Concurrent cardiovascular and resistance training in healthy older adults

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ABSTRACT

WOOD, R. H., R. REYES, M. A. WELSCH, J. FAVALORO-SABATIER, M. SABATIER, C. M. LEE, L. G. JOHNSON, and P. F. HOOPER. Concurrent cardiovascular and resistance training in healthy older adults. Med. Sci. Sports Exerc., Vol. 33, No. 10, 2001, pp. 1751–1758. **Purpose:** The recommendations for exercise training and physical activity for older adults include cardiovascular and resistance training components (CVT and RT, respectively). The purpose of the present investigation was to compare the fitness benefits of concurrent CVT and RT with those attained through an equivalent duration of CVT or RT alone. **Methods:** Thirty-six participants (ages 60–84) were assigned to a control group or to one of three exercise treatment groups. The treatment groups exercised three times per week for 12 wk using RT (**N** = 11), CVT (**N** = 10), or CVT and RT (**BOTH**, **N** = 9). Pre- and post-training, participants performed a submaximal exercise test (GXT), five repetition-maximum strength tests (5RM), and the AAHPERD functional fitness test for older adults. **Results:** All exercise treatment groups revealed lower resting heart rate and rate-pressure product; lower exercise diastolic blood pressure and rating of perceived exertion; increased GXT duration; increased leg, back, and shoulder 5RM scores; and improved AAHPERD flexibility, coordination, and cardiovascular endurance scores. The exercise treatment groups responded differently on the following: RT and **BOTH** enhanced arm and chest strength more than CVT; and **BOTH** enhanced AAHPERD strength and agility scores more than CVT or RT. **Conclusions:** Concurrent CVT and RT is as effective in eliciting improvements in cardiovascular fitness and 5RM performance as CVT or RT, respectively. Moreover, incorporating both CVT and RT in exercise programs for older adults may be more effective in optimizing aspects of functional fitness than programs that involve only one component. **Key Words:** PHYSICAL FITNESS, EXERCISE, AGING, FUNCTIONAL ABILITY

Several studies conducted over the last 20 years indicate that exercise training among healthy older adults elicits improvements in fitness similar to those observed in young adults. For example, moderate-intensity cardiovascular training enhances maximal oxygen consumption in the range of 10–30% (14,28). In addition, programs of moderate- to vigorous-intensity resistance training have resulted in impressive strength gains and enhanced muscle cross-sectional area in older men and women (5,6,12,13,25). Such evidence provides the basis for the American College of Sports Medicine’s Position Stand on Exercise and Physical Activity for Older Adults (21), which promotes the inclusion of both cardiovascular and resistance training components in the exercise prescription.

Interestingly, however, few studies have examined the benefits of programs that include both resistance and cardiovascular components, and no studies of healthy older adults have compared the effects of combination programs with those of resistance and cardiovascular training alone. Among younger adults, such combination programs have been effective in enhancing cardiovascular fitness to a similar extent as cardiovascular training only (15,16). However, these studies have identified an “interference” of combination training on strength development. That is, combination programs do not result in as great an improvement in strength as can be attained through resistance training only (8,15,27). For example, Hickson’s 10-wk training study (8) indicated that participants engaged in both resistance and endurance activities had similar 1 RM leg strength gains as those training with resistance activities only during the first 7 wk of training. However, in the remaining weeks, strength gains continued in the resistance-training group but leveled off in the group employing resistance and endurance activities. Because these subjects performed both modalities of exercise 5 d·wk−1, it was suggested that the frequency and volume of activity might have led to some residual fatigue that could have affected strength gains. Dudley and Djamil (8) further investigated this issue using a 3 d·wk−1 approach with a minimum of 48 h between sessions and reported similar results. More specifically, however, they reported that the interference of endurance training on strength development was primarily evident at higher velocities of movement. The mechanism(s) responsible for the apparent interference of endurance training on strength gains is not well established.

This “interference” of combination training on strength development may be of particular importance in populations for whom strength development is of paramount importance, as in the case of older adults. Studies indicate that age-related losses of muscle mass and strength can result in a significant decay in functionality (3,20,26). Thus, as maximization of strength is critical for this population, it is
important to ascertain whether combination programs will “interfere” with strength development in older adults. To date, the interference theory has not been tested in older adults.

Accordingly, one important purpose of this investigation was to compare the effects of 12 wk of resistance and CV training conducted alone and combined on selected measures of physical fitness. Based on the findings of Dudley and Djamil (8), Hickson et al. (15,16), and Sale et al. (27), it was hypothesized that combination training would result in similar improvements in cardiovascular fitness as “cardiovascular training only” but smaller strength gains than “resistance training only.”

An additional purpose of this investigation was to examine the influence of these training protocols on functional fitness among older adults. An important outcome of physical activity is to optimize and maintain independent living throughout the life span and to delay the onset of disability. The sociomedical model of the disablement pathway (30) suggests that developmental or pathological alterations in cellular function may lead to organ system impairment, that such impairment may negatively influence functional ability, and that the loss of physical function may result in disableness. Tests of physical functional ability have recently emerged in an effort to further describe physical function as it relates to an older adult’s ability to perform activities of daily life. Therefore, the AAHPERD functional fitness test for older adults (23) was used to assess functional fitness. This test battery has been validated as a useful tool for measuring functional fitness in several domains (i.e., body composition, flexibility, agility/dynamic balance, muscular strength and endurance, and cardiovascular endurance) (23). Exercise programs have generally been associated with improvements in functional fitness scores in older adults (7,29); however, no studies have simultaneously compared changes in functional fitness after CV, resistance, and combination exercise programs. Therefore, although we can hypothesize that exercise treatment will enhance functional fitness, the question as to which exercise protocol will be of greatest value in this regard is empirical.

METHODS

Participants

Sixty-seven adults between ages 60 and 84 responded to an invitation to participate in this study. Respondents provided informed consent to participate in the study and were screened for the presence of diseases or conditions that would place them at high risk for adverse responses to exercise (1). Exclusion criteria for the study included history of surviving sudden cardiac death, recent myocardial infarction, unstable angina, poorly controlled hypertension, poorly controlled diabetes mellitus, frequent or complex ventricular ectopy, or significant cognitive dysfunction that might interfere with one’s ability to adhere to exercise protocols. Moreover, adults in the inflammatory stage of arthritis or those receiving medical treatment for osteoporosis were also excluded from the study.

Study Design

All procedures were approved by the Institutional Review Board of the host site. An initial visit was conducted wherein each respondent was provided details about the treatment intervention. After providing informed consent, the participant was interviewed regarding his or her health status. A modified version of the Health Status Questionnaire (17) was used as a screening tool. A 1-yr physical activity recall questionnaire for older adults (31) was also completed during this initial visit. This activity inventory inquires as to the number of hours per week spent performing various activities from household chores to more vigorous activities. After completion of the above, each respondent signed a request for physician consent to participate and a request that medical records be sent to the principal investigator of the study. After review of the medical records and physician consent, participants were scheduled for three assessment sessions within a time span of 7–10 d. The order of tests was as follows: 1) field-tests of functional fitness; 2) a submaximal graded exercise tolerance test; and 3) a 5-repetition maximum (5RM) strength test using seven different Med-X (Med-X Corp., Ocala, FL) brand resistance machines. After these tests, participants were randomly assigned to one of four treatment groups (described in detail below): a cardiovascular training group, a resistance training group, a group employing both cardiovascular and resistance training components, and a control group. Subsequently, the participants trained three times per week for a period of 12 wk, after which the assessments were repeated.

Experimental Procedures

Session I. Field tests of functional fitness. The AAHPERD assessment of functional fitness for adults over 60 yr of age (23) was used to assess functional fitness. This test includes several items that have demonstrated good reliability and criterion validity for use in this age group (23). The test-retest reliability coefficients for the items in this test battery have been reported in the range of r = 0.80–0.99 (23). These items include: the “Ponderal Index,” which is an indicator of body composition that is derived as the quotient of height (inches) divided by weight1/3 (lbs.); flexibility as determined by the sit-and-reach test; agility/dynamic balance assessed by a time to completion task involving repeatedly standing from a chair, walking around cones, and returning to the chair; coordination assessed by a time to completion task requiring the participants to manipulate 12-oz. soda cans in a precise fashion; muscular strength and endurance reported as the number of biceps-curl repetitions performed during a 30-s time period (4 lbs. for women, 8 lbs. for men); and cardiovascular endurance, which involved the time to complete an 880-yard walk.

The AAHPERD test (23) provides standardized instructions for each test item that is read to the participants. Furthermore, the test procedures provide practice and mul-
tiple trials to reduce any influence of learning for all of the test items with the exception of the muscular strength and endurance, and cardiovascular endurance items. For a complete description of the AAHPERD test, see Osness et al. (23).

Session II. Submaximal cardiorespiratory test. Participants were asked to perform a modified U.S. Airforce graded exercise treadmill protocol (1) to a submaximal level. The purpose of this test was to estimate cardiorespiratory exercise capacity and to examine cardiorespiratory responses to submaximal work. Participants reported to the laboratory 12 h postprandial and were asked to discontinue any cardiac or vasoactive drugs for 12 h preceding the test. Before the test, ECG electrodes were applied to the participant’s torso. The test involved incrementally increasing the grade of the treadmill by 3% every 3 min, while a constant speed of 2.0 mph was maintained throughout the test. During the test, the examiner monitored heart rate (HR), blood pressure (BP), and rating of perceived exertion (RPE) according to Borg’s 20-point scale (1). The examiner increased the workload every 3 min until the participant either achieved a heart rate equal to 70%–85% of age-predicted maximum (220 – age), achieved an RPE ≥ 15, requested to stop, or presented signs or symptoms indicating termination of the test (1). The variables of interest from the submaximal GXT were test duration; RPE during the second stage of the protocol; resting and exercise heart rate (HR); systolic, diastolic, and mean arterial blood pressure (SBP, DBP, and mean arterial pressure (MAP), respectively); and rate pressure product (RPP). The reported resting values for these parameters were collected in the supine position, and the exercise values were obtained during the second stage of the GXT. RPP was derived by the equation HR × Systolic BP. MAP was derived as DBP + (SBP-DBP)/3 at rest and DBP + (SBP-DBP)/2 during the GXT.

During this same session, after the GXT, the participant was introduced to seven Med-X strength-training devices. The participant received instruction as to how to perform the resistance exercises and was given an opportunity to practice at a very low intensity. At this time the examiner explained the 5RM test, which was performed on the next visit.

Session III. 5RM strength testing. This test made use of seven Med-X resistance exercise machines, with stackable weights allowing increments of as small as 2 foot-lbs. The test involved gradually increasing the resistance on the Med-X machines until the participant could successfully execute 5 repetitions only. Each activity test was completed within five to six sets. Between each set, participants were given 1 min of rest and 1 min of stretching the involved muscle groups. Analysis of the control group data (N = 6) indicated a 3-month stability of 5RM performance with intra-class correlation coefficients in the range of 0.82–0.91 across the seven tests.

Treatment Groups

Cardiovascular training (CVT). These participants exercised on treadmills and Monark cycle-ergometers. Intensity was maintained at 60–70% of estimated HR, and RPE was maintained between 11 and 13. When the HR response was less than 60% of estimated reserve and the RPE response was under 11, the intensity of the work was increased until these criteria were met. The initial duration of the CV work was 21 min per session, and the duration was increased by 3 min-wk−1 until a maximum of 45 min was achieved and maintained throughout the remainder of the program. Each session included a warm-up and cool-down period involving 3 min of low-intensity cycling or walking and light stretching activities.

Resistance training (RT). These participants engaged in eight resistance-training activities, using Med-X brand devices. The activities were performed in this order: 1) seated leg-press, 2) leg-extension, 3) seated leg-curl, 4) seated row, 5) chest-press, 6) lateral shoulder-raise, 7) seated dip, and 8) biceps-curl. Participants were initially instructed to perform one set of 12–15 repetitions of each activity, at an intensity of 75% of the 5RM. The workload was increased by 5–10% per workout until an 8–12RM was achieved. By no later than 4 wk into the program, the participants progressed to two sets of 8–12RM. The intensity of 8–12 RM was maintained throughout the treatment period. If participants were able to successfully complete more than 12 repetitions, the workload was subsequently increased by 5–10%. Stretching exercises were performed between activities. The warm-up and cool-down for this group included 5 min of low-intensity walking and some light stretching.

Combination training (BOTH). The participants in this group performed both CVT and RT activities during each of the 36 exercise sessions. However, the BOTH participants progressed to a maximum of 30 min of CVT work, performed only one set of 8–12RM and did not stretch between resistance activities.

Control group (CON). The participants in this group underwent testing as described above and were asked not to make significant changes in their physical activity and nutrition habits over the 12-wk treatment period. They received monthly follow-up phone calls during the treatment period.

To control for as many aspects of exercise prescription as possible, we elected to match the groups for frequency, intensity, and total duration of exercise sessions. By the last 4 wk of the 12-wk treatment program, all participants
exercised between 50 and 60 min per session. To achieve this, the BOTH group performed less cardiovascular work than the CVT group, and only performed one set of resistance activities as compared with the two sets performed by the RT group. Although other designs exist, we believe this design is the most appropriate for addressing the question as to which modality or combination of modalities should be prescribed for apparently healthy older adults when a specific duration of activity (in this case 50–60 min) is a constraint. It is important to note that in order to ensure that the RT group had an equivalent duration of activity as the other groups, we employed a two-set approach. However, this should not be construed as a limitation of the study design as it is clear that strength gains are not different between groups performing 1 versus 2 sets of equivalent intensity resistance exercise (see Feigenbaum and Pollock for a review) (9).

### Data Analysis

The following statistical models were employed: 1) one-way ANOVA was used to compare the mean ages, heights, weights, physical activity scores across all groups and to compare the number of sessions attended for each of the three exercise-treatment groups. The appearance of any group differences in these variables would necessitate their inclusion as covariate(s) in subsequent analyses; 2) $4 \times 2$ mixed model ANOVAs with repeated measures were used to examine main effects of group and treatment period and group by treatment period interactions on the dependent variables. These included the AAHPERD fitness items, 5RM test scores, and the GXT data including resting (supine) and exercise (2nd stage) HR, SBP, DBP, MAP, RPP, as well as RPE during the 2nd stage and test duration. The mixed model ANOVAs were followed-up by t-tests on the pre- and post-training values for each group. In the case of significant interactions, Duncan’s multiple range tests were applied to the group means of the absolute magnitudes of change; and 3) lastly, because strength gains are often reported as percent improvement, one-way ANOVAs were used to compare the percent improvements in strength by group. Duncan’s multiple range post hoc tests were employed where indicated. Alpha was set a priori for all tests at 0.05.

### RESULTS

Of the 67 respondents, 45 passed screening and elected to continue with the study. Of the 22 respondents who did not participate in the study, eight withdrew before providing informed consent, whereas 14 did not meet the inclusion criteria. The latter either had signs or symptoms consistent with elevated risk according to the ACSM guidelines (1), or their physicians did not provide medical clearance for their participation. Included among the reasons for failing medical screening were recent history of chest pain, uncontrolled blood pressure, and significant osteoporosis. Of the 45 participants, seven did not maintain at least 80% attendance, one had a significant medication change and was discontinued from the study, and one was involved in an automobile accident and therefore could not continue. None of the dropouts left the program as a result of adverse responses to the treatment. Therefore, the following data are from 36 participants (CVT group $N = 11$; RT group $N = 10$; BOTH group $N = 9$; CON group $N = 6$). The descriptive statistics for all variables (i.e., group characteristics, and CV, strength, and AAHPERD test items) can be found in Tables 1–4, respectively. ANOVAs of the group characteristics revealed no group differences in age, height, weight, or physical activity recall scores. The exercise groups did not differ in number of sessions attended.

### Analysis of Variance

The results of the $4 \times 2$ mixed models ANOVAs revealed no significant main effects for group or treatment. However, there were several group by treatment period interactions. Follow-up t-tests and Duncan’s multiple range comparisons revealed that in many cases the group by treatment interactions were the result of similar treatment effects for all groups except the control, as the control group did not improve on any test score. In other instances, the interactions were also indicative of differences in the response of the exercise treatment groups to the training period. As to the former, after the treatment all exercise groups demonstrated similar changes in the following: lower supine HR and RPP; lower RPE (i.e., during the 2nd stage of the test); and longer GXT duration. With respect to muscular strength, all exercise treatment groups improved equally on 5RM strength for the leg-extension, leg-curl, seated row, and lateral-raise. Lastly, all exercise treatment groups im-

<table>
<thead>
<tr>
<th>Group</th>
<th>CVT</th>
<th>RT</th>
<th>BOTH</th>
<th>CON</th>
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</thead>
<tbody>
<tr>
<td>No. of subjects</td>
<td>10</td>
<td>11</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Gender</td>
<td>5 male, 6 female</td>
<td>5 male, 5 female</td>
<td>4 male, 5 female</td>
<td>3 male, 3 female</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>69.1 ± 5.3</td>
<td>69.8 ± 6.0</td>
<td>66.1 ± 5.5</td>
<td>68.0 ± 5.4</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>170.1 ± 3.67</td>
<td>168.8 ± 3.4</td>
<td>172.0 ± 3.9</td>
<td>168.8 ± 3.5</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>84.8 ± 5.7</td>
<td>77.7 ± 6.2</td>
<td>81.6 ± 4.1</td>
<td>78.1 ± 6.9</td>
</tr>
<tr>
<td>Physical Activity Score</td>
<td>9.38 ± 7.43</td>
<td>7.42 ± 7.92</td>
<td>5.68 ± 4.37</td>
<td>9.68 ± 4.25</td>
</tr>
<tr>
<td>Attendance (of 36 sessions)</td>
<td>34.9 ± 1.3</td>
<td>34.9 ± 1.7</td>
<td>34.3 ± 1.7</td>
<td>—</td>
</tr>
</tbody>
</table>

Values are mean ± SD. CVT, cardiovascular group; RT, resistance group; BOTH, combination group; CON, control group. There were no group differences in any variables at $P < 0.05$. 

### TABLE 1. Descriptive characteristics.

- **No. of subjects**: 10 (CVT), 11 (RT), 9 (BOTH), 6 (CON)
- **Gender**: 5 male, 6 female (CVT), 5 male, 5 female (RT), 4 male, 5 female (BOTH), 3 male, 3 female (CON)
- **Age**: 69.1 ± 5.3 (CVT), 69.8 ± 6.0 (RT), 66.1 ± 5.5 (BOTH), 68.0 ± 5.4 (CON)
- **Height**: 170.1 ± 3.67 (CVT), 168.8 ± 3.4 (RT), 172.0 ± 3.9 (BOTH), 168.8 ± 3.5 (CON)
- **Weight**: 84.8 ± 5.7 (CVT), 77.7 ± 6.2 (RT), 81.6 ± 4.1 (BOTH), 78.1 ± 6.9 (CON)
- **Physical Activity Score**: 9.38 ± 7.43 (CVT), 7.42 ± 7.92 (RT), 5.68 ± 4.37 (BOTH), 9.68 ± 4.25 (CON)
- **Attendance (of 36 sessions)**: 34.9 ± 1.3 (CVT), 34.9 ± 1.7 (RT), 34.3 ± 1.7 (BOTH), — (CON)
Values are mean ± SD.

GXT, test duration in minutes; CVT, cardiovascular group; RT, strength group; BOTH, combination group; CON, control group; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; RPP, rate pressure product (HR × SBP) (RPP = value × 10²); RPE, rating of perceived exertion (Borg 20-point scale).

*Exercise values were obtained during the last minute of the second stage of each test.

* Post different from Pre (P < 0.05).

Values are mean ± SD. Means are compared with Duncan’s multiple-range tests indicated that the BOTH group outperformed the CVT and RT group on the strength and agility items after training.

ANOVA on Percent 5RM Strength Improvement

The results of the ANOVA on the percent improvement in 5RM strength were consistent with the results described above. That is, the scores for the control group did not change significantly, and the percent improvement in chest-press and biceps-curl 5RM performances were greater in the RT group than in the CV group, and the RT and BOTH improved more on the seated dip 5RM than did the CV group. There were no differences between RT and BOTH group strength gains.

DISCUSSION

This study investigated the benefits of three exercise training protocols with respect to selected measures of

TABLE 3. Group comparison of cardiovascular parameters.

<table>
<thead>
<tr>
<th></th>
<th>CVT</th>
<th>RT</th>
<th>BOTH</th>
<th>CON</th>
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<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>GXT time (min)</td>
<td>8.5 ± 4.1</td>
<td>12.1 ± 4.1*</td>
<td>7.8 ± 3.7</td>
<td>10.1 ± 2.26*</td>
</tr>
<tr>
<td>Supine</td>
<td>HR</td>
<td>67.8 ± 9.3</td>
<td>62.2 ± 9.4*</td>
<td>67.3 ± 10.2</td>
</tr>
<tr>
<td></td>
<td>SBP</td>
<td>133.7 ± 16.4</td>
<td>123.4 ± 13.0*</td>
<td>129.1 ± 22.5</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td>76.8 ± 7.0</td>
<td>73.2 ± 11.9</td>
<td>75.1 ± 10.3</td>
</tr>
<tr>
<td></td>
<td>MAP</td>
<td>95.8 ± 8.7</td>
<td>89.9 ± 11.3</td>
<td>93.1 ± 13.2</td>
</tr>
<tr>
<td></td>
<td>RPP</td>
<td>8.9 ± 2.0</td>
<td>7.5 ± 1.4*</td>
<td>8.7 ± 1.1</td>
</tr>
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</table>

Exercise

|                  | HR  | 115.6 ± 17.8 | 112.1 ± 18.0 | 117.1 ± 12.9 | 110.6 ± 12.4 | 113.0 ± 14.7 | 112.9 ± 14.3 | 116.4 ± 9.2 | 109.4 ± 9.4 |
|                 | SBP | 153.3 ± 10.8 | 146.6 ± 15.6 | 172.4 ± 16.8 | 162.3 ± 15.6 | 149.4 ± 25.6 | 146.3 ± 22.6 | 171.4 ± 20.6 | 172.0 ± 27.1 |
|                 | DBP | 81.3 ± 7.2 | 70.9 ± 8.2* | 85.0 ± 7.3 | 75.6 ± 6.5* | 78.1 ± 4.4 | 78.3 ± 12.6 | 89.4 ± 15.8 | 88.6 ± 10.8 |
|                 | MAP | 108.8 ± 6.7 | 96.1 ± 9.1* | 115.3 ± 10.0 | 104.5 ± 5.2* | 102.2 ± 13.9 | 99.3 ± 13.5 | 114.7 ± 19.0 | 114.7 ± 15.1 |
|                 | RPP | 17.9 ± 2.0 | 16.7 ± 3.8 | 20.4 ± 4.1 | 17.9 ± 3.2 | 16.8 ± 3.6 | 16.6 ± 4.1 | 20.3 ± 3.8 | 18.6 ± 4.3 |
|                 | RPE | 12.2 ± 1.6 | 10.0 ± 1.7* | 12.7 ± 2.1 | 11.5 ± 2.2* | 12.4 ± 2.6 | 11.5 ± 1.9* | 12.1 ± 2.3 | 11.6 ± 2.3 |

Values are mean ± SD. Units are foot-lbs.

* Post greater than Pre (P < 0.05).
† Absolute magnitude of change greater than CVT (and CON) groups (P < 0.05).
§ Change greater than in CVT (and CON) groups (P < 0.05).

EXERCISE TRAINING IN OLDER ADULTS
TABLE 4. Exercise-training and functional fitness scores.

<table>
<thead>
<tr>
<th></th>
<th>CVT</th>
<th>RT</th>
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<tbody>
<tr>
<td><strong>Pre</strong></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Ponderal Index</td>
<td>11.8±0.7</td>
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<td>12.1±0.6</td>
<td>12.1±0.6</td>
</tr>
<tr>
<td>Flexibility (inches)</td>
<td>25.3±4.7</td>
<td>25.2±5.2*</td>
<td>22.7±5.6</td>
<td>24.5±5.7*</td>
</tr>
<tr>
<td>Agility/balance (s)</td>
<td>24.7±3.2</td>
<td>23.0±3.0*</td>
<td>24.1±2.6</td>
<td>22.8±3.4*</td>
</tr>
<tr>
<td>Strength (repetitions)</td>
<td>24.3±6.0</td>
<td>26.7±6.0</td>
<td>26.8±6.1</td>
<td>29.7±5.1*</td>
</tr>
<tr>
<td>Coordination (s)</td>
<td>11.0±1.0</td>
<td>10.2±1.4*</td>
<td>11.3±1.3</td>
<td>10.1±1.0*</td>
</tr>
<tr>
<td>CV endurance (s)</td>
<td>531.0±64.4</td>
<td>496.9±81.0*</td>
<td>476.7±67.0</td>
<td>440.6±38.0*</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td></td>
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<tr>
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</tr>
</tbody>
</table>

Values are mean ± SD.

CVT, cardiovascular group; RT, strength group; BOTH, combination group; CON, control group.

* Post different from Pre (P < 0.05).

† Magnitude of change greater than CVT and RT (and CON) groups (P < 0.05).

physical fitness and functional fitness in adults whose ages ranged from 60 to 84 yr. The study is unique in that it is the first to report the simultaneous comparison of cardiovascular, resistance, and combination protocols on several measures of fitness in older adults, and the first to test the “interference theory” in older adults. The findings confirm previous studies showing the benefits of cardiovascular and strength training in relatively healthy older adults. More importantly, this study indicates that a combination of strength and cardiovascular training results in similar physiologic improvements as compared with cardiovascular or resistance alone, indicating there was no evidence of “interference” of cardiovascular exercise on strength gains.

The pretraining values for the 1-yr physical activity recall scores are similar to those from Voorrips et al. (31). However, the group means for the present study sample were slightly below the average value previously reported (31) for men and women between 60 and 83 yr of age (11.0 ± 4.6), suggesting our participants were no more than moderately active before the treatment. The hemodynamic responses to submaximal exercise testing (Table 2) were as expected. The results of the AAHPERD functional fitness test battery (Table 4) are commensurate with the expected range of values reported by Osness et al. (23). Finally, although the 5RM strength scores seem reasonable, this appears to be the first study in this population to report 5RM strength using commercially available, calibrated equipment. The Med-X equipment is among the most sensitive devices available using the 5RM test. Furthermore, the present data do not necessarily refute these previous reports. However, our data indeed suggest that combining cardiovascular and 8–12RM resistance training will not interfere with 5RM strength gains in older adults.

The absence of differences in strength gains between groups is even more interesting considering the fact that the RT group performed twice the volume of resistance exercise reported gains in 5RM performance, which ranged from 21 to 64%, appear perfectly in line with Pyka et al. (25), who reported 23–62% improvements in strength after the first 15 wk of a progressive resistance-training program. Thus, these data are consistent with previous work, demonstrating construct validity of the 5RM test. Furthermore, the present data are consistent with those of Charette et al. (6), who reported 28–115% increases in 1RM performance after 12 wk of resistance training in older women, and are consistent with the results of Menkes et al. (22), who reported an average 45% improvement in 3RM upper and lower body strength after 16 wk of resistance training in 50- to 70-yr-old men.

Few studies have examined strength gains subsequent to combination training in older adults. Cress et al. (7) employed similar training intensities to those of the present investigation and reported gains of 33% and 11% in strength and maximal oxygen consumption, respectively. Kelemen et al. (18) employed circuit weight training in addition to traditional cardiac rehabilitation activities in a group of CVD patients and reported gains of 24% and 12% in strength and treadmill time. More recently, Fragnoli-Munn et al. (11) observed 39% and 14% increases in lower- and upper-body 1RM strength, respectively, in 19 older (68 ± 3 yr) CAD patients. However, none of these investigations compared combination training with resistance training only and thus did not address the “interference” theory. The lack of “interference” of combination training on 5RM strength gains in older adults, observed in the present investigation, stands in contrast to reports in younger adults (8,15,27).

Close inspection of previous work, however, reveals that the present investigation differed in two ways. First, Dudley and Djamil (8) only reported interference of CVT on strength gains at high velocities of isokinetic testing. The participants in the present study trained and were tested at slow velocities to ensure a controlled movement pattern. Interestingly, Dudley and Djamil did not observe group differences at slower velocities of testing. Second, Hickson (15) and Sale et al. (27) employed lower training stimulus (15–20RM) protocols in comparison with the present investigation. Thus, the present data do not necessarily refute these previous reports. However, our data indeed suggest that combining cardiovascular and 8–12RM resistance training will not interfere with 5RM strength gains in older adults.
compared with their BOTH counterparts. This finding supports previous work that suggests strength gains are not different between groups employing 1 versus 2 sets of equivalent intensity resistance training (see Feigenbaum and Pollock (9)).

Of additional interest is the appearance of impressive gains in leg strength in the CVT group. Although the RT and BOTH groups improved in measures of upper body strength to a greater degree than the CVT group, there were no group differences with respect to improvements in leg strength. Although this area of investigation is largely unexplored in older adults, this finding is in contrast to at least one study (18) wherein traditional cardiac rehabilitation activities did not appreciably enhance leg strength. However, those patients had been participating in a traditional cardiac rehabilitation program before strength training, which may have influenced any further strength gains in the legs. The older age of our participants, combined with the modest activity level of our sample, may explain why walking and cycling at 60–75% of estimated maximal work capacity provided an important stimulus for leg strength gains.

Although changes in cardiovascular fitness were not the focus of this investigation, these data are of some interest and warrant discussion. The data from the present investigation document significant improvements in resting cardiovascular efficiency after the treatment period across all groups. This is best evidenced by lower supine HR and RPP observed for all groups after the treatment period. All subjects increased the length of time on the GXT before termination criteria were achieved (HR >85% age predicted max, or RPE ≥ 15), indicating improved cardiovascular endurance. Thus, these data are consistent with previous reports indicating that cardiovascular, strength, and combination-training programs are all effective in improving cardiovascular fitness among older adults. Kohrt et al. (19) observed lower resting heart rates in men and women after 9–12 months of cardiovascular training. Hagberg et al. (14) reported lower HR responses and RPEs during submaximal treadmill exercise after 26 wk of cardiovascular training. Interestingly, however, Hagberg et al. did not observe improvements in cardiovascular function after 26 wk of strength training. In contrast, Parker et al. (24) and Ades et al. (2) independently demonstrated that resistance training in healthy older adults results in improved hemodynamic responses to, and time to, fatigue during incremental cardiovascular work. The difference in these results may be explained, in part, by the observation that the participants in Hagberg et al.’s study did not increase lean muscle mass. Although there is no evidence of changes in body composition among the RT group in the present investigation, the ponderal index is not a measure of lean body mass per se. Therefore, the present study is limited with respect to reconciling disparate findings regarding the influence of resistance training on cardiovascular function. Combination protocols in older adults have also yielded significant improvements in cardiovascular function. Ferko et al. (10) reported improved time to reach termination criteria on submaximal GXTs among 60- to 75-yr-old women. Be-niamini et al. (4) also reported improved time to exhaustion on symptom-limited GXT tests among ischemic heart disease patients in a cardiovascular and resistance training program. In contrast to the present findings, these investigators found that concurrent cardiovascular and resistance training had a more pronounced effect on GXT-time than when resistance training was not included in the protocol. The present data do not support the hypothesis that one particular training protocol was more effective than the others for evoking improvements in any of the cardiovascular parameters examined at rest or during exercise.

An additional important aspect of this investigation was the examination of the influence of various training protocols on measures of functional fitness. The results of the present investigation indicate that each mode of exercise resulted in significant improvements on each aspect of the AAHPERD test, with the single exception that the CVT group did not improve in the AAHPERD muscular strength and endurance item. Although many studies have documented improvements in physical functional ability after various exercise interventions (see Tseng et al. (29) for a review), few have actually examined this issue in relatively healthy and independent living older adults. Cress et al. (7) recently demonstrated significant improvements in functional fitness scores after 6 months of cardiovascular and resistance training. Moreover, this is the first investigation to simultaneously compare the efficacy of cardiovascular, resistance, and combination training on measures of physical function in relatively healthy, independent-living older adults. The results of this comparison suggest that combination training is more effective than RT or CVT in enhancing certain aspects of physical functional ability. This is particularly evident in the group by treatment period interaction on the AAHPERD agility and strength items. Interestingly, we have previously observed a relationship between agility performance and health-related quality of life in older adults (32). Therefore, the findings of the present investigations may have implications for extending functional life span and optimizing quality of life throughout the life span.

In conclusion, the results of the present investigation support the position taken by the American College of Sports Medicine (21) that indicate the importance of comprehensive exercise programs for older adults that incorporate both cardiovascular and strength training components. Moreover, these data suggest that apparently healthy older adults who engage in combination training programs do not jeopardize potential strength gains that could be achieved through strength training alone. Lastly, and perhaps more importantly, these data suggest that combination training is of significantly greater value than cardiovascular or strength training alone with respect to optimizing certain aspects of functional fitness. Future work should include longitudinal examinations of the benefits of combination training on the compression of morbidity and disablement, and quality of life in older adults.

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