THE EFFECTS OF A COMBINED RESISTANCE TRAINING AND ENDURANCE EXERCISE PROGRAM IN INACTIVE COLLEGE FEMALE SUBJECTS: DOES ORDER MATTER?

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ABSTRACT

Davitt, PM, Pellegrino, JK, Schanzer, JR, Tjonas, H, and Arent, SM. The effects of a combined resistance training and endurance exercise program in inactive college female subjects: Does order matter? J Strength Cond Res 28(7): 1937–1945, 2014—Although both endurance (E) and resistance (R) exercise improve various health and fitness variables, there is still debate regarding the optimal ordering of these modes of exercise within a concurrent bout. The purpose of this study was to determine the effects of performing E before R (E-R) or R before E (R-E) on strength, V̇O₂ max, and body composition over the course of an 8-week exercise program. Inactive female subjects (N = 23; 19.8 ± 0.22 years; 61.0 ± 2.5 kg) were randomly assigned to either an E-R (n = 13) or an R-E (n = 10) group. Subjects trained 4 d·wk⁻¹ over the 8-week study. The E portion consisted of 30 minutes of aerobic exercise at 70–80% heart rate reserve (HRR). The R portion used a 3-way split routine with subjects performing 3 sets of 8–12 repetitions for 5–6 different exercises using a load equal to 90–100% 10 repetition maximum. There were 2 days of testing before and after 8 weeks of training to determine performance and body composition. There were significant improvements in chest press (p < 0.001), leg press (p < 0.001), V̇O₂ max (p < 0.001), and lean body mass (LBM) (p = 0.005) across both groups. Weight significantly increased (p = 0.038), but percent body fat did not change (p = 0.46). There were no differences as a function of group (p > 0.267). There were significant improvements in performance and LBM over an 8-week concurrent training program in inactive college female subjects, regardless of the order in which R and E were performed. It seems that fitness markers improve similarly regardless of the order of R or E in a 4 d·wk⁻¹ program in inactive female subjects. Therefore, the order of these modalities for beginning exercisers should be based on personal preference and to facilitate adherence.

KEY WORDS aerobic capacity, strength, lean body mass, body composition

INTRODUCTION

The benefits of both chronic endurance exercise (E) and resistance training (R) are well documented, and both are recommended to improve health and fitness. For many years, E has been seen as a benefit to one’s health and fitness because it improves aerobic capacity, capillary and mitochondrial density, lipid profiles, vascular flexibility, and weight loss (8,9,13,14,22,25,26,28,32). The benefit of R has been largely recognized for its impact on strength and lean body mass (LBM), and for its impact on fat loss and improvements in lipid profiles (9,16,25,29,32). Current recommendations for exercise prescription suggest a combination of E and R because the benefits may provide an overall synergistic effect, and each intervention has overlapping and unique benefits (2,24).

Studies comparing E or R alone with a combined training group have found that the combined groups did have positive improvements in strength and aerobic fitness and increases basal metabolic rate and fat loss (13,16,22,24,26). However, several of these studies suggest that the benefits of combining exercises into 1 session may not always result in the same magnitude of selected outcomes compared with performing R-only with a combined R and E group. Kraemer et al. (21) have shown an attenuation of strength gains when comparing R-only with a combined R and E group. Still, the argument for using combined training is that it may be more beneficial as a whole for overall health purposes (16,22,24).

Although the benefits of combining E and R into 1 session have been demonstrated for strength and aerobic capacity, the sequence in which the modalities are performed may also be an important consideration to maximize benefits. Chitra et al. (8) found that performing E before R improved 4-km time trial and maximal oxygen consumption (V̇O₂ max) or aerobic power significantly more than performing R before E and either exercise modality (R or E) alone, in
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a fit male population. It was suggested that performing R before E fatigues the muscles that are used during the aerobic bout (8). However, contrary to the suggestions of Chata et al. (8), other researchers have found no significant impact of the order of these modalities on oxygen consumption during the exercise bout (1). Conversely, attenuations in chronic strength gains when performing E before R have been explained by a diminished ability of the neuromuscular pathway leading to the reduction in strength gains (5,23). As evidence for this effect, Cadore et al. (5) saw a significantly greater increase in strength gained in subjects performing R before E in comparison to a group performing E before R, which was related to an increase in the qualitative force generation of the muscle per unit of muscle mass. However, there were no differences in aerobic fitness gains between the exercise sequences (5). Other research has indicated no significant difference in either aerobic or strength gains when comparing the sequence in which both E and R were performed (11,18). One potential reason for the discrepancies may be the variability in training frequency and intensity given that many of the studies had subjects only training 2–3 days per week and performing exercises of low-to-moderate intensity (5,8,9,18). Average increases in aerobic capacity and strength varied from approximately 5 to 14% and from approximately 12 to 33%, respectively (5,8,9,11,18,28). Duration, frequency, and intensity play an important role in determining the effectiveness of desired outcomes, and 2 days per week of lower-to-moderate intensity training may not be sufficient to elicit large enough changes to see differences in the ordering of the exercises.

Aside from the aerobic and strength gains, a chronic benefit of adding R to E, in a combined exercise regimen, is increased LBM (13,19,22). Given the variability in strength gains when implementing different exercise order sequences (5,9,18,28), it stands to reason that there may have been differences in LBM gains. Interestingly, all of the studies mentioned above have measured body composition, but none have reported on the significance or differences in LBM, specifically (5,9,18,28). Therefore, the differences between performing E before or after R on changes in LBM warrant further investigation.

Selecting an exercise program that will maximize efficacy and allow an individual to achieve the optimal benefits is important. Although both R and E have been shown to improve various health and fitness variables, there is still considerable debate regarding the optimal ordering of these modes of exercise within an exercise bout. Given the few studies that exist, there is need to determine the effects that E and R have on specific desired outcomes (i.e., strength, aerobic fitness, and body composition). It is often assumed that order should be dictated by the priority of the desired fitness and health outcomes. Therefore, the purpose of this study was to determine the effects that the order of exercise modality has on strength, VO$_{2}$max, body weight, body fat (%BF), and LBM over the course of an 8-week exercise program.

### Methods

#### Experimental Approach to the Problem

To determine if there is a significant difference between R-E and E-R on changes in aerobic fitness, strength, weight, LBM, and %BF, we used an 8-week combined exercise program using aerobic exercise (70–80% of heart rate [HR] reserve) and a comprehensive resistance training protocol (90–100% of 10 repetition maximum [RM]) using inactive and low-active college-aged female subjects. Subjects participated in 2 days of familiarization (introduction of each exercise with proper technique instruction), 2 days of pretesting, 8 weeks of exercise intervention, and 2 days of posttesting. After completing baseline testing, subjects were matched on body weight and randomly assigned to either an R-E or E-R group.

#### Subjects

Inactive and low-active college-aged female subjects ($N = 29$; $19.8 \pm 0.2$ years; $163.5 \pm 1.7$ cm; $61.0 \pm 2.5$ kg) volunteered to participate in the study. Subjects were informed of the study protocol and signed an informed consent before participation. This study was approved by the Institutional Review Board of the Rutgers University. Inclusion criteria required that subjects did not exceed 90 minutes of aerobic exercise per week, engage in R more than 2 times per week, take any medications or have any illnesses that would disrupt metabolic activity or body composition, or have any disabilities that would inhibit them from engaging in the required physical activities. A total of 23 subjects completed the study. The additional 6 subjects either withdrew from the study ($n = 3$) or were dismissed for noncompliance ($n = 3$). Baseline data of the included subjects as a function of group were shown in Table 1.

#### Procedures

**Body Composition.** Body composition was determined by measuring body volume through air displacement plethysmography using the BOD POD (Life Measurements Instruments, Concord, CA, USA), as described in the previous literature (12,35), with %BF calculated through a 2-stage procedure. In addition to %BF, LBM was also calculated. Using the BOD POD, the error of body volume reading is approximately 0.02%, which allows for the calculation of %BF with only 0.01% error (12,35). Height and weight were recorded in conjunction with body composition assessment. All subjects were required to fast for at least 3 hours, arrive normally hydrated, and without having exercised before the test. Compliance with these conditions was assessed by means of interview when the subjects arrived at the laboratory for testing.

**VO$_{2}$max.** Study participants underwent a progressive exercise test to determine aerobic fitness (VO$_{2}$max) before and after the 8-week intervention. A continual progressive protocol (a standard Bruce protocol) was used to determine VO$_{2}$max with an increase in work output at 3-minute intervals until
volitional exhaustion (4). The test and experimental trials were performed on a high-speed treadmill (Trackmaster, Newton, KS, USA), and direct gas exchange (\( \text{V}_\text{O}_2 \text{ and } \text{V}_\text{CO}_2 \)) measurements were made using a ParvoMedics TrueOne 2400 metabolic cart (ParvoMedics, Provo, UT, USA). The maximal graded exercise test was considered valid if 3 or more of the following 4 criteria were met: (a) HRmax within \( \pm 15 \text{ b.min}^{-1} \) of age-predicted maximum HR or a HR that fails to increase with increased workload, (b) respiratory exchange ratio \( >1.10 \), (c) rating of perceived exertion (RPE) greater than 17 (6–19 scale), and (d) plateau of \( \text{V}_\text{O}_2 <2.0 \text{ ml.kg}^{-1}.\text{min}^{-1} \) despite an increase in workload (2). Intraclass correlation for this protocol in our laboratory is \( r = 0.93 \). Heart rate was measured throughout the graded exercise test and experimental trials using a Polar S610 HR monitor (Polar Electro Co., Woodbury, NY, USA).

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\text{TABLE 1. Subject characteristics.} \ast
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<table>
<thead>
<tr>
<th>Variable</th>
<th>R-E ( (n = 10) )</th>
<th>E-R ( (n = 13) )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>19.9 ± 0.4</td>
<td>19.8 ± 0.3</td>
<td>0.78</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.3 ± 2.6</td>
<td>162.9 ± 2.7</td>
<td>0.67</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.4 ± 3.8</td>
<td>61.5 ± 3.4</td>
<td>0.84</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>26.8 ± 2.1</td>
<td>29.6 ± 1.8</td>
<td>0.32</td>
</tr>
<tr>
<td>Lean body mass (kg)</td>
<td>43.8 ± 2.1</td>
<td>42.8 ± 1.8</td>
<td>0.74</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>16.6 ± 2.3</td>
<td>18.6 ± 2.0</td>
<td>0.52</td>
</tr>
<tr>
<td>( \text{V}_\text{O}_2 \text{max} ) (ml.kg(^{-1}).min(^{-1}))</td>
<td>37.4 ± 2.2</td>
<td>39.9 ± 1.9</td>
<td>0.4</td>
</tr>
</tbody>
</table>

\ast Values expressed as mean \( \pm \) SEM.

Forty-eight h after the \( \text{V}_\text{O}_2 \text{max} \) test, subjects came back to the laboratory to determine maximal strength for each participant, using a 10RM. This is considered a safer and more reliable form of testing than the 1RM because the subject pool is unskilled in weight training (3). The 10RM was assessed for chest press and leg press. Subjects warmed up for 3–5 minutes on a stationary bicycle at 50\% of their HR\(_{\text{max}} \) to increase blood flow and prepare for the maximal testing. The subjects completed 2 warm-up sets. The first warm-up set consisted of 10 repetitions with 65\% of estimated 10RM load followed by a 2 minutes of rest. The second warm-up set consisted of 10 repetitions with 75\% estimated 10RM load followed by a 3 minutes of rest. After the warm-up sets, the subjects attempted 100\% of estimated 10RM load. The 10RM load was determined within 3–5 attempts with 3-minute rest between each attempt. If the estimated load was too heavy, the load was decreased by subtracting 2.5–5\%. If the estimated load was too light, the load was increased by adding 5–10\%. The 10RM was achieved within 4 sets for all subjects (4).

Intraclass correlation for 10RM testing in our laboratory is \( r = 0.94 \).

Experimental Protocol. Subjects were randomly assigned to perform either R before E (R-E) or E before R (E-R). The training program consisted of 4 sessions per week for 8 weeks, with each session lasting approximately 1 hour. Subjects had to complete ≥27 sessions to be included in the final analysis. The aerobic component of the program consisted of 30 minutes of moderate to moderate-high intensity E at 70–80\% HR reserve (HRR), with HR and RPE being monitored continuously throughout each session. The cardiovascular exercise intensity was progressively increased each week based on RPE and HR response (2). The R component used a 3-way split routine (chest and back, shoulders and arms, lower body) with subjects performing 3 sets of 8–12 repetitions for 5–6 different exercises using a load equal to 90–100\%
10RM. The rest period between sets and exercises was 60–90 seconds. The weight for each R exercise was recorded, and when 12 repetitions could be attained, adjustments were made to allow progressive overload in accordance with exercise prescription guidelines (2). To ensure safety and proper technique of the exercises, a trained research staff member supervised each exercise session. The time between E and R was no more than 5 minutes.

Statistical Analysis
The results are expressed as mean ± SEM. Repeated measures multivariate analysis of variance with univariate follow-ups were used. The design consisted of a 2-way (group × time) analysis with repeated measures for the last factor. VO₂max, 10RM chest press, 10RM leg press, body weight, %BF, and LBM were the dependent variables and were compared before and after 8 weeks of training for the R-E and E-R groups. Statistical significance was set at p ≤ 0.05 with a calculated power of 0.8 for this sample size. Effect sizes (ES) were computed using Hedges’ g formula. Statistical analyses were performed using SPSS version 19 software (SPSS Inc., Chicago, IL, USA).

RESULTS
VO₂max Changes
VO₂max increased significantly (p ≤ 0.05) in both the E-R and R-E groups (E-R: pre, 39.9 ± 1.9; post, 46.2 ± 1.8 ml·kg⁻¹·min⁻¹; ES = 1.1; R-E: pre, 37.4 ± 2.2; post, 43.2 ± 2.0 ml·kg⁻¹·min⁻¹; ES = 0.7; p ≤ 0.05) (Figure 1). There was no significant difference between the groups (p > 0.05; ES = 0.2).

Strength Changes
There was a significant increase in muscular strength for chest press (E-R, 13.1 ± 1.2 kg; ES = 1.7; R-E, 9.9 ± 1.8 kg; ES = 1.4; p < 0.001) and leg press (E-R, 30.2 ± 4.8 kg; ES = 1.8; R-E, 28.6 ± 4.4 kg; ES = 0.7; p < 0.001) (Figure 2). Increases in strength were not significantly different as a function of group for chest press (p = 0.38; ES = 0.7), or leg press (p > 0.05; ES = 0.1).

Body Composition Changes
Lean body mass increased significantly in both the E-R and R-E groups (E-R, 1.2 ± 0.3 kg; ES = 0.3; R-E, 0.6 ± 0.6 kg; ES = 0.1; p ≤ 0.05) (Figure 3A). Both groups significantly increased LBM, but there were no significant differences between the groups (p ≤ 0.05; ES = 0.4). There was a small but significant increase in body weight for both E-R and R-E groups (E-R, 0.8 ± 0.6 kg; ES = 0.1; R-E, 1.0 ± 0.5 kg; ES = 0.1; p = 0.038), but there were no significant differences between the groups (p > 0.05; ES = −0.1) (Figure 3B). There were no significant changes in %BF for either group over the course of 8 weeks (E-R, −0.9 ± 0.6%; ES = −0.1; R-E, 0.2 ± 0.7%; ES = 0.0) (Figure 3C).
DISCUSSION

The findings of this study indicate that the combination of E and R into 1 session results in an improvement in aerobic fitness, strength, and LBM in inactive college-aged female subjects. These effects were seen independent of the order in which the modes of exercise were performed. The increase in $\text{VO}_2\text{max}$ seen with both groups in our study (R-E, 15.3%; E-R, 15.6%, respectively) was similar to improvements seen in other studies comparing exercise sequence. Chata et al. (8) demonstrated 13.6% and 10.7% increases in $\text{VO}_2\text{max}$ for both E-R and R-E groups, respectively. The increase in $\text{VO}_2\text{max}$ in their E-R group was significantly different than that in the group that performed R first. They argued that performing R before E resulted in an inferior improvement in aerobic capacity as a result of the resultant fatigue from the previous R workload (8). However, they did indicate that the R-E group increased aerobic capacity similar to an E-only group, which means the addition of R before E improved aerobic fitness to a similar extent as E-only (8). Although we did not see significant differences in $\text{VO}_2\text{max}$ between the groups, 1 difference between our study and that of Chata et al. (8) was that we used inactive and low-active female subjects and they used active aerobically fit male subjects. Perhaps, the changes as a function of exercise modality order are not as pronounced in the population we studied, and there may be greater impact for trained individuals.

In comparing a combined E and R protocol versus each

![Figure 3. A) Changes in lean body mass before and after 8 weeks of training. Changes in lean body mass were significantly different as a function of time ($p = 0.005$) but not as a function of group ($p > 0.05$). *Significantly different from corresponding pre value. B) Changes in weight before and after 8 weeks of training. There were significant differences as a function of time ($p = 0.038$) but not as a function of group ($p > 0.05$). *Significantly different from corresponding pre value. C) Changes in percent body fat before and after 8 weeks of training. The changes in body fat were not significantly different ($p = 0.461$).](https://www.nsca.com)
exercise modality alone, Dolezal and Potteiger (13) reported that using a combined R-E protocol is inferior to E-only for producing improvements in \( V\_2\max \) in aerobically fit men (\( V\_2\max \geq 50 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \)). This is interesting because it has been reported that the addition of R to E improves the efficiency of the muscles through a shift in the type of muscle fiber, with a transformation of type IIB fibers into type IIA (34), which can aid in overall oxidative metabolic capabilities (33). Although Dolezal and Potteiger (13) did not compare different exercise order groups, they did indicate that their combined group always performed R first, and this disrupted the gains in aerobic fitness, which supports the findings of Ch'tara et al (8). They postulate that the impedance of aerobic gains with R inclusion is a result of a reduction in capillary and mitochondrial volume density. Several other studies comparing exercise order used non–endurance-trained participants and revealed no difference in \( V\_2\max \) between the groups (5,11,18). Another study that also compared the sequential ordering of exercises used active female subjects and found that after 12 weeks of training, both exercise orders increased \( V\_2\max \), but only the group that performed R first increased \( V\_2\max \) significantly (18). This is contrary to previous research, and the authors indicate that a reduction in 1 particular subject’s \( V\_2\max \) may have contributed to the lack of significance in the E-R group (18).

Collins and Snow (11) used both male and female subjects in a 7-week study and saw significant \( V\_2\max \) increases for both exercise orders, but no significant difference between the groups (R-E, 6.7%; E-R, 6.2%). The lack of significant difference between the sequential ordering in the study by Collins and Snow closely resembled the results of our study. Regardless of the differences (or lack thereof) between the groups, the \( V\_2\max \) improvements in the current study were higher than any of the previously mentioned studies (5,8,11). Although conflicting conclusions may persist in this area, inclusion of a combined program resulted in significant improvements in \( V\_2\max \) across studies, regardless of the order in which the exercise is performed. Perhaps, the different findings among previous and current research can be attributed to the intensity, duration, and frequency of the various training protocols. For example, the average sessions attended per week by both the groups in the current study was 3.4, which was higher than all previously reported studies comparing exercise sequence (5,8,11,18,28). Other important factors, as discussed above, include training status and fitness level.

With regards to strength changes in a combined program, we saw significant improvements for both chest press (27.4%, 39.5%) and leg press (33.2%, 44.1%) for R-E and E-R, respectively. Further analysis indicates an ES for chest press of 0.7, in favor of E-R. The ES for leg press was small (0.1), but interestingly, the ES for group gains were both large yet over twice as large for E-R (R-E: ES = 0.7; E-R: ES = 1.8). The between-subject variability may be contributing to the lack of statistical difference despite the ES values. The overall changes in strength were similar in both the groups and were in accordance with several other studies examining combined exercise modalities (11,13,18,22,26). One study showed that a combined group having similar significant increases in both chest press and squat (18%, 22%) when compared with an R-only group (18%, 23%) using a training schedule that had subjects exercising 3 days per week for 10 weeks using a high-intensity R protocol (26). Comparing the sequential ordering of E and R in active female subjects, Gravelle and Blessing (18) found no significant differences between exercise orders, even though both groups saw significant increases in leg press (R-E = 26.6%; E-R = 27.4%). It is also worth noting that E did not appear to inhibit strength improvements considering that an R-only group had a similar increase in leg press when compared with both exercise order groups (25.9%) (18), which is consistent with other findings in both male and female participants (11). This is in conflict with some previous findings of exercise modality order reporting that R before E did result in significantly greater strength gains than E before R in elderly men (5). Other studies comparing a combined R and E versus R-alone have indicated the addition of E to R results in inferior strength gains in men (13,21).

Previous findings of attenuations in strength gain from the addition of E to an R program may suggest the mechanism of action to be decreased neuromuscular motor unit time or recruitment, and therefore, less muscle tissue being used to carry out the exercise (19,21). In cyclists, diminished muscular power after a previous bout of E appears to be the result of a reduction in muscular recruitment (23). This can be explained by the different bioenergetic demands of E and R. For example, R typically results in hypertrophy of fast twitch, type II muscles, with an increased recruitment of faster and more force-generating muscle fibers and is highly reliant on ATP-PCr and glycolysis (21,27,33,34). Conversely, E (which relies on oxidative phosphorylation) induces changes in the metabolic machinery to increase oxidative metabolism capabilities, often times reducing hypertrophy and power-generating muscle fibers, which would impede overall gains in muscular strength and anaerobic power (15,21). However, not all research using a concurrent E and R program saw decrements in strength gain compared with R-alone (22,26). Lemura et al. (22) used a similar population to the current study and reported significant increases in strength for a R-only group and a combined R and E group, with no significant differences between the groups. Again, even though there were discrepancies between studies, all seem to agree that there are benefits and gains to be made, whether E is added to R and regardless of the order in which the modalities are performed. It remains possible that the order of E and R within an exercise bout (or even the use of concurrent training in general) could result in differences in peak performance in populations looking for maximal gains in either strength or endurance. This
may be particularly true if using heavier loads (i.e., 3–5RM) for R or greater intensities for E.

It is important to note is that there are several major differences between the studies in this area. These include, but are not limited to, the subjects’ activity status, the frequency of exercise during the study, and the duration of the study. Some studies have had their subjects training as little as 2 days per week (8,28), whereas others, including the current study, have used as many as 4 days per week of training. The subjects being sedentary vs. active or even male vs. female will potentially play a large role in determining the somewhat short-term effects of both E and R. For the sedentary individual or novice exerciser, the initial changes and improvements may be from the subjects learning and mastering proper form and from neuromuscular adaptations, which will simply allow them to become more efficient (7). When using a previously sedentary population for examining exercise modality order effects, perhaps differences would emerge with longer periods of training. This is partly supported by an interference and actual decrease in strength gains in a combined E and R group only showing up after 8 weeks of training (20). Given the rather large initial fitness improvements that would be seen for a sedentary population compared with an active one, it is possible that any exercise modality order effects are superseeded by the robust physiological effects simply produced by a combined protocol.

The combining of E and R into 1 exercise session is very common, especially for those individuals who have limited time to exercise. It has also been the intention of individuals to try and achieve the specific adaptations that each exercise provides. Body composition change (fat loss and muscle gain) is perhaps one of the most sought after benefits that people seek when beginning an exercise program. These changes have been attributed to both E and R programs alike. Many times when combining a program of R and E, the individual will see dramatic changes in body composition, which is typically from a loss of body fat and an increase or maintenance in LBM (13,22). The body composition results of the current study were similar to many other studies that used a combined exercise group and saw increases in total body weight (9,11,13,28). Lean body mass increased significantly for both the groups (E-R, 1.2 kg and R-E, 0.6 kg), and there was a significant increase in body weight (E-R, 0.8 kg and R-E, 1.0 kg). However, there were no significant differences between the groups. Chata et al. (9) showed a significant difference between pre and post body fat percentages in R-E (−2.2%) and E-R groups (−2.2%) with no difference between groups. Okamoto et al. (28) used sedentary male and female subjects to study sequential ordering of exercise and found a significant decrease in body fat percentage in both the groups, with no significant difference between the groups (E-R, −2.9%; R-E, −2.7%). Although LBM changes were not reported, it can be assumed that there was an increase in LBM considering that subjects lost body fat and increased total weight by about 1 kg (11). There were also significant increases in strength, which support the findings that all of the studies mentioned: regardless of exercise order, strength increases were concomitant with increases in LBM (5,8,9,11,13,18,28). Differences in strength and LBM gains are likely attributable to the various intensities, durations, frequencies, training status, age, and gender.

Within the current study, there was no significant difference between the groups with regard to a change in body fat percentage from pre to post (E-R, 0.64% and R-E, −2.99%). This is consistent with some previous findings (18,30) but inconsistent with others (8,11,28). Given the significant increases in strength, VO2 max, and LBM, we would have generally expected to see a decrease in fat mass, given a frequency of 4 days per week of exercise. However, this was not the case. Although we cannot entirely account for the lack of body fat change, we do recognize that subjects were instructed to continue their regular diet throughout the training program. Given the subject population, the body fat results in the current study are not completely unexpected because it is consistent with weight gain typically seen in college underclassmen (10,17). Upon calculation of ES for body fat percentage (~0.5), we notice a moderate-to-large difference between the groups. Again, subject variability likely influenced the lack of statistical differences.

In summary, there were significant improvements in VO2 max, 10RM chest press, 10RM leg press, and LBM after an 8-week concurrent E and R program. When E and R are combined into a single session, there does not appear to be an effect of exercise order in untrained female subjects. Additionally, there were no changes in body fat mass or percentage body fat when participants were not instructed to change their dietary habits. The current study suggests that a combined program of high-intensity R using typical hypertrophy repetition ranges and moderate-high intensity E produces significant changes in functional health and fitness markers in an untrained female population.

**Practical Applications**

There are a limited number of studies performed examining the sequential order of exercise modalities in a single session, although several others have compared combined training against each exercise alone. Although 1 study did demonstrate inferior aerobic fitness gains when E was preceded by R (8), the overall consensus seems to be that concurrent use of R and E in a single session does not appear to, consistently and significantly, influence the adaptations to training, regardless of the order or sequence in which one performs them. The exception to this observation appears to be whether an individual is primarily aiming to maximize improvements in muscular strength, as concurrent E and R has been shown to cause inferior gains in strength compared with R-alone (19–21,31). Although an increase in strength will ensue, it is typically not to the extent of an R-only program. Perhaps, for the untrained or sedentary person, the
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exercise modality order (R-E or E-R) may not necessarily matter, as either will produce neuromuscular adaptations and improvements in aerobic fitness. If both orders provide similar benefits, the only rationale for prescription may be personal preference with implications toward adherence. Further research is needed to determine if the lack of significant differences seen in sequential ordering, within an untrained population, persist when continued for more than 8 weeks. Based on the results of this study, it can therefore be advised to recommend a concurrent and combined exercise program consisting of E and R, regardless of sequential ordering, toward the improvement of one’s health and fitness in an inactive female population.

REFERENCES


