A CLINICAL TRIAL OF STRENGTHENING AND AEROBIC EXERCISE TO IMPROVE GAIT AND BALANCE IN ELDERLY MALE NURSING HOME RESIDENTS[1]

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ABSTRACT Sauvage LR Jr, Myklebust BM, Crow-Pan J, Novak S, Millington P, Hoffman MD, Hartz AJ, Rudman D: A clinical trial of strengthening and aerobic exercise to improve gait and balance in elderly male nursing home residents. *Am J Phys Med Rehabil* 1992;71:333–342

The purpose of this study was to determine whether a moderate to high intensity strengthening and aerobic exercise program can improve the strength, exercise capacity, gait and balance of deconditioned male nursing home residents. Ambulatory subjects who scored 30 or less on the modified Tinetti gait and balance assessment scale, who demonstrated less than 80% of age-matched lower extremity strength on isokinetic muscle testing and who gave informed consent were enrolled. Subjects were randomized to either an exercise (n = 8) or a control (n = 6) group. All participants underwent an exercise test to determine maximal oxygen uptake ($V_{O_2\,max}$) and received quantitative gait and balance measurements. The subjects assigned to the exercise group then completed a 12-wk program of weight training for the lower extremities and stationary cycling. Both the exercise and control groups were then retested. Ten outcome variables were assessed: Tinetti mobility scores, $V_{O_2\,max}$, isokinetic-tested lower extremity strength and endurance, stride length, gait velocity, stance time, gait duration, cadence and balance. The exercise group, after completion of the program, demonstrated significant improvements in Tinetti mobility scores ($P < 0.05$), combined right and left quadricep muscle strength ($P < 0.01$), right and left lower extremity muscular endurance ($P < 0.01$), left stride length and gait velocity ($P < 0.05$), although other outcome variables changed insignificantly. The control group revealed no changes of significance with the exception of improvement of the combined right and left hamstring muscle strength ($P < 0.05$). Nevertheless, for those outcome variables that had improved significantly in the exercise group, the changes amounted to only a 5 to 10% increase over the baseline measurements. These findings showed that an appropriately designed high intensity exercise program can result in significant although limited improvements for clinical mobility scores, strength, muscular endurance and certain gait parameters.

Loss of the ability to walk safely is often a primary reason for nursing home placement.[1, 2] The most common causes of such gait and balance disturbances are organic brain syndromes and musculoskeletal disorders.[3, 4] But even in the absence of specific diseases, disturbances in gait and balance may produce disability in up to 13% of older individuals.[5] Furthermore, nonspecific changes in gait and balance affect nearly all older individuals and are attributed to the normal aging process. Reported changes have included increased postural sway accompanied by decreases in ambulatory velocity, step and stride length, step cadence and swingtime ratio.[6–9]

Impairments in gait and balance lead to such undesirable consequences as fear of falling, falls with fractures, loss of confidence, loss of independence and lowered quality of life.[10–13] Within long-term care institutions, between 40 and 50% of residents will fall during any given year.[14] Musculoskeletal weakness, poor balance and number of prescribed medications have been associated with falling among institutionalized subjects.[15] Additionally,

0894-9115/92/7106-0333$03.00/0
AMERICAN JOURNAL OF PHYSICAL MEDICINE & REHABILITATION

This work was supported by the Department of Veterans Affairs Medical Research Service and Rehabilitation Research and Development Service.

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isokinetic testing of institutionalized fallers has demonstrated both knee and ankle weakness compared with controls.[16] Postural sway has also been found to be higher among those who fall.[17] Gait comparison of subjects hospitalized after falls versus controls has demonstrated slow walking speed, short step length, narrow stride width, a wide range of stepping frequency, a large variability of step length and increasing variability with increasing step frequency.[18]

Although many of the causes of gait and balance disturbances resulting in falls are unmodifiable, some may be correctable. One of these causes is disuse atrophy due to inactivity. With aging, individuals frequently develop a more sedentary lifestyle. The resultant immobility causes loss of bone and muscle mass.[19] The associated decrease in muscle strength creates a greater risk for falls. The gait profile may also deteriorate, because muscle strength has been correlated with gait velocity.[20]

Physical reconditioning has gained attention as a means of reversing the effects of disuse atrophy. In the healthy elderly, increases in strength and $Vo_{2\ max}$ have been achieved with high-intensity weight training and endurance exercise programs.[21, 22] The spontaneous walking speed of active healthy older people approached that of younger individuals.[23] Nevertheless, exercise programs designed to improve flexibility, reaction time and some components of strength have so far been unsuccessful in improving balance.[24, 25] The subjects participating in these studies were relatively healthy females residing in apartments or rest homes. One study in such individuals, which utilized light strengthening exercises, reported that gait speed was enhanced.[25] Positive effects of a strengthening program have been described in frail elderly men and women residing in a community nursing home.[23] With high-intensity weight training, institutionalized nonagenarians increased their muscle size, strength and tandem walking speed. The spontaneous walking speed, however, did not increase. The absence of an observed increase in freely chosen walking speed in this high-intensity weight training program was attributed to the lack of aerobic exercises performed in conjunction with weight training exercises.

To date no studies have reported the effects on gait and balance in the frail elderly of a combined strengthening and aerobic exercise program. Because lower extremity muscle strength has been correlated with falls,[16] and both muscle strength and $Vo_{2\ max}$ have been correlated with gait velocity,[20, 26] we considered a logical intervention to be a combined moderate to high-intensity weight training and aerobic exercise program. Accordingly, we have conducted a clinical trial of lower extremity strengthening and aerobic training in deconditioned male nursing home residents. The study was designed to answer the following questions: What proportion of nursing home residents actually are candidates for a moderate to high-intensity exercise program? Can deconditioned elderly subjects participate in and complete such a program? Will the participants increase their strength and exercise capacity? Do their mobility, gait and balance scores improve?

METHODS

Subjects

Subjects were recruited from the 200-bed Zablocki Veterans Affairs Medical Center (ZVAMC) Nursing Home Unit (NHCU), which has a turnover of ~200 residents per year and serves predominantly elderly men. The protocol was approved by the Human Research and Review Committees at the ZVAMC and the Medical College of Wisconsin.

Potential participants were identified via a memorandum to the NHCU staff that described the inclusion and exclusion criteria listed in Table 1. Chart reviews, interviews and examinations were conducted by the principal investigator to determine eligibility for the study. Men without exclusionary characteristics underwent Tinetti mobility testing[29] and a neuromuscular examination. Scores of 30 or less on the Tinetti mobility test and evidence of lower extremity weakness based on clinical strength measurements of less than five on the standard muscle strength scoring system[27] qualified subjects

TABLE 1
Inclusion/exclusion criteria

Criteria
Inclusion
1. Age ≥ 60
2. Capacity to ambulate independently without an assistive device
3. Evidence of gait and balance difficulties reflected by an abnormal Tinetti score ≤ 30
4. Lower extremity weakness by manual testing of the quadriceps and hamstring muscle groups scoring < 5 based on the grades established by Kendall and McCreary
5. Isokinetic quadricep and hamstring muscle strength < 80% of age predicted normal values
6. Provision of informed consent
Exclusion
1. *Moderate to severe dementia which prohibits* subject from following directions based on a Folstein minimental status score < 22
2. Asymmetrical focal neurologic deficits
3. Lower extremity amputation
4. Leg length discrepancies > 1 inch
5. Significant systemic diseases including active cancer, major organ system failure with advanced heart, lung or kidney failure, or progressive neurologic diseases such as Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis or advanced sensory or motor neuropathies
6. Refusal to provide informed consent

for further consideration. These candidates after signing an informed consent were then randomized into either the exercise or the control group. The final eligibility determination was made after participating men demonstrated <80% of age-specific normal lower extremity strength on isokinetic muscle strength testing.[30]

Protocols for the Exercise and Control Groups

Men randomized to the exercise group entered a progressive resistance lower extremity weight training and aerobic conditioning program at the ZVAMC Cardiopulmonary Rehabilitation Center. Weight training was conducted on a multipurpose weight machine (Marcy Gymnasium Equipment Co.) and aerobic conditioning was completed on stationary Air Dyne or cycle ergometers (Air Dyne & Ergo Metric Exercisor Models by Schwinn). Weight measurements were determined with a 23-kg load cell (Sensotec 31/143) and appropriate instrumentation (Sensotec HH).

Exercise sessions were conducted 3 days a week for 12 wk totaling 36 sessions. Each session lasted between 45 and 75 min depending on the number of participants. All missed sessions were made up at a later date unless continuation was not possible because of medical or personal problems. Heart rates were continuously monitored by telemetry (Transkinetics TEM-4100) during the exercise sessions and estimated average heart rates were recorded during aerobic training.

Each exercise session included: (1) a warm up of leisurely cycling for 3–5 min, (2) aerobic exercise on either the Air Dyne or cycle ergometer, (3) strength training and (4) a warm down of cycling for 3–5 min. The aerobic exercise was performed for a duration of 20 min at a target heart rate of >70% of the exercise stress-tested maximal heart rate. The strength training was performed on the hip flexors, hip extensors, hip abductors, hip adductors, knee extensors and ankle plantar flexors. The hip muscle groups were exercised in succession with a standard weight and pulley system attached by a Velcro strap to the ankle with the subjects in a standing position. Four maneuvers were required for each extremity, totaling eight different hip exercises. To exercise the knee extensors, the subjects were required to lift the training weight from a sitting position with 90° of knee flexion to full knee extension using both knees simultaneously. The ankle plantar flexors were exercised with the subjects standing, holding the training weight with arms and back straight, and rising from the foot flat position to maximal plantar flexion. A one repetition maximum, defined as the most weight a subject could lift through a full range of motion one time, was determined for each of the muscle groups before the first exercise session.

At the first session, the weight load was set at 40 to 60% of the one repetition maximum so that the subjects could complete 10 repetitions. Sequential load adjustments were made in subsequent sessions to maintain a maximal fatigue level after completion of the 10 repetitions. The subjects rotated to three weight stations performing one set of 10 repetitions for each of the hip muscle groups and two sets of 10 repetitions for both the knee extensors and ankle plantar flexors. The order of weight training exercises varied depending on preference and station availability.

Subjects assigned to the control group received usual care within the NHCU during the study period. When indicated, this care included maintenance physical therapy. No dietary limitations were imposed on either group. After completion of the study period, a subset of the control subjects crossed over to the exercise group. Subjects in either group requiring hospitalization secondary to a medical illness were dropped from the study.

Testing Procedures

All study participants completed manual muscle and Tinetti mobility testing, isokinetic strength testing of the quadriceps and hamstring muscle groups, exercise stress testing and gait and balance testing both at the beginning and end of the 12-wk study period. These measurements were made by blinded examiners at baseline and 7 to 10 days after completion of either the exercise or control protocols. Positioning of the subjects for manual muscle testing of the various lower extremity muscle groups and the zero to five muscle strength grading system were based on the positions and grades established by Kendall and McCreary.[27] Modifications in muscle testing were made as necessary following the procedures recommended by Daniels and Worthingham.[28] Leg length discrepancies and significant joint motion limitations were recorded at this time.

Clinical gait and balance were measured with a modified version of Tinetti's instrument.[29] This mobility test involves a series of simple tasks including sitting, standing up from and sitting down in a chair, standing and tandem standing both with eyes open and closed, turning in a circle, turning head from side to side, standing on one leg, reaching and bending to pick up an object, withstanding a nudge on the sternum while standing and walking short distances with or without the aid of an assistive device. Observations of gait were made for gait initiation, step length and height, step symmetry, step continuity and gait path. Each task was scored on a zero to one or zero to two scale.

Isokinetic muscle strength testing was performed at 60° per second to obtain concentric isokinetic strength measurements for knee flexion and extension, utilizing the Cybex II isokinetic dynamometer (Lumex, Inc., Bayshore, NY) and single-channel chart recorder. Adjustments for age were determined by estimating a 1% decline in strength per year after age 40.[30] Measurements of endurance were recorded by tabulating the number of repeti-

tions completed at 180° per second before strength declined to <50% of peak torque.

Exercise stress testing was performed with a 1 or 2 mph Balke protocol.[31] If the subjects could not ambulate on a treadmill even at the slowest speed, exercise capacity was assessed with leg cycle ergometry.[32] This protocol consisted of 3-min stages, beginning at 150 kpm and increasing 150 kpm/stage. The subjects were instructed to maintain a rate of 50 rpm with the exception of the maximal effort stage. Oxygen consumption (V_{O_2}) was measured during each minute of exercise by open circuit spirometry.

Gait and balance measurements were obtained using a modification of the method of Murray et al.[33] The measured gait variables included: stride length, velocity, stance time, duration and cadence. Gait measurements were obtained by a videotape motion analysis system. Kinematic (time and distance) measurements of sagittal plane movements and kinetic (reaction force) parameters were measured during level walking by using digitized video analysis (Motion Analysis Corp.) and the Kistler force plate, which was mounted in the walkway. Two-dimensional walking patterns were videotaped with normal room light by using two video cameras, one for observational purposes and one for kinematic analysis. Retroreflective markers were taped to nine standard body landmarks: head, shoulder, tip, iliac crest, second sacral vertebra, knee, ankle, heel and the fifth metatarsal head. A minimum of four gait cycles were videotaped for each subject in each direction with the arms at the side and then crossed, while wearing low-heeled shoes. A gait cycle is the time period from heel strike to heel strike of the same limb as subjects traveled ~20 feet in one direction across the walkway. If the subject fatigued while walking, he was allowed to sit and rest. Data were analyzed on the IBM-AT computer using Expert Vision System software. Kinematic measurements for three representative gait cycles were averaged per side per subject. Under standardized conditions, videotapes of two two-dimensional walking patterns were obtained with two digital cameras. To identify body landmarks for digital processing of video images, retroreflective markers were taped to the body to identify eight standard landmarks: head, shoulder, hip, knee, ankle, heel, the fifth metatarsal head and a line which bisected the anterior and superior iliac spines. A minimum of four gait cycles were videotaped for each subject in each direction with the arms at the sides and then crossed. The digitized data were averaged for each of the measured gait variables. For postural stability and steadiness testing, the subjects were asked to stand quietly in a comfortable stance near the center of a Kistler force platform, with arms at the side, and look straight ahead at a visual reference for 30 s. Approximately 2 min after the eyes-open trial, the procedure was repeated with eyes closed. The force plate amplifiers were sampled at 100 Hz. The last 20 s of the 30-s trial were analyzed. The x, y and z axial forces recorded from the force platform were used to calculate the anterior-posterior and medial-lateral center-of-pressure time series. The average distance from the geometric mean center-of-pressure and the total excursions or total distance traveled by the center-of-pressure were calculated.

Reliability Testing

The intrarater correlation coefficient for the Tinetti mobility assessment was 0.92 when 15 randomly selected subjects from the NHCU were tested and retested within 72 h. Correlation coefficients of 0.90 and 0.86 were achieved for intrarater isokinetic strength and endurance measurements when study subjects underwent repeated testing within 48 to 72 h.

Statistical Analysis

P values, based on two-tailed matched-pair *t* tests, were calculated for comparisons between the before and after study period data. *P* values based on two-tailed, unequal-variance independent sample *t* tests were calculated for comparisons of the response variables between the exercise and control groups. Significance was assumed to be at the $P < 0.05$ level. Spearman correlation coefficients were calculated for intrarater and inter-rater reliability for both the Tinetti mobility assessment and for the isokinetic muscle testing.

RESULTS

Results of the Recruitment Process

The study groups were drawn from a population that consisted of 200 predominantly male subjects residing at the ZVAMC NHCU from October 1989 to October 1990. The recruitment period extended from October 1989 to June 1990 and the exercise program was conducted from January to October of 1990.

The inclusion and exclusion criteria shown in Table 1 were applied to the study population. Independent ambulation, requiring no supervision with or without an assistive device, was a prerequisite for study consideration. Because of this criterion, 112 of the NHCU residents were excluded from the study. Another 60 residents were omitted because of significant illness, dementia, leg amputation or dependence on an assistive device for ambulation. Of the remaining 28 subjects, 5 were excluded because they scored above the predetermined cut off point on the Tinetti mobility assessment scale; it was felt these individuals were too functional to derive significant benefit from the intervention program. Of the 23 remaining subjects, 15 provided informed consent. Because of resource and supervisory limitations only three to four individuals could reasonably participate in the exercise sessions at any one time. Consequently, only 12 of

the potential 15 subjects were actually able to participate in the study. Six subjects joined the exercise group and six the control group. After completion of the control protocol, four of the control subjects then participated in and completed the exercise protocol. Of the original subjects in the exercise group two were forced to withdraw because of intercurrent illness, leaving a total of eight subjects to complete the exercise group protocol and six to complete the control group protocol. Selected characteristics of the subjects are described in Table 2. No significant differences were noted between the initial profiles of the exercise and control groups, although weight, length of stay and number of major diagnoses demonstrated more variability than age, height and number of scheduled medications.

Baseline Testing of the Exercise and Control Subjects

Baseline data for the participants who completed the study indicated that their initial scores for strength, work capacity and gait were substantially lower than age-specific normal values recorded in the literature.[30, 31, 33] The participants demonstrated deficiencies of 21% for Tinetti mobility skills, 62% for the isokinetics quadriceps and hamstring muscle strength, 46% for $Vo_{2\,max}$ measurements, 60% for gait velocity and 56% for stride length. The exercise and the control groups were not significantly different with regard to their profile of baseline deficiencies in these functional capacities.

Experience of the Exercise Group

Compliance

The eight exercise group subjects completed all 36 sessions. However, before completing all exercise sessions, a total of 16 sessions were missed accounting for an overall compliance rate of ~95%. The average heart rate of 103 beats/min, achieved during stationary cycling, equaled 82% of the exercise stress-tested maximal heart rate and 70% of the age-predicted maximal heart rate. The exercise participants used the Air-Dyne model cycle ergometers 85% of the time and the Ergo-Metric models the remaining 15%. Because of the added upper extremity exercise provided by the reciprocal arm movements, the subjects achieved higher average heart rates and were encouraged to use the Air-Dyne model cycle ergometers.

Safety and Intercurrent Illness

The exercise program was safe with no apparent adverse side effects and no sessions were missed because of musculoskeletal complications. None of the subjects dropped out because of dissatisfaction with the program. Two participants, both in the exercise group, were forced to withdraw from the study because of intercurrent illnesses.

Results of Testing at the End of the Exercise Program

Comparison of the first to the last exercise sessions showed that each of the men participating in the exercise program increased the amount of weight lifted in the 10 repetition maximum. Baseline weight lifted averaged 7.6 lbs for the hip muscle groups, 28 lbs for the knee extensors and 46 lbs for the ankle plantar flexors. The increase in weight lifted over the course of the study averaged 7.3 lbs (99%) for the hip muscle groups, 21 lbs (81%) for the knee extensors and 37 lbs (80%) for the ankle plantar flexors. Although one repetition maximum values were measured before the first exercise session, they were not repeated at the end of the exercise program. The control subjects did not undergo baseline weight measurement determinations.

Table 3 provides information regarding each of the before and after variables measured in the exercise group. The mean increase in Tinetti mobility scores of +3.37 was significant ($P < 0.05$), with each subject scoring higher after completion of the exercise program. The Tinetti scale was divided into three parts, consisting of strength items (12 points), items combining strength and balance (6 points) and items that were primarily related to balance (16 points). Increases in items primarily related to strength were significant ($P < 0.01$), while increases in balance-related items approached significance ($P < 0.06$).

TABLE 2
Clinical characteristics of the participating subjects[a]

Characteristics	Exercise (n = 8)	Control (n = 6)
Age (yr)	73.38 ± 4.04	73.83 ± 4.74
Weight (kg)	73.01 ± 6.78	83.41 ± 6.91
Height (cm)	164.53 ± 1.93	166.67 ± 3.50
Length of stay in NHCU (mo)	22.00 ± 12.74	12.00 ± 4.27
No. of scheduled medications	3.75 ± 0.86	4.17 ± 1.08
No. of major diagnoses	3.88 ± 0.74	4.67 ± 0.61

[a] Primary diagnoses for the exercise subjects included chronic liver disease (1), osteoarthritis (1), normal pressure hydrocephalus (1), depression (1), schizophrenia (1), hemochromatosis (1), diabetes mellitus (2). Primary diagnoses for the control subjects included schizophrenia (2), hemochromatosis (1), diabetes mellitus (2), and benign prostatic hypertrophy (1).

TABLE 3

Baseline and follow-up data for clinical mobility assessment, strength, $Vo_{2\ max}$ and gait and balance measurements for the exercise group (n = 8)

Variable	Baseline	Follow-up	Change	P
Tinetti	24.38 ± 0.91	27.75 ± 0.82	+3.37	0.012
Strength	9.25 ± 0.77	11.00 ± 0.42	+1.75	0.013
Strength and balance	3.88 ± 0.23	4.12 ± 0.30	+0.24	NS
Balance	11.25 ± 0.41	12.62 ± 0.32	+1.37	0.054
$Vo_{2\ max}$ (ml/kg/min)	12.88 ± 0.78	13.22 ± 0.56	+0.34	NS
Quadriceps, right (ft lbs)	49.00 ± 6.87	52.88 ± 5.49	+3.88	NS
Hamstrings, right (ft lbs)	34.12 ± 4.51	36.25 ± 3.50	+2.13	NS
Endurance, right (rep)	12.88 ± 4.18	19.12 ± 3.91	+6.24	0.035
Stride length, right (cm)	57.10 ± 6.32	61.10 ± 6.26	+4.00	NS
Velocity, right (cm/sec)	45.82 ± 4.34	48.78 ± 5.25	+2.96	NS
Stance, right (%)	68.01 ± 1.14	67.00 ± 1.45	+1.01	NS
Stance, right (sec)	0.86 ± 0.02	0.85 ± 0.04	+0.01	NS
Gait duration, right (sec)	1.26 ± 0.03	1.26 ± 0.03	0	NS
Cadence, right (steps/min)	95.88 ± 1.94	95.62 ± 2.50	−0.26	NS
Quadricep, left (ft lbs)	46.62 ± 6.83	56.12 ± 7.24	+9.50	0.068
Hamstring, left (ft lbs)	32.12 ± 4.27	36.00 ± 3.80	+3.88	NS
Endurance, left (rep)	12.88 ± 3.60	22.62 ± 4.24	+9.74	0.012
Stride length, left (cm)	53.71 ± 6.11	63.67 ± 6.63	+9.96	0.003
Velocity, left (cm/sec)	43.09 ± 4.84	52.01 ± 5.68	+8.92	0.009
Stance, left (%)	68.25 ± 1.16	66.54 ± 1.27	+1.71	NS
Stance, left (sec)	0.06 ± 0.02	0.83 ± 0.02	+0.03	NS
Gait duration, left (sec)	1.25 ± 0.03	1.23 ± 0.03	+0.02	NS
Cadence, left (steps/min)	96.00 ± 2.28	97.75 ± 2.77	+1.75	NS
Strength total (ft lbs)	40.47 ± 3.04	45.31 ± 2.99	+4.84	0.007
Quadriceps, right and left (ft lbs)	47.81 ± 4.69	54.50 ± 4.41	+6.69	0.023
Hamstrings, right and left (ft lbs)	33.12 ± 3.01	36.12 ± 2.49	+3.00	NS
Stride length, average (cm)	55.41 ± 6.13	62.39 ± 6.42	+6.98	0.003
Velocity, average (cm/sec)	44.46 ± 4.50	50.39 ± 5.44	+5.93	0.013
Balance eyes open (mm)	960.58 ± 90.01	948.46 ± 73.54	+12.12	NS
Balance eyes closed (mm)	1216.84 ± 237.31	1076.45 ± 123.00	+140.42	NS

Isokinetic strength measurements that increased significantly included overall strength combining the individual muscle group measurements ($P < 0.01$), combined right and left quadriceps strength ($P < 0.05$) and right- and left-handed muscular endurance ($P < 0.05$). Left quadriceps strength improvements approached, but did not achieve significance ($P < 0.07$). Post-strengthening measurements of gait and balance revealed significant improvements in left-sided stride length ($P < 0.005$), left gait velocity ($P < 0.01$) and average stride length ($P < 0.005$) and velocity ($P < 0.05$). No significant changes occurred for the other measured parameters including $Vo_{2\ max}$ and balance.

Experience of the Control Group

The results for the control group can be found in Table 4. All control subjects completed the testing protocol without complications. No outcome variable improved significantly at the end of the 12-wk control period with the exception of the combined hamstring strength ($P < 0.05$).

Between Group Comparisons

Table 5 compares the magnitude of change between the before and after test measurements in the exercise v the control group. Differences of significance included the Tinetti mobility scores ($P < 0.005$), left stride length ($P < 0.05$), left velocity ($P < 0.05$), average stride length ($P < 0.05$) and average velocity ($P < 0.05$).

DISCUSSION

The aim of the study was to evaluate the applicability, acceptability, safety and effectiveness of the exercise intervention program for the population of this VA nursing home. The results indicated limited applicability, high acceptability and safety and partial effectiveness.

Only ~10% of the male residents of the ZVAMC NHCU were found to be candidates for the moderate to high-intensity exercise program employed in this study. Furthermore, only two of three qualified candidates consented to participate. The resulting

TABLE 4

Baseline and follow-up data for clinical mobility assessment, strength, $Vo_{2\ max}$ and gait and balance measurements for the control group (n = 6)

Variable	Baseline	Follow-up	Change	P
Tinetti	26.50 ± 1.31	25.33 ± 1.36	−1.17	NS
Strength	10.83 ± 0.75	9.67 ± 1.09	−1.16	NS
Strength and balance	3.83 ± 0.17	3.83 ± 0.17	0	NS
Balance	11.83 ± 0.79	11.83 ± 0.48	0	NS
$Vo_{2\ max}$ (ml/kg/min)	12.67 ± 0.76	13.46 ± 0.69	+0.79	NS
Quadriceps, right (ft lbs)	54.67 ± 5.50	58.00 ± 7.78	+3.33	NS
Hamstrings, right (ft lbs)	31.17 ± 2.04	37.33 ± 4.72	+6.16	NS
Endurance, right (rep)	7.83 ± 1.96	11.50 ± 3.05	+3.76	NS
Stride length, right (cm)	58.03 ± 5.08	56.53 ± 7.59	−1.50	NS
Velocity, right (cm/sec)	48.63 ± 5.21	47.98 ± 6.03	−0.65	NS
Stance, right (%)	68.67 ± 1.28	69.23 ± 1.06	−0.56	NS
Stance, right (sec)	0.84 ± 0.04	0.84 ± 0.03	0	NS
Gait duration, right (sec)	1.21 ± 0.05	1.21 ± 0.04	0	NS
Cadence, right (steps/min)	99.67 ± 3.60	100.00 ± 2.96	+0.33	NS
Quadricep, left (ft lbs)	60.17 ± 6.80	56.83 ± 6.19	−3.34	NS
Hamstring, left (ft lbs)	31.33 ± 2.06	35.00 ± 3.63	+3.67	NS
Endurance, left (rep)	12.50 ± 3.40	15.50 ± 3.11	+3.00	NS
Stride length, left (cm)	55.40 ± 4.74	53.35 ± 7.01	−2.05	NS
Velocity, left (cm/sec)	45.58 ± 4.49	45.38 ± 6.26	−0.20	NS
Stance, left (%)	68.58 ± 1.04	67.67 ± 1.35	+0.91	NS
Stance, left (sec)	0.85 ± 0.05	0.81 ± 0.03	+0.04	NS
Gait duration, left (sec)	1.24 ± 0.06	1.20 ± 0.04	+0.04	NS
Cadence, left (steps/min)	98.67 ± 4.57	101.00 ± 3.40	+2.33	NS
Strength total (ft lbs)	44.33 ± 3.50	46.79 ± 3.50	+2.46	NS
Quadriceps, right and left (ft lbs)	57.42 ± 4.25	57.42 ± 4.74	0	NS
Hamstrings, right and left (ft lbs)	31.25 ± 1.38	36.17 ± 2.86	+4.92	0.013
Stride length, average (cm)	56.72 ± 4.82	54.94 ± 7.22	−1.78	NS
Velocity, average (cm/sec)	47.11 ± 4.79	46.68 ± 6.10	−0.43	NS
Balance eyes open (mm)	789.57 ± 65.84	851.31 ± 74.73	−61.74	NS
Balance eyes closed (mm)	849.37 ± 65.26	863.93 ± 59.76	−14.56	NS

estimate that only ~8% of the male residents were candidates for the exercise intervention should, however, be considered a lower limit. Other appropriate candidates may have been excluded during the screening process because of the rigid criteria. The largest number of independent ambulators who were excluded from the study consisted of individuals requiring an assistive device. Of this group many had suffered a previous stroke or hip fracture resulting in asymmetrical focal deficits. Certainly some of these individuals were physically capable of participating. Individuals with Parkinson's disease or other early forms of progressive illness, although excluded by the screening criteria, may also have been able to participate in the study and may have benefited from the program.

The intervention was found to be acceptable and safe for the selected deconditioned elderly subjects. No sessions were missed because of exercise-induced musculoskeletal complaints, nor did any subjects drop out because of dissatisfaction with the program. Medical illness requiring hospitalization did cause two participants to withdraw, illustrating the role of intercurrent illness as a cause of deconditioning and progressive debilitation.[34]

The conclusion that the intervention was only partially effective is based on the evaluation of five types of outcome variables. Strength, endurance and gait improved significantly, but left the treated patients still considerably below age-matched healthy individuals in these respects. Aerobic work capacity and balance were not improved by the 12 wk of exercise. The participants in the exercise program did increase their lower extremity muscle strength. The isotonic strength measurements increased symmetrically, whereas the isokinetic strength measurements revealed left-sided gains to be greater than those on the right. In addition to strength, both right and left lower extremity muscular endurance improved significantly. At the end of the exercise program, however, the average scores for strength and endurance were still only about 65% of age-matched normal values.

The $Vo_{2\ max}$ did not rise significantly despite increases in leg strength and muscular endurance. Potential reasons for this lack of improvement are

TABLE 5
Comparison of change between exercise and control groups

Variable	Between Group Difference	Between Group Significance
Tinetti	+4.54	0.004
$Vo_{2\ max}$ (ml/kg/min)	−0.45	NS
Quadricep, right (ft lbs)	+0.55	NS
Hamstring, right (ft lbs)	−4.03	NS
Endurance, right (reps)	+2.57	NS
Stride length, right (cm)	+5.50	NS
Velocity, right (cm/sec)	+3.61	NS
Stance, right (%)	+1.57	NS
Stance, right (sec)	+0.01	NS
Gait duration, right (sec)	0	NS
Cadence, right (steps/min)	−0.59	NS
Quadricep, left (ft lbs)	+12.84	0.074
Hamstring, left (ft lbs)	+0.21	NS
Endurance, left (reps)	+6.74	NS
Stride length, left (cm)	+12.01	0.023
Velocity, left (cm/sec)	+9.12	0.043
Stance, left (%)	+0.80	NS
Stance, left (sec)	−0.01	NS
Gait duration, left (sec)	−0.02	NS
Cadence, left (steps/min)	−0.58	NS
Strength total (ft lbs)	+2.38	NS
Quadriceps, right and left (ft lbs)	+6.69	NS
Hamstrings, right and left (ft lbs)	−1.92	NS
Stride length average (cm)	+8.76	0.034
Velocity average (cm/sec)	+6.36	0.044
Balance eyes open (mm)	+73.86	NS
Balance eyes open (mm)	+154.98	NS

the complex interaction of multiple disease processes, inadequate duration or intensity of training or the diminished end organ response to exercise training in the frail elderly. The exercise subjects did on average maintain an adequate heart rate response during aerobic training, achieving 82% of their exercise-tested maximal heart rate and 70% of their age-predicted maximal heart rate.[35] The duration of 20 min three times weekly may have been suboptimal, with some authors recommending 30 min of aerobic training three times weekly for elderly individuals.[36, 37] Twenty minutes is considered to be the minimal time necessary to obtain an aerobic response.[38] These results are consistent with the conclusion of Naso et al.[34] that it is difficult to improve aerobic capacity in mild to moderately impaired and deconditioned nursing home residents. In addition, it must be noted that attainment of an accurate $Vo_{2\ max}$ depends heavily on subjective factors such as muscle fatigue, perceived exhaustion, level of motivation and the examiner's willingness to allow subjects to reach exhaustion. A true $Vo_{2\ max}$ may therefore be difficult to obtain in the frail elderly. The leg muscles frequently reach exhaustion before the cardiopulmonary system attains its maximal capacity and a valid $Vo_{2\ max}$ is never achieved.[36]

Clinical mobility scores, as measured by the modified Tinetti assessment scale, did improve significantly. Whether the improved Tinetti scores would be associated with improved activities of daily living or a decreased incidence of falls in the treated men remains to be learned. One participant in the exercise program who initially required the assistance of his arms to stand from a chair was able to stand without arm assistance after completion of the program. The two subjects who routinely used a cane or walker for added stability during ambulation continued to do so after completion of the exercise program.

Although quantitative gait measurements demonstrated significant improvements in left-sided stride length and velocity with lesser increases in right-sided stride length and velocity, other gait characteristics, namely stance time, gait duration and cadence, did not change significantly. Furthermore, balance measurements of total excursion revealed no significant changes with the eyes open or closed. These observations suggest that neurologic impairment may have been a more important cause than muscle weakness in causing the ambulatory difficulty of the subjects studied. On the other hand, exercise of greater intensity or longer duration re-

quires testing before a contributory role of weakness can be excluded. The finding of insignificant balance changes is consistent with results obtained in prior studies.[24, 25]

The gains in muscle strength, stride length and gait velocity were greater in the left leg than in the right leg. All study participants were right side dominant. The most plausible explanation for the consistently greater nondominant side improvements is that the left lower extremity may have been subject to greater disuse atrophy than the right lower extremity. The finding of asymmetrical left lower extremity strength improvement in conjunction with left stride length and velocity improvement supports the work of Bassey et al.[20] correlating muscle strength to customary gait velocity.

The percentage improvements in strength, Tinetti mobility score, stride length and stride velocity were only 6, 10, 5 and 3% of the baseline values, respectively. These changes appeared to be small in relationship to the baseline deficiencies of 62% for strength, 71% for Tinetti score, 56% for stride length and 60% for gait velocity. Such changes are likely not trivial, however, because increases in gait speed of the magnitude produced by the present exercise program have proven to be predictors of eventual independent mobility in poorly mobile subjects.[39] It is also possible that the type of exercise utilized in this particular study, but with greater intensity or longer duration, could magnify the gains. Finally, it needs to be emphasized that the inclusion/exclusion criteria for the study, in addition to the complexity of the protocol, resulted in an extremely small sample size. The small group of subjects may not have been representative of the entire ZVAMC NHCU population. These considerations limit the generalizability of the study's conclusions.

ACKNOWLEDGMENTS

We would like to thank Sarah Dougherty, MS, Nancy Wilke, BS, Scott Levandoski, MS and Doris Kreis for their support and assistance in completing the exercise stress testing and gait and balance testing, and Judi Wildes for manuscript preparation.

REFERENCES

1. Teresi JA, Golden RR, Gurland BJ: Concurrent and predictive validity of indicator scales developed for the Comprehensive Assessment and Referral Evaluation interview scale. *J Gerontol* 1984;39:158–165.

2. Libow LS, Sherman PT: *Core of Geriatric Medicine. A Guide for Students and Practitioners*. St. Louis, Mosby, 1980.

3. Sudarsky L, Ronthal M: Gait disorders among elderly patients. A survey of 50 patients. *Arch Neurol*. 1983;40:740–743.

4. Sudarsky L. Geriatrics: Gait disorders in the elderly. *N Engl J Med*. 1990;322:1441–1446.

5. Larish DD, Martin PE, Mungiole M: Characteristic patterns of gait in the healthy old. *Ann NY Acad Sci* 1988;515:18–32.

6. Murray MP, Kory RC, Clarkson BH: Walking patterns in healthy old men. *J Gerontol* 1969;24:169–178.

7. Finley FR, Cody KA, Finizie RV: Locomotion patterns in elderly women. *Arch Phys Med Rehabil* 1969;50:140–146.

8. Sheldon JH: The effect of age on the control of sway. *Gerontol Clin* 1963;51:129–138.

9. Murray MP, Seireg AA, Sepic SB: Normal postural stability and steadiness: Quantitative assessment. *J Bone Joint Surg [Am]* 1975;57:10–16.

10. Murphy J, Isaacs B: The post-fall syndrome. A study of 36 elderly patients. *Gerontology* 1982;28:267–270.

11. US Department of Health, Education, and Welfare: PHS Publication 1549. 1970;1:27–28.

12. Rubenstein LZ, Robbins AS, Schulman BL, Rosado J, Osterweil D, Josephson KR: Falls and instability in the elderly. *J Am Geriatr Soc* 1988;36:266–268

13. Tinetti ME, Speechley M, Ginter SF: Risk factors for falls among elderly persons living in the community. *N Engl J Med* 1988;319:1701–1707.

14. Nickens H. Intrinsic factors in falling among the elderly. *Arch Intern Med* 1985;145:1089–1093.

15. Robbins AS, Rubenstein LZ, Josephson KR, Schulman BL, Osterweil D, Fine G: Predictors of falls among elderly people. Results of two population-based studies. *Arch Intern Med* 1989; 149:1628–1633.

16. Whipple RH, Wolfson LI, Amerman PM: The relationship of knee and ankle weakness to falls in nursing home residents: An isokinetic study. *J Am Geriatr Soc* 1987;35:13–20.

17. Fernie GR, Gryfe CI, Holliday PJ, Llewellyn A: The relationship of postural sway in standing to the incidence of falls in geriatric subjects. *Age Ageing* 1982;11:11–16.

18. Guimaraes RM, Isaacs B: Characteristics of the gait in old people who fall. *Int Rehab Med* 1980;2:177–180.

19. Bortz WM 2d: Disuse and aging. *JAMA* 1982;248: 1203–1208.

20. Bassey EJ, Bendall MJ, Pearson M: Muscle strength in the triceps surae and objectively measured customary walking activity in men and women over 65 years of age. *Clin Sci* 1988;74: 85–89.

21. Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ: Strength conditioning in older men: Skeletal muscle hypertrophy and improved function. *J Appl Physiol* 1988;64: 1038–1044.

22. Seals DR, Hagberg JM, Hurley BF, Ehsani AA, Holloszy JO: Endurance training in older men and women. I. Cardiovascular responses to exercise. *J Appl Physiol* 1984;57:1024–1029.

23. Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ: High-intensity strength training in nonagenarians. Effects on skeletal muscle. *JAMA* 1990;263:3029–3034.

24. Lichtenstein MJ, Shields SL, Shiavi RG, Burger C: Exercise and balance in aged women: A pilot controlled clinical trial. *Arch Phys Med Rehabil* 1989;70:138–143.

25. Crilly RG, Willems DA, Trenholm KJ, Hayes KC, Delaquerriere-Richardson LF: Effect of exercise on postural sway in the elderly. *Gerontology* 1989;35:137–143.

26. Cunningham DA, Rechnitzer PA, Pearce ME, Donner AP: Determinants of self-selected walking pace across ages 19 to 66. *J Gerontol* 1982;37:560–564.

27. Kendall FP, McCreary EK: *Muscles, Testing and Function*, ed 3. Baltimore, Williams and Wilkins, 1983.

28. Daniels L, Worthingham C: *Muscle Testing: Techniques of Manual Examination*, ed 4. Philadelphia, Saunders, 1980.

29. Tinetti ME: Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc* 1986;34:119–126.

30. Davies GJ: *A Compendium of Isokinetics in Clinical Usage*, ed 2. LaCrosse, WI, S&S Publishers, 1984.

31. American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription*, ed 3. Philadelphia, Lea & Febiger, 1986.

32. Levandoski SG, Sheldahl LM, Wilke NA, Tristani FE, Hoffman MD: Cardiorespiratory responses of coronary artery disease patients to arm and leg cycle ergometry. *Cardiopulmonary Rehabil* 1990;10:39–44.

33. Murray MP, Drought AB, Kory RC: Walking patterns of normal men. *J Bone Joint Surg [AM]* 1964;46:335–360.

34. Naso F, Carner E, Blankfort-Doyle W, Coughey K: Endurance training in the elderly nursing home patient. *Arch Phys Med Rehabil* 1990;71:241–243.

35. Gossard D, Haskell WL, Taylor CB, Mueller JK, Rogers F, Chandler M, Ahn DK, Miller NH, DeBusk RF: Effects of low- and high-intensity home-based exercise training on functional capacity in healthy middle aged men. *Am J Cardiol* 1986;57: 446–449.

36. Posner JD, Gorman KM, Klein HS, Woldow A: Exercise capacity in the elderly. *Am J Cardiol* 1986;57:52C–58C.

37. Smith EL, Gilligan C: Physical activity prescription for the older adult. *Physician Sports Med* 1983;11:91–101.

38. Anonymous. American College of Sports Medicine. Position statement on the recommended quantity and quality of exercise for developing and maintaining fitness in healthy adults. *Med Sci Sports* 1978;10:vii-x.

39. Friedman PJ, Richmond DE, Baskett JJ: A prospective trial of serial gait speed as a measure of rehabilitation in the elderly. *Age Ageing* 1988;17:227–235.