ORIGINAL RESEARCH

Effects of shortening and lengthening resistance exercise with low-intensity on physical fitness and muscular function in senior adults

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OBJECTIVE: To identify effects of shortening and lengthening low-intensity resistance exercise together with aerobic exercise on physical fitness and muscular strength in senior adults.

METHOD: Seventeen males (58-72yrs) and sixteen females (58-68yrs) participated in this study: seven male and six female as control subjects, ten male and ten female as exercise subjects: these subjects completed an 8-week training program (two times/week) consisting of 15 minutes of aerobike exercise at 50% of VO_{2max} and six shortening-lengthening resistance exercises (3 exercises for upper body and 3 exercises for lower body). The subjects exercised resistance training (5 sec for shortening, 5 sec for lengthening) at 50% of one repetition maximum. Primary outcome measures included physical fitness tests (grip strength, sit-ups, sit-and-reach, 6 minutes of walking, single-leg balance test with open eyes), timed up-and-go test (UP&GO), and one repetition maximum of the same six exercises. This study examined joint angle of knee flexion and elbow flexion, visual analog scale, and muscular strength test to identify delayed onset muscle soreness.

RESULTS: The resting blood pressures in both exercising groups were significantly decreased after 16 sessions of exercise intervention ($p < 0.05$). The training group significantly increased muscular strength and improved physical fitness, UP&GO, and one repetition maximum of 6 resistance exercises ($p < 0.05$). The combined exercise did not induce delayed onset muscle soreness.

CONCLUSION: The present study showed that the combined shortening and lengthening resistance training with aerobic exercise in senior male and female adults was effective in decreasing blood pressure and increasing muscular strength and physical fitness.

KEYWORDS: muscle strength; blood pressure; delayed onset muscle soreness.

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INTRODUCTION

The decline in VO_{2max} and the increase in blood pressure with age appear to be inevitable, and a major contributing factor may be the decline in maximal cardiac output and the decrease in stretch and subsequent recoil of arterial walls. Maximal stroke volume may or may not decrease, and physical training status may be a determining factor.[1,2] Strength loss with age has serious health consequences because it is related to sarcopenia, a reduction of muscular mass and muscular fiber atrophy.[3] The structural changes are accompanied by impaired neural function. Additionally, it has been reported that seniors should perform at least two non-consecutive days of moderate to high-intensity resistance training each week.[4] Older adults, who performed aerobic exercise and resistance exercise regularly, had higher muscular strength, aerobic capacity, and bone density as compared with older adults with no physical activity.[5–8] Resistance training not only increased physical fitness and decreased fatness, but also improved quality of life, cognitive function, and degree of independence.[9] Braith et al.[10] reported that resistance training decreased resting blood pressure. Thus, resistance training for older adults not only increases muscular strength and physical fitness, but also affects blood pressure.

In general, high intensity resistance exercise (70 to 80% of one repetition maximum – 1RM) is recommended to increase muscular strength and to enhance muscular mass.[11] To increase muscular endurance, the intensity and the repetition of resistance exercise must be 50% 1RM, with more than 20 repetitions. However, to our knowledge, few studies have examined the effects of low-intensity resistance exercises and their effects upon muscular strength and size. One study with low-intensity resistance training in young adults reported that slow movement low-intensity resistance

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training enhanced hormonal response secretion, muscular strength, and cross-sectional area.[12] Goto et al.[13] claim that the slow movement type of resistance training with 40% 1RM lowered muscle oxygenation levels and enhanced hormonal response to increase muscular strength.

Lengthening resistance-training interventions completed by the elderly have been implemented in various forms. Lengthening training induced hypertrophy and gain in muscular function more than shortening training.[14,15] It has also been demonstrated that, compared to standard shortening single joint movement strength training, lengthening overload and isokinetic exercises can lead to better strength gains in young and old individuals.[16,17] Heinemier et al.[18] concluded that the effect of lengthening was significantly greater than that of shortening on collagen expression in both skeletal muscle and tendon tissue after short-term training in young rats. Although the varying muscle response may simply relate to force production, it is still interesting that skeletal muscle tissue appears sensitive to the specific force development and/or contraction type. Less attention has been devoted to adaptations to exercise with muscle lengthening in women, even though adaptation of women to resistance exercise is similar to that observed for men.[19] In another low-intensity resistance training report by Hiruma et al.,[20] the shortening-lengthening resistance training with low-intensity in young female collegiate students did not induce **delayed onset muscle soreness** (DOMS), but muscular strength of knee extensors improved. Thus, the second aim of the present study was to examine the effect of lengthening and shortening resistance training on muscle adaptation and physical fitness in older adults.

The effect of a program focusing on the effect of low-intensity resistance training, which does not induce DOMS, has not been investigated. DOMS may cause individuals to stop exercising. The hypothesis underlying any such program is that there will be a significant increase of muscular strength and physical fitness in older adults; it may also be expected that blood pressure changes related to resistance exercise with low-intensity and slow-movement will be found.

Therefore, the purpose of this investigation was to identify the effects of aerobic exercise and the shortening-lengthening resistance exercise with low-intensity on physical fitness and muscular strength when performed for eight weeks by older adults.

METHODS

Participants

Thirty-three senior adults (17 males and 16 females; 57-72 years) volunteered for this study; ten men and ten women were assigned to a training group, while seven men and six women composed a control group. These volunteers had not participated in any resistance or aerobic training for at least 1 year. Subjects were free of any musculoskeletal or other disorders that might have affected their ability to complete the eight weeks of training required for this study. Exclusion criteria were defined as any that would preclude successful participation in the exercise program and included cardiac or peripheral vascular disease, orthopedic limitations, and/or type 2 diabetes. None of the subjects were being treated with exogenous testosterone or other pharmacological interventions known to influence muscular mass or DOMS. Participants were clearly warned against performing any extra exercise during this study period. Subjects participated in this study after signing a written informed consent, which was approved by Ethical Committee of Teikyo University Medical (TEIRIN #08-026-2). All subjects received a physical examination by a licensed physician who certified that they had no known risks that would prevent them from participating in this study. The licensed physician evaluated resting electrocardiograms and blood pressure; additionally, a Physical Activity Readiness Questionnaire (PAR-Q; Canadian Society of Exercise Physiology, Inc.,)[21] was used to identify any abnormalities that might put the subjects at risk.

Study Design

Subjects went through pre-training measurements which consisted of anthropometry and body composition, sub-maximal aerobic fitness test with the YMCA cycle ergometry protocol,[21] physical fitness tests (grip strength, sit-up test, one-leg balance test with open eyes, 6 minutes of walking), timed up-and-go test, one repetition maximum (1RM) of 6 exercises, and multiple analysis blood profiles. Blood samples were withdrawn from antecubital vein. The same measurements were repeated after the eight-week training program.

The following anthropometric and body composition parameters were assessed: height, body weight (BW), percent body fat (%fat), lean body mass (LBM), and body mass index (BMI). Height was measured to nearest 0.1 cm. BW and %fat were assessed to the nearest 0.1 kg and 0.1% using a body composition analyzer (Tanita Co., Inc, Tokyo, Japan). LBM was calculated through the following formula; BW × (100%-%fat). BMI was calculated by dividing weight by height squared ($kg*m^{-2}$).

Subjects were submitted to the following tests (a) 12-lead ECG (Fukuda Denshi Co., Ltd., Tokyo, Japan) to determine ECG response at rest; (b) blood pressure determination (Senoh Corp., Tokyo, Japan) to determine HR, systolic blood (SBP) and diastolic (DBP) blood pressure at rest. Body weight and blood pressure were measured before and after each training session. Subjects completed a graded sub-maximal bicycle ergometry test to measure aerobic fitness. This protocol of aerobic test used a YMCA cycle ergometry protocol[21] in which cycling began at 50W and 50 rpm, increased 25W every 3 minutes, and stopped at volitional fatigue and/or 75% of predicted maximal heart rate (predict-HR_{max}). Perceived Exertion scale (Borg Rating - RPE) and heart rate (HR) were taken during the last minute of each stage. Maximum effort was confirmed by reaching >16 of RPE and $>75\%$ of predict-HR_{max}. HR measured during the last minute of each stage was plotted against work rate. The line generated from the plotted points was extrapolated to the age-predicted maximal HR, and a perpendicular line was dropped to the x-axis to estimate the work rate that would have been achieved if the subject had worked to maximum. Subjects exercised at 50% of predicted VO_{2max} with 50 rpm for aerobic exercise. The incremental YMCA cycle ergometory test was undertaken before and after the training period to identify cardiovascular ability.[21]

Fitness Assessment

Fitness assessments consisted of grip strength (GS), sit-up test (SIT-UP), sit and reach (SIT-RE), one-leg balance time test (BALANCE), and 6 minutes of walking (WALK). Isometric grip strength was evaluated though isometric dynamometry

(Takei Scientific Instruments Co., Ltd, Niigata, Japan) when subjects gripped it to maximal effort. Maximal values for each hand were averaged as a value of GS. In the SIT-UP test, subjects started from a supine position with knees flexed to 90 degrees with held arms in front of the chest; the examiner supported feet and lower legs: subjects exercised as many sit-ups as possible during a 30 sec period. In the SIT-RE test, the subjects sat on the floor with knees fully extended and the back flat against the wall. Subjects straightened elbows, put arms on the measurer (Takei Scientific Instruments Co., Ltd, Niigata, Japan), and moved the measurer as far as possible. The best value out of two measurements was recorded. In BALANCE, subjects stood on their dominant leg with eyes open and hands on their waist. Subjects maintained the position for as long as possible: the best value out of two trials was recorded; the maximal time was set at 120 seconds. In WALK, subjects were required to walk at their natural pace around a 20 meter course marked off by two pylons and marked in 5-meter segments. Total walked distance for 6 minutes was measured in cm. In UP&GO (as described by Podsiale and Richardson[22]) subjects started with their back against a chair, their arms resting on the chair's arms, and their walking aid at hand. Subjects got up and walked at a comfortable and safe pace to a marker 3 meters away, turned, returned to the chair, and sat down again. The total time spent walking was measured to the nearest 0.01 second. The one repetition maximum of 6 separate resistance exercises was measured. These measurements were assessed before and after 8 weeks of training program.

Exercise Intervention Program

Subjects' heart rate and blood pressure were measured at rest before and after each training session. The training protocol consisted of 15 minutes of warm up, 15 minutes of aerobic exercise with bicycle ergometer as an additional warm up, 35 minutes of resistance exercise, and 15 minutes of cooling down. Subjects exercised between 8:00 AM and 10:00 AM, 2 days per week for 8 weeks. During training, subjects were supervised by an experienced fitness trainer and by a certified physician. In the aerobic exercise, subjects cycled with the intensity of 50% predicted-VO_{2max} at 50 repetitions per minute. Between the aerobic and the resistance exercise, a cool down of 1-2 minutes was allowed.

The resistance exercise consisted of leg-extension (L-exten), leg-curl (L-curl), leg press (L-press), chest press (C-press), lateral pull-down (LP-down), and shoulder press (S-press) exercises. The method of the resistance training followed the Hiruma et al.[20] protocol. Subjects exercised at 40-50% 1RM with 5 seconds for lengthening and 5 seconds for shortening. Each exercise was repeated 15 times, with 2 minutes of rest before going to the next exercise. Subjects exercised with set speed established by a metronome (YAMAHA Corp., Shizuoka, Japan). As training progressed, resistance was incremented: whenever a subject completed 15 repetitions or more for at least 2 sessions at a given load while maintaining proper form, the intensity was increased by 5%. The goal of this progression was to induce volitional fatigue in the 12 to 15 repetition range of each subject throughout the training program.

Criteria for the Measurement of Delayed Onset Muscle Soreness (DOMS)

Exercise-induced pain is often used as an indicator of muscle damage.[23] Muscle soreness (M-SOR) during flexing and extending the elbow joint and the knee joint during resting and walking was evaluated by visual analog scale (VAS) using a 100-mm line with "no pain" on one end (0 mm) and "extremely painful" on the other end, at 10 cm. Subjects marked their subjective scale of soreness on the line under the supervision of the examiner. The length of the line from 0 to the marked point provided a numeric measure of soreness. M-SOR was evaluated before, immediately after, and 1 and 2 days after every exercising session in this training period.

Range of motion during voluntary flexion (F-RANG) and extension (E-RANG) of the elbow joint in a sitting position and the knee joint in a prone position were measured. F-RANG and E-RANG were measured twice for each measurement by goniometer. The angle subtracted F-GANG from E-RANG was used as range of motion (ROM). The best value was used as a measurement.

Statistical Analysis

All values were expressed as means ± SD. Statistical analysis was using SYSTAT (version 11; SYSTAT software, Inc., Richmond, CA). The independent sample t-test was used to examine any differences between the training group and the control groups for each variable. Repeated measurements were used to examine any differences between baselines and after intervention values in the trained group and the control group. Statistical significance was set at $p < 0.05$.

RESULTS

Physical Characteristics

None of the participants in this study exercised in daily life. The training groups attended this program more than 15 times (more than 90% of attendance). Table 1 exhibits anthropometric data and blood pressure values for all participants. Male and female training and non-training groups exhibited normal levels of % body fat and body mass index. Systolic and diastolic blood pressure in the male training group (145.3 ± 11.0 and 91.0 ± 10.9 mmHg) was in stage 1 hypertension; in the female training group (133.8 ± 20.0 and 85.0 ± 11.1 mmHg) these values were in the high normal category. The control groups had significantly lower blood pressure as compared with the training groups ($P < 0.01$).

The changes in physical characteristics and blood pressures in the training group following the 8-week training program were as follows: (a) there were no significant changes in body weight, lean body mass, and body mass index in the training and in the control group; (b) males and females in the training group, however, significantly decreased %body fat ($p < 0.05$) from 20.91 ± 3.81% to 19.69 ± 3.44% (males) and from 29.69 ± 4.47% to 27.84 ± 5.97% (females); (c) both training groups, significantly decreased systolic and diastolic pressures after the training program as compared with the initial measurement ($p < 0.05$-0.001). The control group did not show significant changes ($P > 0.05$).

Table 1 - Changes in physical characteristics and blood pressure in male and female subjects after 8 weeks of exercise (16 sessions)

	Age (yrs)	Height (cm)	Body Weight (kg)	Blood pressure Systolic (mmHg)	Diastolic (mmHg)	%Body fat (%)	Lean Body Mass (kg)	BMI (kg. m^{-2})
MALE:								
Training group								
Pre-training	66.9 ± 8.8	168.2 ± 6.2	66.4 ± 9.10$^{\partial}$	145.3 ± 11.0$^{\partial\partial}$	91.0 ± 10.9$^{\partial}$	20.91 ± 3.81	52.66 ± 8.23$^{\partial\partial}$	23.3 ± 1.8
Post-training	66.9 ± 8.8	168.2 ± 6.2	65.4 ± 8.84$^{\partial}$	132.5 ± 13.5*$^{\partial}$	77.6 ± 12.1***	19.69 ± 3.44*	52.57 ± 7.82$^{\partial}$	23.1 ± 1.9
Control group								
Initial values	61.4 ± 0.5	171.6 ± 2.8	72.90 ± 7.17	118.7 ± 11.5	76.6 ± 8.52	21.94 ± 4.75	56.80 ± 5.86	24.7 ± 1.9
Final Values	61.4 ± 0.5	171.6 ± 2.8	72.50 ± 6.84	120.7 ± 11.40	78.9 ± 10.9	22.93 ± 3.81	55.66 ± 8.23	24.2 ± 1.8
FEMALE:								
Training group								
Pre-training	62.8 ± 5.3	154.22 ± 7.05	52.51 ± 7.77	133.8 ± 20.0$^{\partial}$	85.0 ± 11.1$^{\partial\partial}$	29.69 ± 4.47$^{\partial}$	36.93 ± 7.42	22.0 ± 2.4
Post-training	62.8 ± 5.3	154.22 ± 7.05	52.20 ± 8.08	126.3 ± 14.8*$^{\partial}$	76.5 ± 8.4**$^{\partial}$	27.84 ± 5.97*$^{\partial}$	37.33 ± 3.51	21.9 ± 2.3
Control group								
Initial values	61.2 ± 0.8	160.22 ± 3.31	52.32 ± 3.01	111.3 ± 14.0	69.2 ± 6.7	23.95 ± 4.27	39.73 ± 1.45	20.4 ± 1.5
Final Values	61.2 ± 0.8	160.22 ± 3.31	53.36 ± 5.10	115.8 ± 11.0	73.1 ± 10.9	25.91 ± 5.62	39.32 ± 3.24	21.3 ± 1.8

Note: Values are mean ± standard deviation.
Significant difference between pre- and post-training (*:$p < 0.05$,**:$p < 0.01$,***:$p < 0.001$)
Higher values in the training group vs. the control group ($^{\partial}$: $p < 0.05$, $^{\partial\partial}$: $p < 0.01$)
BMI = Body Mass Index

Resistance Exercise Intensity

In the training group, male and female subjects exercised 13 to 15 repetitions and 12 to 15 repetitions during this training session, respectively at 50% of 1RM. Two male and one female subject in the training group could not attend more than 90% of the exercise sessions; their data were excluded. Trained subjects did not exhibit altered DOMS criteria during this training period.

The exercise loads of the six exercises were gradually increased from the 1st to the 16th session in both groups as a function of increased repetitions. The exercise loads of all 6 exercises at the 16th session in both groups were significantly increased ($p < 0.05$-0.01) as compared with the 1st session. Time-Force integral [exercise load (kg) multiplied by the number of repetitions] for the six resistance exercises at 16th session significantly increased in both groups as compared with the initial session ($p < 0.05$) as shown Fig. 1.

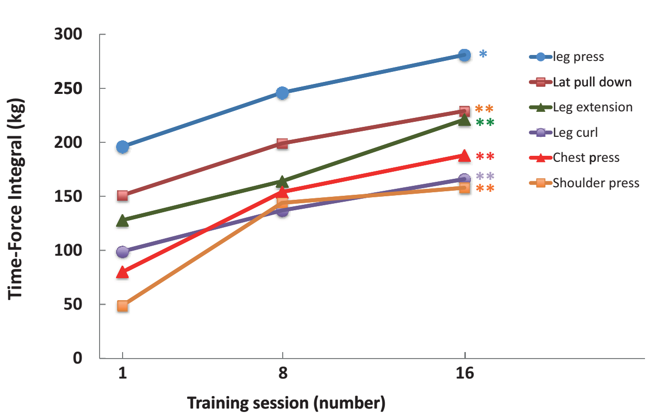

Figure 1 - Time-force integrals of 6 exercises performed at the initial, the 8th and the 16th session of resistance training in female group. Significant differences between the initial session and the 16th session (*:$p < 0.05$, **:$p < 0.01$). The male group significantly increased the time-force integrals (p's < 0.05–0.01: data not shown).

The maximal voluntary muscular strengths in both training groups were increased at the end of the 16 training sessions, as shown in Table 2. In the male training group muscular strength increased significantly for all the exercises: L-exten (24%), L-curl (12%), L-press (18%), C-press (37%), LP-down (44%), and S-press (36%) after the 16 sessions. The corresponding and equally significant increases for the female training group were 16%, 25%, 15%, 28%, 29%, and 46%. Both training groups exhibited more intense increases of muscular strengths in the lower extremities as compared with those in the upper extremities. There were no significant changes in the control group ($P > 0.05$).

The changes of the physical fitness tests and the UP&GO test in the training group after the 8-week training program are presented in Table 3. The male training group experienced a significant increase in the SIT-UP ($p < 0.01$), SIT-RE ($p < 0.05$), and WALK ($p < 0.01$), and a significant decrease in UP&GO test ($p < 0.01$) over the course of the 8-week training period. GS and BALANCE increased, but not significantly. The female training group significantly increased GS ($p < 0.01$), SIT-UP ($p < 0.001$), SIT-RE ($p < 0.01$), WALK ($p < 0.01$), and BGALANCE ($p < 0.05$), and decreased UP&GO test ($p < 0.01$). No significant changes of the physical fitness test and the UP&GO test occurred in the control group ($P > 0.05$).

No statistical differences in the training and control groups were found in aerobic performance with YMCA ergometry test and in the multiple analysis blood profiles after the training program as compared with those at the initial measurement ($P > 0.05$).

DISCUSSION

Effect of exercise intervention on cardiorespiratory fitness and anthropometry

Recent studies have reported that aerobic exercise intervention for both hypertensive and normotensive

Table 2 - Changes in muscular strength after 8 weeks of exercise (16 sessions)

	Chest press (kg)	Shoulder press (kg)	Lat-pull Down (kg)	Leg Extension (kg)	Leg Curl (kg)	Leg Press (kg)
MALE:						
Training group						
Pre-training	31.3 ± 9.6	36.0 ± 7.4	30.0 ± 4.8	32.3 ± 6.1	26.1 ± 5.1	41.7 ± 11.6
Post-training	38.8 ± 10.4**$^{\partial}$	40.4 ± 9.0**$^{\partial}$	35.4 ± 9.2*$^{\partial}$	44.4 ± 13.7**$^{\partial\partial}$	37.5 ± 9.9**$^{\partial}$	56.6 ± 19.9*$^{\partial}$
Control group						
Initial values	31.7 ± 6.8	30.7 ± 6.1	28.7 ± 3.5	28.7 ± 6.6	23.9 ± 4.7	39.4 ± 9.8
Final Values	32.7 ± 8.2	31.2 ± 6.9	29.2 ± 4.1	30.0 ± 6.5	24.7 ± 4.6	41.1 ± 10.9
FEMALE:						
Training group						
Pre-training	21.0 ± 6.0	20.9 ± 2.9	22.2 ± 4.2	25.8 ± 3.8	17.7 ± 4.6	24.9 ± 9.8
Post-training	24.6 ± 7.5*$^{\partial}$	25.7 ± 3.9**$^{\partial\partial}$	25.5 ± 4.6*$^{\partial}$	33.0 ± 3.6***$^{\partial\partial}$	22.9 ± 4.7*$^{\partial}$	36.4 ± 9.5*$^{\partial}$
Control group						
Initial values	19.2 ± 2.9	20.3 ± 3.6	20.5 ± 4.5	23.8 ± 2.9	14.3 ± 6.5	19.1 ± 11.0
Final Values	20.7 ± 4.2	21.5 ± 3.8	21.4 ± 5.6	26.6 ± 2.7	16.9 ± 4.7	21.4 ± 10.3

Notes: Values are mean ± standard deviation.
Significant difference between pre- and post-training (*:$p < 0.05$,**:$p < 0.01$,***:$p < 0.001$)
Higher values in the training group vs. control group ($^{\partial}$: $p < 0.05$,$^{\partial\partial}$: $p < 0.01$)

Table 3 - Changes in physical fitness tests after 8 weeks of exercise (16 sessions)

	Grip Strength (kg)	Sit-ups (time)	Sit and Reach (cm)	Open-eyes Foot-Balance (second)	6 min walking (m)	Up&Go test (second)
MALE:						
Training group						
Pre-training	35.78 ± 6.67	8.5 ± 6.4	26.89 ± 6.78	61.38 ± 40.68	561.6 ± 81.4	6.619 ± 1.625$^{\partial}$
Post-training	37.57 ± 7.55	15.0 ± 6.7**$^{\partial}$	32.45 ± 6.59*$^{\partial}$	80.86 ± 39.71$^{\partial}$	621.0 ± 65.0**$^{\partial}$	5.953 ± 1.288**
Control group						
Initial values	36.96 ± 6.24	9.7 ± 5.8	27.80 ± 6.77	67.36 ± 39.96	584.1 ± 54.7	6.143 ± 0.980
Final Values	37.63 ± 6.64	9.1 ± 2.7**	29.23 ± 6.88	73.00 ± 35.94	596.0 ± 48.3	5.962 ± 1.032
FEMALE:						
Training group						
Pre-training	5.962 ± 1.032	6.9 ± 2.4	38.81 ± 4.87	97.25 ± 27.86	457.6 ± 75.5	5.953 ± 0.601
Post-training	27.05 ± 3.64**$^{\partial}$	10.6 ± 2.7***$^{\partial}$	42.5 ± 4.61**$^{\partial}$	120.00 ± 0.00*$^{\partial}$	560.0 ± 24.3**$^{\partial}$	5.093 ± 0.524**$^{\partial}$
Control group						
Initial values	26.38 ± 3.04	6.5 ± 2.6	38.42 ± 5.25	89.67 ± 28.47	456.3 ± 73.4	5.792 ± 0.610
Final Values	26,73 ± 2.34	6.7 ± 2.3	39.17 ± 5.42	89.17 ± 30.73	465.5 ± 69.4	5.202 ± 0.573

Notes: Values are mean (±standard deviation).
Significant difference between pre- and post-training (*:$p < 0.05$,**:$p < 0.01$,***:$p < 0.001$)
Higher values in the training group vs. control group ($^{\partial}$: $p < 0.05$)

persons reduced resting and exercising blood pressure.[9,24,25] Myslivecek et al.[26] reported that walking exercise with low-intensity (40% of heart rate reserve) for middle-aged women increased vagal modulation and lowered sympathetic modulation. Ferketich et al.[27] suggested that greater improvement in sub-maximal time to fatigue and strength was achieved when resistance training was added to an aerobic training program with high intensity (70 to 80% of VO_{2peak}) in healthy elderly women. Nakamura et al.[28] reported that older women need aerobic exercise and resistance training at least three times per week to improve functional fitness and cardiorespiratory fitness. The aerobic ability during YMCA cycle ergometer test in the present study did not change significantly after 8 weeks of training in terms of the predicted VO_{2max}, HR, and RPE. However, in regard to the effect of body composition, a resistance training frequency of only two times per week for 12 weeks decreased body fat by 5%.[29] Thera-tubing training was effective to decrease %fat and to increase free fat mass.[30] The trained subjects in this study had enough resistance training to change body composition. The results in our study are also supported by data reported by Sanal et al. showing that women submitted to the combined exercise mode reduced fat mass more effectively.[31]

In our study, systolic and diastolic pressures were reduced after the eight-week exercise program. It is well known that both pressures increase with age, at rest and during exercise. The mechanisms responsible for arterial wall alterations are determined by both structural and functional components. The structural components are related to the relative arterial composition of elastin and collagen and the functional component is a consequence of the vasoconstrictor tone exerted by vascular smooth muscular cells. Braith et al.[10] concluded that a combined aerobic and resistance exercise program was more effective to decrease resting BP than the resistance program alone. Additionally, Barone et al.[9] reported that aerobic exercise at moderate-high (60-90% HRmax) intensity combined with a low-intensity resistance exercise training program in old adults decreased resting and exercising blood pressure. Our study provides similar results. Pratley et al.[32] report that resistance training increased resting hormonal norepinephrine levels, which was a surrogate marker of enhanced sympathetic nervous system. They noted that the increased sympathetic nervous system vasoconstrictor tone was likely to be greater to peripheral muscular arteries as compared to central elastic arteries. The protocol of resistance training in the present study prescribed that subjects moved weights slower than in previous studies.[9,10,32] The continuous force generation during resistance training suppressed blood inflow to and outflow from exercising muscle groups due to intramuscular tension in these muscles. Blood flow changed in the peripheral arteries and resulted in decreased blood pressure at the end of the program. Thus, this training program stimulated blood vessels and may have changed the elasticity of blood vessels; together with the increase in peripheral blood flow, this could be an effective means of decreasing blood pressure at rest.

Effect of exercise intervention on muscular strength

Campos et al.[11] found that resistance exercise at very high intensity [>90% 1RM] with 3-5 repetitions, as well as high intensity [75% 1RM] with 9-11 repetitions produced a significant increase in muscular size and strength, and that a low intensity protocol [50% 1RM] with 20-28 repetitions improved muscular endurance. Fatouros et al.[33] reported that three different groups of older males performed resistance training programs with different intensities (high, moderate, and low-intensity) for 6 months. The three groups significantly increased muscular strength. In other studies using low intensity [<50% 1RM] resistance training, slow-speed resistance exercise (3 sec for lifting, 1 sec for resting, and 3 sec for lowering) resulted in increases in muscular strength and muscular hypertrophy; plasma growth hormone concentrations with low intensity training were similar to those observed with high intensity training.[12,13] The resistance protocol in this study for the subjects that trained with low intensity [50% 1RM] and slow movement [5 sec for lifting and 5 sec for lowing] was the same as described in a study by Hiruma et al.[20] This study provided results similar to these former studies[12,13,20] in that 1RM of 6 resistance exercises after 16 regimens with low-intensity were significantly changed in both groups.

We proposed the hypothesis that resistance training, with combined shortening and lengthening muscular contraction, was superior to produce neuromuscular adaptation and muscular strength. The shortening and lengthening training had a greater influence on functional capacity as compared with the shortening training alone.[34] It appears that lengthening training induces greater increase in muscular strength and muscular size than shortening training.[14,15] On the basis of these findings, it may be suggested that lengthening muscular contraction generated higher mechanical forces than shortening muscular contraction.[16] The lengthening training with an intensity of 50% maximum isometric force induced muscular damage.[35] Mueller et al.[29] showed that eccentric ergometry training with minimally induced DOMS for 12 weeks changed muscular function, muscular tissue, maximum isometric muscular strength and eccentric coordination. They concluded that eccentric ergometry training with low frequency (two times per week) and low intensity (female 30W, male 50W) was effective to decrease the typeIIx/typeII ratio and to increase relative thigh lean content. Hiruma et al.[36] reported that the calf-raise exercises with a person's own body weight were similar to those observed during daily-life activity to induce a level of soft tissue damage and DOMS.

It is interesting to note that the changes in fascicle length, muscle strength and muscle thickness significantly increased after five weeks of eccentric training.[37] Garfinkel et al.[38] suggested that initial strength gains were largely due to nonhypertrophic factors such as increased motor unit activation, reflected by increased EMG activity after training, even though this measurement was not described. They concluded that one of the effects of the resistance training was an increase of motor unit activation and/or reduced coactivation in antagonist muscles. The neuromuscular adaptation induced muscular function and muscular power. Our present results are consistent with those of previous studies.[38,39] It seems likely that much of the demonstrated improvements in strength were the result of remodeling in neuromuscular recruitment that resulted from this resistance training. Training regimens should incorporate a shortening and lengthening contraction component with slow movement to optimize the potential of increasing muscular strength. Additionally, the muscular strength in the lower body increased more than that in the upper body.

Effect of exercise intervention on physical fitness and function

The last observation in this study refers to the effect of combined aerobic and resistance exercise on physical fitness and physical function. The endurance exercise increased physical function.[40] Grip strength was related to physical function and quality of life.[41] Newman et al.[42] concluded that grip muscular strength and knee extension are markers of muscular quality, which are more important than their quality in estimating mortality risk. The muscular strength of lower body resulted in functional mobility.[43] Progressive resistance training has been shown to alleviate age-related reduction in maximal voluntary strength usually experienced by older adults.[44,45] The muscular strength in the lower body decreases more intensely compared to that in upper body regardless of sex.[46] Symons et al.[17] reported that eccentric, concentric, and isometric training improved self-paced stepping time and timed 80 meters of walking. This effect of lower body increased BALANCE, WALK, and UP&GO; this may be because this training program changed the lower body more than the upper body. This result is similar to those previously reported, showing that resistance training improved both leg strength and walking endurance in healthy older adults.[47] Resistance training with high-intensity and high-frequency for 5 months in older females significantly improved muscular strength, physical fitness, quality of life and cognitive function.[48] Besides, subjects in this study significantly increased all measurements of physical fitness and UP&GO, even though the intensity of the resistance training was 50% 1RM. These changes were related to the improved muscular strength in upper and lower body. Walking speed over 7 meters in community-dwelling older adults was a more powerful predictor of mortality as compared with skeletal muscular mass.[49] Subjects significantly increased their performance in the 6 min walk test; this was related to cardiorespiratory fitness because of improvement of muscular strength in the lower extremites.[50] Lean body mass, determined by either computer tomography scanning or by dual energy X-ray absorptiometry, was not strongly related to mortality, but muscular strength in the quadriceps muscular group and grip strength were strongly related to mortality.[42] The loss of maximal voluntary strength, particularly in the lower limbs, could dramatically reduce functional mobility, such as gait speed, balance, stair climbing, and chair rising performance.[43] It is important to note that resistance training composed of shortening and lengthening muscular action with slow movement converts to improved physical fitness. Additionally, we showed that age-related decrease in physical fitness could be reversed by combining resistance training with endurance training in elderly women. This combined training program increased muscular strength in the lower body more than in the upper body. Thus, this shortening and lengthening resistance training is effective to improve muscular strength and physical fitness in older adults who may be able to lead to more independent lives and to reduced mortality.

In summary, after 8 weeks of combined aerobic intervention and shortening and lengthening resistance intervention, subjects demonstrated a decrease in systolic and dyastolic blood pressure at rest. Training with improved muscular strength of upper and lower body increased physical fitness and functional mobility. One caveat is that the sample for this study consisted of a relatively small and homogeneous group of healthy older adults, so these results should not be generalized broadly to the elderly population.

■ CONCLUSION

The present study showed that 1) a shortening and lengthening resistance exercise program in older adults was effective in increasing strength after the 8-week training period with 2 times per week and 2) the combined resistance exercise and aerobic exercise training program was effective in increasing physical fitness, and 3) this shortening and lengthening resistance program with 50% 1RM did not induce DOMS.

■ EFEITOS DE EXERCÍCIOS RESISTIVOS DE ENCURTAMENTO E ALONGAMENTO, EM BAIXA INTENSIDADE, SOBRE CONDICIONAMENTO E FUNÇÃO MUSCULAR EM ADULTOS SÊNIOR■ RESUMO

OBJETIVO: Identificar os efeitos de encurtamento e alongamento através de exercício resistivo de baixa intensidade, juntamente com exercício aeróbico sobre a aptidão física e força muscular em idosos.

MÉTODO: Dezessete homens (58-72 anos) e dezesseis mulheres (58-68 anos) participaram deste estudo: 7 homens e 6 mulheres como controles, 10 homens e 10 mulheres submetidos aos exercícios: um programa de treinamento bissemanal de 8 semanas, consistindo em dez minutos de aerobike a 50% do VO_{2max} e seis exercícios de alongamento/encurtamento (três para membros superiores e três para membros inferiores). Cada exercido foi repetido quinze vezes (50% de Uma-Repetição-Máxima – 1RM) com 5 seg para encurtamento e 5 seg para alongamento). Foram medidos: força de preensão, sit-ups, sentar-e-alcançar, 6 minutos de caminhada, teste de equilíbrio de single-leg com os olhos abertos), teste up-and-go (UP & GO), 1RM dos mesmos seis exercícios, ângulo articular de flexão do joelho e flexão de cotovelo, escala analógica visual, e teste de força muscular para identificar dor muscular tardia.

RESULTADOS: A pressão arterial em repouso do grupo exercício apresentou diminuição significativa após as 16 sessões de exercício. O grupo de treinamento aumentou significativamente a força muscular com melhoria da aptidão física, UP & GO, e uma repetição máxima de 6 exercícios de resistência. O exercício combinado não induziu dor muscular tardia.

CONCLUSÃO: O presente estudo mostrou que o encurtamento/alongamento combinado com o exercício aeróbico em adultos idosos do sexo masculino e feminino foi eficaz para a diminuição da pressão arterial e aumento de força muscular e aptidão física.

UNITERMOS: força muscular, pressão sanguínea, dor muscular tardia.

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