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Efficacy of a home-based training program for older adults using elastic tubing

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Abstract. The purpose of this study was to investigate the efficacy of, and the adherence to, a 12-week home-based progressive resistance training program for older adults utilizing elastic tubing. Sixty-two adults (mean age, 71.2 years) qualified to participate in the study. Subjects were randomly assigned to either the exercise (E) ($n=31$) or non-exercise (NE) group ($n=31$). Pre- and post-testing included isokinetic (1.05 rad$\cdot$s^{-1}) concentric/eccentric knee extension/flexion strength testing and flexibility measures of the hip, knee, and ankle. The E group trained three times per week, performing one to three sets of 10–12 repetitions for each of 12 resistance exercises. The exercises involved muscles of both the lower and upper body. Within the E group, 25 of the 31 subjects (80.6%) completed the study. Of the E subjects completing the study adherence to the three training sessions per week was 90% (range 72%–100%). Training resistances used during workouts increased significantly with the average estimated increase being 82% ($P<0.001$). The E group also demonstrated significant ($P<0.05$) increases in isokinetic eccentric knee extension (12%) and flexion (10%) strength. No other significant changes were observed between E and NE groups. These results suggest that home-based resistance training programs utilizing elastic tubing can serve as a practical and effective means of eliciting strength gains in adults over the age of 65.

Key words: Aged – Exercise – Strength – Cooperative behavior

Introduction

Strength decline with aging is no longer viewed as a time-dependent process over which the individual has no control. Some strength decline is the result of physical inactivity and acceptance of a sedentary lifestyle (Agre et al. 1988; Charette et al. 1991; Fiatarone et al. 1990; Frontera et al. 1988). These studies have shown that progressive resistance exercise using weights or exercise machines can increase muscle strength and size in older adults ($\geq$65 years). In fact, the muscles of older adults are as trainable as those of their youthful counterparts (Brown et al. 1990; Frontera et al. 1988; Kauffman 1985). These findings add impetus for further research into developing effective resistance training programs that address limitations faced by the older adult.

Older adults may not have adequate money or transport to enable them to obtain access to equipment, usually avaliable in health clubs, which has been shown to produce increases in strength (Brock et al. 1990; Duensing 1988; Schick 1986). In addition, they may be self-conscious and intimidated by the idea of exercising with younger people. Thus, their ability and willingness to take part in regular exercise away from home may be inhibited. In order to make the benefits of resistance exercise available to as many older adults as possible, alternative modes of resistance exercise which are more economical and practical need to be developed and evaluated for effectiveness.

Elastic tubing has been used in rehabilitative medicine and in the health/fitness industry as a means of increasing dynamic muscular strength. Several companies are now making tubing of different sizes, thus offering a range of resistances. The elastic tubing is inexpensive, compact, and is easy to use. As a result, elastic tubing could be used in home-based strength training-programs for older adults. However, the efficacy of training with elastic tubing has not been documented. The purpose of this study was to investigate the efficacy of, and adherence to, a home-based progressive resistance training program using elastic tubing in a group of adults age 65 and older.

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Methods

Subjects. Local residents aged 65 and older were recruited via advertisement in local pharmacies, newspapers, and senior centers (Topp and Bawell 1992). Sixty-six volunteered. All were functionally independent and had not participated in a resistance training program during the previous 6 months. All were informed of the risks and benefits involved with the project and signed informed consent statements approved by the Institutional Review Board of the University. Initial screening of all volunteers involved a health history questionnaire and a physical examination conducted by a nurse practitioner. Results were reviewed by a physician and volunteers were excluded if they exhibited functional disabilities or contraindications which would prohibit them from beginning a moderate intensity exercise program (American College of Sports Medicine 1991). Four of the volunteers were excluded in the initial screening because of pre-existing medical problems (recent myocardial infarction, uncontrollable angina, recent stroke, and history of ventricular fibrillation); thus 62 subjects qualified to participate in the study.

Experimental design. Following baseline measurement, each subject was randomly assigned to an exercise (E) or non-exercise (NE) group by the toss of a coin. Block randomization was used on the last 2 days of baseline testing to assure equal group size. All subjects were asked not to alter their usual daily activities during the 12-week study. Subjects in the E group resistance trained using elastic tubing. The NE subjects served as the controls and were asked to attend two 3-h automobile driving safety classes during weeks 4 and 8. In addition, the NE subjects were informed that they would be given elastic tubing and supervised instruction upon completion of the 12-week study so that they could begin their own resistance training program. Both E and NE subjects were tested 12 weeks later.

Resistance training program. The progressive resistance training program (Topp et al. 1994) used Theratubing (The Hygenic Corporation, Akron, Ohio, USA) and consisted of six upper body and six lower body exercises which were performed three times per week for 12 weeks. Once per week the E subjects were requested to attend a supervised exercise class. The two remaining weekly resistance training sessions were performed without supervision at home. Each exercise session consisted of active warm-up (5 min), resistance training with elastic tubing (45 min), and cool-down (5 min). Briefly, the resistance exercises performed using elastic tubing were chair squats, hip flexions, knee extensions, knee flexions, ankle dorsiflexions, wall push-ups, back rows, shoulder abductions, triceps extensions, and biceps curls. Ankle plantar-flexions and abdominal curl-ups were performed using body weight as resistance. At the first supervised training session, the E subjects were given an exercise instruction booklet and a set of five elastic tubes offering different resistances. The initial supervised training sessions were devoted to teaching proper exercise technique and to establishing starting elastic tubing size for each exercise. Starting tubing size varied with each exercise and was based on the subject's ability to perform ten repetitions without sacrificing proper exercise form on the last repetitions. The eccentric phase of each exercise was emphasized. Subjects were told "not to let the tubing snap them back to the start position but to consciously control the return movement such that it would take twice as long as the stretching movement." Subjects performed one set of each exercise during weeks 1 and 2, two sets of each exercise during weeks 3 and 4, and three sets of lower body and two sets of upper body exercises during the remaining weeks. Subjects were instructed to move to the next larger tubing size when they could perform 12 repetitions with good exercise form during their last set. This progression was monitored by the project staff during the weekly supervised exercise class.

Compliance, attendance and adherence. Project compliance was calculated as follows: (subjects completing post-testing/subjects completing pre-testing) $\times 100$. E subject participation in the weekly supervised exercise sessions was recorded by the exercise leader. NE subject participation in the automobile driving safety classes was monitored through sign-in sheets. Attendance for all subjects was calculated as follows: (sessions attended/total number of sessions) $\times 100$. Adherence of each E subject to training three times per week was monitored weekly via an exercise log book and expressed as a percentage of the 36 possible training sessions. Three months after completion of the project all subjects were contacted by telephone to determine whether they were still regularly exercising using the elastic tubing.

Muscle strength testing. Concentric and eccentric strength of the right knee flexors and extensors was evaluated using an isokinetic dynamometer (KIN-COM III, Chattecx, Chattanooga, Tenn., USA) (Farrell and Richards 1986). Prior to baseline testing, the isokinetic dynamometer was calibrated using weights, a goniometer, and video analysis. Subsequent calibration during testing used the internal diagnostic software. The test angular velocity was 1.05 $rad \cdot s^{-1}$ and all measures were gravity-compensated for the weight of the lower leg. An angular velocity of 1.05 $rad \cdot s^{-1}$ was chosen based on previous studies involving the elderly (Agre et al. 1988; Frontera et al. 1988) and unpublished pilot data from our laboratory suggesting that elderly subjects have difficulty performing strength tests at higher angular velocities. Subjects were tested in the seated position with stabilizing straps around the waist, thigh, and over the left shoulder. The range of movement was from 1.4 rad of knee flexion to 0.17 rad of knee flexion with 0 rad denoting full knee extension.

Each subject was instructed as to the purpose of the testing and given time to familiarize him-/herself with the testing equipment. Subjects performed five warm-up contractions with the last one being a maximal effort. Subjects then performed three to six maximal concentric/eccentric contractions with 30 s of rest between maximal efforts. The strength curve demonstrating the greatest peak force output was used for subsequent data analysis.

Flexibility assessment. Flexibility was assessed before strength testing. Flexibility of the right hip, knee, and ankle was measured during active stretch using a Leighton Flexometer (Leighton 1955). Subjects performed three trials for each joint movement and the average was taken as their measured range of motion in radians. If a measure varied by more than 0.09 rad, a fourth measurement was taken.

Anthropometric measures. Anthropometric measures included height, mass, and skinfold measures. Skinfold measurements were taken at the triceps, subscapular, suprailiac, chest, abdomen, and thigh sites by a trained, experienced technician. All skinfold measures were taken in triplicate and averaged. Resting blood pressure and heart rate were recorded with subjects seated.

Quantification of elastic tubing resistances. Three resting lengths (102, 305, and 711 mm), comparable to those used in the exercises, of the five different sizes of tubing were stretched from 51 to 965 mm while the resistance was measured using the transducer from the isokinetic dynamometer (Fig. 1). The lengths to which the tubing was stretched were randomly chosen. Three trials were performed for each stretch length and the resistances averaged.

Statistical analysis. Data analysis included computation of descriptive statistics of subject demographics [mean (SD)] and all other variables [mean (SEM)]. A 2×2 (Group $\times$ Test) ANOVA design with repeated measures on the second factor was used to test for significant differences at the 0.05 level of significance. Significant interactions were analyzed using an analysis of simple main effects.

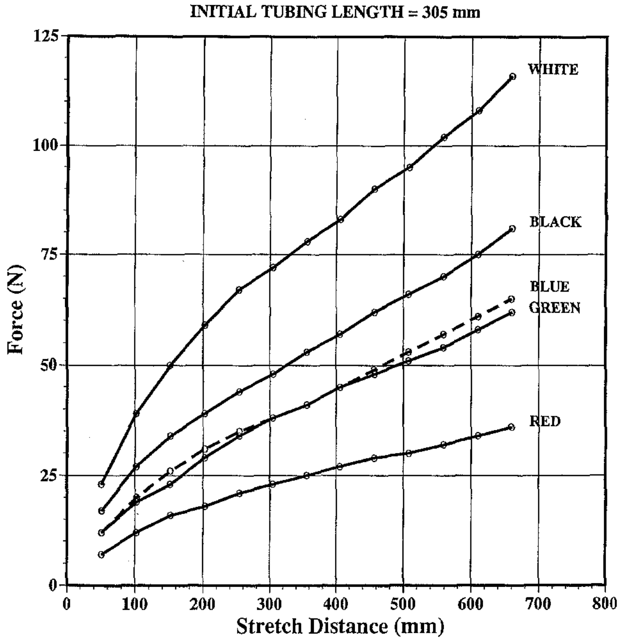

Fig. 1. The measured resistances of the different tubing sizes versus the distance the tubing was stretched. The initial length of tubing (unstretched) was 305 mm for all tubing sizes. The tubing color corresponds to the tubing size with red being smallest and white being the largest

Table 1. Anthropometrics of subjects completing the program

	Exercise group	Non-exercise group
Subjects (n)	25	30
Men	8	13
Women	17	17
Age (years)	69.2 (4.0)	72.8 (5.7)*
Percentage having chronic health conditions	67.2%	63.8%
Median annual income ($)	31000	27500
Education (years)	14.7 (2.7)	14.0 (2.6)

Values are mean (SD)
* Significant difference between groups ($P<0.05$)

Results

Baseline isokinetic testing revealed peak concentric knee extension strengths of 166 (46) Nm and 99 (35) Nm and knee flexion strengths of 78 (23) Nm and 46 (16) Nm for the men and women, respectively. Other pre-training subject characteristics are shown in Table 1. The most common chronic diseases reported by the subjects were hypertension (28%, E group; 20%, NE group) and arthritis (16%, E group; 10%, NE group). Other chronic diseases reported included diabetes, asthma, emphysema, prostate cancer, and allergies. Although the NE subjects were slightly older than the E subjects, there were no significant differences in height, mass, annual income or educational background. The resistance training did not result in any significant changes in anthropometric or flexibility measures (Table 2).

The 12-week resistance training program resulted in significant increases in training resistances (i.e., tubing sizes used; Fig. 2) and isokinetic eccentric knee extension (11.7%) and flexion (10.1%) strength (Fig. 3) in the E group. The 2×2 ANOVA revealed significant interactions ($P<0.05$) in the measures for eccentric isokinetic strength but not for concentric strength. Post-hoc analysis of the data revealed that the eccentric strength increases in the E group were larger than the changes in the NE group. Concentric strength measures increased but not significantly greater than the changes in the NE group.

Overall project compliance was 80.6% and 96.8% for the E and NE groups, respectively. Of the six E subjects (four women, two men) who did not finish the study, three did not return after baseline testing; thus they never began the training program and three withdrew due to illness (stroke, emphysema, and neck pain due to chronic nerve impingement). Except for a lower median income ($ 17500), there were no differences between the descriptives of those who did not complete the program versus those who did (see Table 1).

The attendance of the NE subjects to the automobile driving safety classes averaged 76.7%. The attendance of the E subjects to the supervised weekly exercise class averaged 86.6%. Training adherence by the E

Table 2. Anthropometric, physiological, and flexibility measures before and after the 12-week progressive resistance training program

	Exercise group		Non-exercise group	
	Before	After	Before	After
Mass (kg)	74.2 (2.7)	73.4 (2.6)	73.0 (2.1)	71.8 (2.2)
Height (m)	1.64 (0.14)	1.64 (0.14)	1.66 (0.18)	1.65 (0.18)
Sum of skinfolds (mm)	151.1 (10.2)	143.5 (8.2)	133.5 (7.6)	134.6 (6.4)
Resting heart rate (beats·min^{-1})	73.6 (2.2)	70.5 (1.8)	70.3 (2.0)	67.5 (2.0)
Systolic blood pressure (kPa)	19.0 (0.4)	18.5 (0.5)	19.1 (0.4)	18.8 (0.5)
Diastolic blood pressure (kPa)	11.4 (0.4)	10.4 (0.3)	11.5 (0.2)	10.3 (0.3)
Hip flexion-extension (rad)	2.32 (0.06)	2.38 (0.06)	2.26 (0.05)	2.27 (0.05)
Knee flexion (rad)	2.23 (0.04)	2.28 (0.04)	2.17 (0.04)	2.28 (0.04)
Ankle dorsi-plantar flexion (rad)	1.07 (0.03)	1.09 (0.03)	1.02 (0.03)	0.99 (0.03)

Values are mean (SEM)

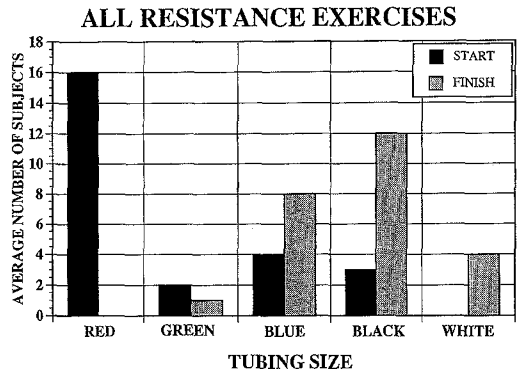

Fig. 2. Comparison of the tubing sizes used at the start and finish of the 12-week training program

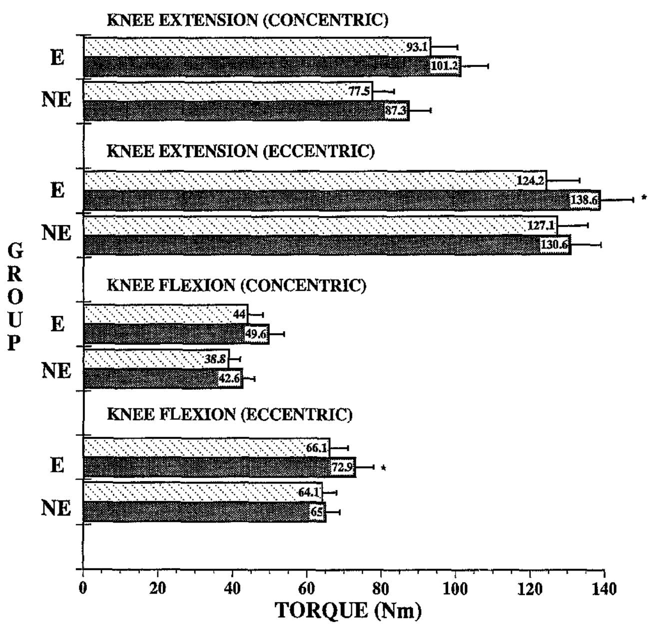

Fig. 3. Comparison of the average pre-training and post-training isokinetic (1.05 rad·s^{-1}) strength measures between the exercise (E) and non-exercise (NE) groups [mean (SEM)]. * Significantly different from NE changes ($P<0.05$). ▤, before; ■, after

subjects averaged 90% (range 72%–100%). The follow-up phone interview revealed that only 52% of the E subjects were still performing the training program three times per week. Similarly, only 46.7% of the NE subjects were training three times per week, 3 months after being started on their own training program which had begun at the end of the study.

Discussion

The subjects who volunteered for this project appeared to be comparable to other healthy noninstitutionalized men and women based on their baseline isokinetic strength measures for knee extension and flexion (Frontera et al. 1991). Our findings demonstrate the trainability of these older adults and corroborate the findings of earlier studies involving older adults participating in resistance training programs utilizing exercise machines (Brown et al. 1990; Charette et al. 1991; Fiatarone et al. 1990; Frontera et al. 1988), wrist and ankle weights (Agre et al. 1988), and body mass (Aniansson and Gustafsson 1981; Aniansson et al. 1984). Of these studies none have directly assessed the efficacy of resistance training with elastic tubing. Only one study has mentioned the use of elastic tubing (Aniansson et al. 1984); however, its use was minimal in the overall training program, so comparison with our study is not warranted.

Both concentric and eccentric isokinetic strength increased significantly; however only the eccentric strength increases were significantly different from those of the NE group. One plausible reason why the training program positively effected eccentric isokinetic strength but not concentric isokinetic strength may have been due to the emphasis placed on the eccentric component of each exercise. Another possibility is that older subjects with more practice on the isokinetic dynamometer is needed in order to assess maximal concentric strength. The apparent concentric strength increase in the NE group suggests their true maximal concentric strength was not assessed at baseline. Future studies involving the isokinetic strength testing of older adults may have to allow more practice in order determine maximal concentric strength adequately.

The eccentric strength gains observed are noteworthy for several reasons. Increases in eccentric strength have been shown to decrease anterior knee pain syndrome (Bennett and Stauber 1986) and may have a positive impact on osteoarthrosis (Radin et al. 1991). Furthermore, it is conceivable that eccentric strength increases may decrease the risk for falling in this population since eccentric contractions are often required to counter destabilizing forces. This hypothesis is supported by the findings that the E group demonstrated improvements in static and dynamic balance (Topp et al. 1993) as a result of the training. Such improvements can have a profound effect on both the mobility and functional independence of older adults.

Besides the isokinetic data, there is further evidence for muscle strength increase based on the fact that subjects were using larger-size tubing as the training program progressed (Figs. 1, 2). In an attempt to quantify the strength increase, the initial tubing length and the tubing stretch distance were measured for each exercise using a representative subject (female, height 1.64 m). The estimated resistance of each tubing size for each exercise was then determined using the stretch length to resistance data measured on the isokinetic dynamometer. Strength increases were determined for all subjects on each exercise and then averaged. The estimated strength increase based on change in training tubing size was 82.3% (2.8)%. Compared to the results from other studies using exercise machines and weights, our estimated strength increase falls within the documented strength improvement range of 48%–174% (Brown et al. 1990; Charette et al. 1991; Fiatarone et al. 1990; Frontera et al. 1988). The estimated 82% increase in strength supports the use of elastic tubing as a muscle-strengthening aid for older adults.

Resistance training with the elastic tubing appeared to be well tolerated by the E subjects. In fact, seven subjects had clinically diagnosed osteoarthritis and none complained of increased joint pain or stopped training. Of the six E subjects not completing the project only three dropped out because of conditions that might have been exacerbated by the training. An exit interview revealed that none felt their conditions were training-induced.

Project compliance (81%) and exercise adherence (90%) rates for the E group are comparable to those of other studies involving older adults (≥ 65 years of age) participating in supervised exercise programs (Charette et al. 1991; Fiatarone et al. 1990; King et al. 1991; Morey et al. 1989; Pollock et al. 1991). The similar compliance and adherence results between our home-based study and those involving supervised programs indicate that the decreased exposure time (one supervised training session per week versus three per week) did not negatively affect the subjects' willingness to complete or participate in the study. Conversely, the follow-up phone interview conducted 3 months post-project revealed a decrease in exercise adherence rates. Only about half of the E and NE subjects (52% and 47%, respectively) were still resistance training three times per week on their own. These data suggest that future home-based training studies may include at least one supervised training session per week to maintain adherence rates that are comparable to those of supervised programs.

In summary, these results suggest that home-based resistance training programs utilizing elastic tubing can serve as a practical and effective means of eliciting strength gains in adults over the age of 65. The training program appeared to be well tolerated, as indicated by the absence of exacerbation of chronic disease conditions and lack of training-induced injury. The results of this study are encouraging and indicate that modes of resistance training other than traditional weight-lifting can elicit strength gains. Future studies should be designed to investigate the long-term (>24 weeks) effects of resistance training with elastic tubing and compare results with those of a similar training program using weights.

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