are presented in Table 2. Inspection of baseline leg power between 40% and 90% of the 1RM reveals a typical power curve on which the highest recorded values are seen at approximately 70% 1RM. Leg press data for two of the InVEST subjects could not be included in the analysis because of technical problems at the time of their 12-week testing, leaving a total of nine subjects. InVEST produced between 12% and 36% improvement in leg power across the varying resistances from baseline. Despite the small sample size, statistical significance was achieved at 60%,

Table 1. Average Baseline Characteristics of 21 Community-Dwelling Female Volunteers by Exercise Group

Characteristic	InVEST (n = 11)	Control (n = 10)	P-value
	Mean ± Standard Deviation		
Age	77.1 ± 5.7	78.9 ± 7.8	.547
Body mass, kg	60.1 ± 11.6	65.6 ± 16.5	.400
Body mass index, kg/m^2	26.2 ± 4.1	26.4 ± 4.4	.920
Chronic conditions, n	4.6 ± 2.1	4.8 ± 2.1	.860
Medications, n	5.6 ± 2.9	6.1 ± 3.1	.723
Mini-Mental State Examination score (range 0–30)	28.7 ± 0.9	29.1 ± 1.0	.380
Short Physical Performance Battery (range 0–12)	7.7 ± 1.3	7.3 ± 1.5	.499
Gait speed, m/s	0.80 ± 0.15	0.70 ± 0.16	.145
Unilateral stance, seconds	4.52 ± 5.4	6.05 ± 5.9	.544
Chair-5, seconds	18.5 ± 3.6	19.6 ± 4.1	.539
Leg power, watts	210.9 ± 109.9	267.2 ± 147.5	.331
Leg press one-repetition maximum, N	708.0 ± 223.4	631.0 ± 223.4	.465
Exercise compliance, %	90	88	.570

InVEST = increased velocity exercise specific to task; N = newtons.

75%, 85%, and 90% 1RM. For control (data not shown), improvements in leg power from baseline were seen only between 40% and 60% 1RM, ranged in magnitude between 4% to 14%, and never approached statistical significance at any of the resistance levels.

Comparisons of changes in leg power after 12 weeks of training between InVEST and control are also presented in Table 2 and represent the difference between changes in InVEST minus changes in control at each percentage of the 1RM. Statistically significant improvements were seen between 75% and 90% 1RM, corresponding with the highest resistance levels. Changes at 70% of the 1RM approached statistical significance ($P = .08$), whereas changes at lower intensities did not.

Changes from baseline in physical performance for InVEST and control and between-group comparisons are presented in Table 3. From baseline, InVEST produced significant improvements in the SPPB ($\mu = 2.7$) and significant improvements with chair stand time (44%), gait speed (16%), and unilateral stance time (50%). From baseline, the control exercise produced significant improvements in SPPB ($\mu = 2.2$) and chair stand time (29%). Between-group comparisons reveal significantly greater improvements in chair-stand time with InVEST than with control.

DISCUSSION

The major finding of this pilot study was the demonstration that InVEST, a form of dynamic weighted vest exercise, can effectively improve leg muscle power and chair rise, a measure of mobility, in frail older women. Improvements in leg power from baseline of up to 36% after 12 weeks of training are consistent with other reports using gym-based exercise machines for progressive resistance training[19] and power training.[20] Enhancements in power corresponded

Table 2. Changes in Double Leg Press Power Between Follow-Up and Baseline Assessments at Varying Percentages of the One-Repetition Maximum with InVEST and Comparison of Changes (Δ) in Double Leg Press Power (InVEST Δ – Control Δ) after 12 weeks of Training (InVEST, n = 9; Control, n = 9)

%1RM	Baseline Leg Power (Watts)	Change in Leg Power (Watts) Mean ± SD	% Change	P-value	Group Δ Differences (Mean InVEST Δ – Mean Control Δ) Mean ± SD	P-value
40	140.6	32.0 ± 43.5	23	.058	17.3 ± 57.4	.545
50	167.3	25.2 ± 39.1	15	.089	– 4.3 ± 56.7	.879
60	179.2	31.2 ± 29.7	17	.013	22.1 ± 63.2	.512
70	200.0	24.3 ± 42.0	12	.120	49.7 ± 55.1	.083
75	163.7	48.6 ± 41.0	30	.008	55.9 ± 50.1	.036
80	155.1	42.4 ± 53.1	27	.059	70.3 ± 62.3	.041
85	148.5	53.5 ± 51.0	36	.021	123.1 ± 60.1	.001
90	152.6	39.5 ± 32.8	26	.011	137.6 ± 49.3	.0001

SD = standard deviation; InVEST = increased velocity exercises specific to task;1RM=one repetition maximum.

Table 3. Separate Changes in Physical Performance from Baseline for InVEST and Control and Between-Group Comparisons (Group Δ Differences = InVEST Δ – Control Δ)

Performance Variable	InVEST (n = 11) Mean Δ ± SD	*P*-value	Control (n = 9) Mean Δ ± SD	*P*-value	Group Δ Differences Mean ± SD	*P*-value
Short Physical Performance Battery (range 0–12)	2.7 ± 1.2	< .0001	2.2 ± 1.3	.0009	0.51 ± 1.2	.377
Chair-5 time (seconds)	– 8.2 ± 2.5	< .0001	– 5.7 ± 1.6	< .0001	– 2.5 ± 2.1	.019
Gait speed (m/s)	0.13 ± 0.12	.006	0.06 ± 0.18	.339	0.07 ± 0.15	.356
Unilateral stance time (seconds)	2.24 ± 2.71	.028	0.26 ± 5.7	.900	2.0 ± 4.3	.342

InVEST = increased velocity exercises specific to task; SD=standard deviation.

with improvements in balance and mobility from baseline and improved chair-rise time in contrast to the control group. Participants tolerated this form of training well, with no significant adverse effects of training.

The changes with InVEST in balance from baseline, measured using unilateral stance, and mobility, measured using the SPPB and gait speed, are meaningful despite the lack of statistical significance in comparison to the control group. Using the effect sizes from the between-group comparisons in sample-size calculations suggests that a statistical difference would have been seen if 30, 47, and 91 subjects were in each group for unilateral stance, gait speed, and SPPB, respectively. The magnitude of these effect-size differences in older adults is well within commonly expected ranges for changes in functional outcomes in response to exercise.[21]

Being that this was a pilot study, the magnitude of the change in balance and function with InVEST from baseline is worth considering. As previously discussed, unilateral stance is associated with fall-related injury.[20] Therefore, a 50% improvement suggests that weighted InVEST training could be an important mode of exercise for those at risk for falls. The SPPB and gait speed are predictive of disability, institutionalization, and mortality.[12,13] A mean improvement of 2.7 on the SPPB and 16% enhancement of gait speed correspond with meaningful reductions in risk for these adverse outcomes. For example, based upon equations estimating mortality and disability,[13] the change in SPPB score produced by InVEST corresponds to a 33% reduction in the probability of death over 4 years, from 11.3% to 7.6%. In regard to disability, similarly, over 4 years, this corresponds to a 50% reduction in the probability of developing ADL disability, from 7.9% to 3.8%, and a 32% reduction in the probability of mobility disability, from 40.9% to 28.2%. Nevertheless, such conclusions are only speculative until larger, appropriately powered studies are conducted.

Interestingly, along with InVEST, the control group, which performed three sets of 10 chair rises at each exercise session, had significant improvements in chair-rise time. This led to a mean SPPB improvement of 2.2 from baseline. This occurred despite a lack of significant improvement in muscle power from baseline. These findings speak to a number of important issues. First, they confirm the common recommendation of many experienced clinicians that repeated chair rises are an effective form of exercise for frail older adults to enhance their functioning. The potential for improvement from pure chair-rise activities is likely greater in those who are most limited. The control exercise would likely have had a much smaller effect if the participants had only mild mobility limitations.[22] Second, it underscores the importance of specificity of training, meaning that exercises that closely mimic the targeted functional activity are most likely to enhance the performance of that task. A recent investigation reinforced this point.[23] It successfully used other forms of task-specific exercises (slow velocity) with weighted vests and was able to enhance transfer skills in congregate housing residents. Lastly, even though chair rise was improved within the control group, InVEST produced 15% greater improvement and had a greater influence across the measures of power and some of the remaining functional measures. Therefore, in addition to task specificity, it is likely that the high-velocity and progressive resistance aspects of the InVEST training were important components of the exercise, potentially augmenting functional improvement.

Potential limitations of the study should be mentioned. It is suspected that many of the nonsignificant differences between treatment groups may have been related to the small sample size. Recruitment for this pilot study was based on sample-size estimates derived from power calculations for changes in leg power and not other measures of mobility. As mentioned above, much larger sample sizes would be required to sufficiently evaluate differences in functional outcomes. Additionally, progressive resistance training using free weights is recognized as the best form of home-based exercise to enhance mobility.[24,25] The added value of InVEST, with its emphasis on high-velocity contractions and specificity of training, in comparison with this form of progressive resistance training remains unknown. Additionally, the benefits of InVEST in the home setting remain to be evaluated. Future studies should perform direct comparisons between these two forms of exercise within large, community-based study groups.

Weighted vests serve as a relatively inexpensive (<$100/vest with weights) means of resistance training with great potential. In contrast to a gym membership or home exercise machine, this represents a mode of exercise training that may be affordable and acceptable for large numbers of older women living in the community. Interestingly, another study reported maintenance of bone mass in healthy postmenopausal women with long-term participation in related exercises using weighted vests.[26]

Therefore, the potential benefits of InVEST exercise for elderly women with mobility limitations and risks for falls may be broad.

In conclusion, it was found that, for older adult women with moderate to severe mobility limitations, InVEST training was an effective means of producing improvements in leg power and chair rise. Future investigations should involve larger sample sizes and make direct comparisons with established forms of progressive resistance training.

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