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Original Research Article

# The Optimal Order for Cardiorespiratory, Resistance, Flexibility, and Neuromotor Exercise

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### ABSTRACT

**Background:** Exercise professionals can follow readily available published guidelines, provided from major health organizations, when designing comprehensive exercise programs consisting of cardiorespiratory, resistance, flexibility, and neuromotor exercise. Paradoxically, when combining these types of exercise into the same exercise session, there are no current recommendations for the most appropriate exercise order. **Purpose:** The purpose of this study was to provide preliminary evidence for establishing an optimal exercise order of cardiorespiratory, resistance, flexibility, and neuromotor exercise. **Methods:** A total of 20 participants performed an exercise prescription (ExRx) consisting of all possible sequences (24 combinations) of cardiorespiratory, resistance, flexibility, and neuromotor exercise. Physiological and psychological responses to exercise were measured throughout each exercise session. Repeated-measures ANOVA and polynomial trend analysis were performed to determine if physiological and psychological responses to exercise differed according to exercise order. **Results:** The mean heart rate (HR) response to cardiorespiratory exercise was significantly different ( $p < 0.05$ ) across all exercise sequence positions. When cardiorespiratory exercise was performed first the HR response equated to 56% heart rate reserve (i.e., moderate-intensity exercise). In contrast, the mean HR response equated to 66.7% heart rate reserve (i.e., vigorous-intensity exercise) when cardiorespiratory exercise was sequenced last in the exercise session. Mean resistance exercise rating of perceived exertion (RPE) was similar ( $p > 0.05$ ) when resistance exercise was positioned either first or second in the ExRx; however, post hoc tests showed mean resistance exercise RPE was significantly higher ( $p < 0.05$ ) when the resistance exercise component was positioned third or fourth in the ExRx when compared to either first or second. No significant differences ( $p > 0.05$ ) were found in the physiological responses to either neuromotor or flexibility exercise across all exercise sequence positions. **Conclusion:** Results of this novel study provide important preliminary evidence towards formulating recommendations for an optimal sequence of cardiorespiratory, resistance, flexibility and neuromotor exercise for the ExRx. Findings from the present study suggest cardiorespiratory exercise should always be performed first followed next by resistance exercise. Flexibility and neuromotor exercise can be positioned at a later point in the ExRx.

**KEYWORDS:** Exercise Prescription, Heart Rate, Resistance Training.

## Introduction

### Chronic disease as an epidemic

Chronic diseases are a major cause of death and disability both within the United States and worldwide<sup>1,2</sup>. Maladies including cardiovascular diseases (including hypertension and stroke), type 2 diabetes, obesity, respiratory disease, and some forms of cancer have become so prevalent in today's society that their occurrence is considered an epidemic<sup>3,4</sup>. Biomedical actions have been taken against chronic disease but have been unsuccessful in reversing this epidemic. Medicinal treatments function as secondary or tertiary prevention, meaning they are prescribed after an event or disease occurs. The ongoing upward trend of chronic disease that occurs with biomedical treatments reinforces the need for primary prevention through physical activity<sup>4,5</sup>. Regular physical activity shows considerable promise as a primary preventative strategy. Strong evidence from prospective cohort studies and randomized controlled trials have shown a strong inverse dose response relationship between physical activity and reduced risk of all-cause mortality and other cardiometabolic health outcomes<sup>6</sup>.

### Benefits regular physical activity

Exercise beyond daily activity is essential for improving and maintaining the physical fitness and health of adults. Exercise is beneficial in several ways. First, it has been shown to reduce the risk of all-cause mortality and morbidity. Second, it has been shown to promote psychological health<sup>7,8</sup>.

Through improvements to one's cardiovascular and metabolic health, exercise functions to decrease mortality and morbidity by preventing and eliminating the risk factors of chronic disease<sup>9</sup>.

There are four main types of exercise that promote physical fitness: Cardiorespiratory, resistance, flexibility, and neuromotor. Cardiorespiratory exercise is the most effective way to improve an individual's cardiorespiratory fitness and blood lipid profile. Low cardiorespiratory fitness is considered a risk factor for chronic disease, morbidity, and all-cause mortality. Increasing cardiorespiratory fitness eliminates this risk factor and helps prevent the development of chronic diseases. Cardiorespiratory training improves the blood lipid profile by increasing concentrations of high-density lipoproteins, lowering the concentrations of low-density lipoproteins and triglycerides, and increasing lipoprotein particle size<sup>10,11</sup>. In addition, an increase in caloric expenditure promotes weight loss when the amount of calories expended exceeds the amount consumed<sup>12</sup>. Resistance training functions primarily to improve muscular strength and secondarily to improve body composition, blood lipid profile, blood pressure and insulin sensitivity. These factors are all related to metabolic syndrome and heart disease, so an improvement in these factor profiles can prevent chronic diseases<sup>9</sup>. Resistance training can also reduce the risk of developing musculoskeletal disorders by promoting muscle strength. Flexibility training through stretching can improve

postural stability, balance, and joint range of motion<sup>9</sup>. A muscle that is stretched experiences an increase in flexibility and a temporary decrease in muscle power output<sup>13</sup>. Neuromotor training promotes neuromotor function by improving balance, agility, muscle strength, and proprioception; these areas are improved by incorporating motor skills into different activities that challenge them<sup>9</sup>.

### **Exercise recommendations**

The current ACSM recommendations focus on the frequency, intensity and duration of the four aforementioned exercise types. The cardiorespiratory exercise recommendation for moderate intensity training is 30 minutes a day, five days a week and 20 minutes a day, three days a week for vigorous-intensity training. The recommendations for neuromotor, resistance and flexibility training are to perform each mode two to three days a week<sup>9</sup>. Adherence to these recommendations ensures that the individual training fulfills the maximum frequency requirements for each form of exercise to gain optimal health benefits; however, to fulfill these maximum frequency requirements (14 overall – 5 aerobic sessions, 3 flexibility sessions, 3 neuromotor sessions, and 3 resistance sessions), individuals have to perform two or more of the exercise types in the same day. For individuals with limited time, the exercises may have to be performed not only within the same day, but within the same session. Although the ideal frequency, intensity and duration are known for each exercise mode

individually, the sequence in which to perform the exercises in one program, as would be done in concurrent training, for the best benefits is still unclear.

### **Concurrent training**

Concurrent training is primarily focused on the combination of cardiorespiratory and resistance training in one exercise session, but to meet ACSM recommendations neuromotor and flexibility exercises must also be incorporated. The incorporation of all four types of exercise into one program may be a common occurrence for individuals trying to save time. However, when performing two exercises sequentially, the benefits of one may be altered. For example, when resistance training directly follows aerobic exercise, the strength training may be negatively impacted. A study by Sporer and Wenger (2003) determined that there is reduced strength training performance in the muscle groups that were fatigued during aerobic exercise<sup>14</sup>. This study also found that the volume of work that can be done by the localized muscle groups can be diminished for up to eight hours after aerobic training<sup>14</sup>. In contrast, some studies have shown that concurrent training can result in positive adaptations. For instance, a study performed by Arazi, et al. (2011) found that concurrent training can be effective in improving muscle strength, body composition, aerobic power and muscular endurance<sup>15</sup>. Cardiovascular and cardiorespiratory adaptations have also been observed as a result of concurrent training<sup>16</sup>.

### **Research purpose**

There is currently no evidence for an optimal exercise order when cardiorespiratory, resistance, neuromotor, and flexibility exercise are combined within a single exercise session. Therefore, the purpose of this study was to provide preliminary data for establishing an optimal exercise order for cardiorespiratory, resistance, flexibility, and neuromotor exercise.

### **Methods**

#### **Participants**

A convenience sample of 24 healthy men and women between 18 and 39 years of age was recruited from among university students, faculty, and the surrounding community to participate in the study. The participants were currently active and had previous experience with all types of training. This study was approved by the Human Research Committee at Western State Colorado University. Prior to participation, each participant signed an informed consent form and underwent baseline testing.

#### **Baseline testing**

The measures acquired from the baseline testing were used to establish an individualized exercise prescription (ExRx). Baseline testing consisted of a maximal exercise test to determine maximal oxygen uptake. Additionally, one-repetition maximum (1-RM) testing for eight resistance training exercises was performed. Lastly, a sit-and-reach test, 5-10-5 shuttle run, hexagonal agility test, and single leg half

squats were completed to familiarize participants with the flexibility and neuromotor exercises necessary for the study.

#### **Maximal exercise testing**

Participants were instructed to sit quietly in a chair for five minutes. Their lowest measured heart rate (HR) between the fourth and fifth minute of rest was recorded as being their resting HR. Participants then completed a modified-Balke, pseudo-ramp graded exercise test (GXT) on a power treadmill (Powerjog GX200, Maine). Participants ran at a self-selected pace. Treadmill incline was increased by 1% every minute until the participant reached volitional fatigue. Participant HR was continuously recorded during the GXT via a chest strap and radio-telemetric receiver (Polar Electro, Woodbury, NY, USA). Expired air and gas exchange data were recorded continuously during the GXT using a metabolic analyzer (Parvo Medics TrueOne 2.0, Salt Lake City, UT, USA). Before each exercise test, the metabolic analyzer was calibrated with gases of known concentrations ( $14.01 \pm 0.07\% \text{ O}_2$ ,  $6.00 \pm 0.03\% \text{ CO}_2$ ) and with room air ( $20.93\% \text{ O}_2$  and  $0.03\% \text{ CO}_2$ ) as per the instruction manual. Volume calibration of the pneumotachometer was done via a 3-Litre calibration syringe system (Hans-Rudolph, Kansas City, MO, USA). The last 15s of the GXT were averaged—this was considered the final data point. The closest neighbouring data point was calculated by averaging the data collected 15s

immediately before the last 15s of the test. The mean of the two processed data points represented their  $\text{VO}_2\text{max}$ . Maximal HR was considered to be the highest recorded HR during the GXT. Participant heart rate reserve (HRR) was determined by taking the difference between maximal HR and resting HR.

### 1-RM testing

Participants performed 1-RM testing for eight separate resistance exercises. The following protocol was used for all 1-RM testing<sup>6</sup>:

1. 10 repetitions of a weight the participant felt comfortable lifting (40-60% 1-RM) were performed to warm up muscles.
2. RPE was recorded followed by 1 minute rest period.
3. 5 repetitions of weight 60-80% 1-RM was performed as a further warm up, RPE recorded followed by a 2 minute rest period.
4. First 1-RM attempt at weight of 2.5-20kg greater than warm up, weight was dependent on RPE of warm up:
  - a. If first 1-RM lift was deemed successful by the researcher (appropriate lifting form) weight was increased until

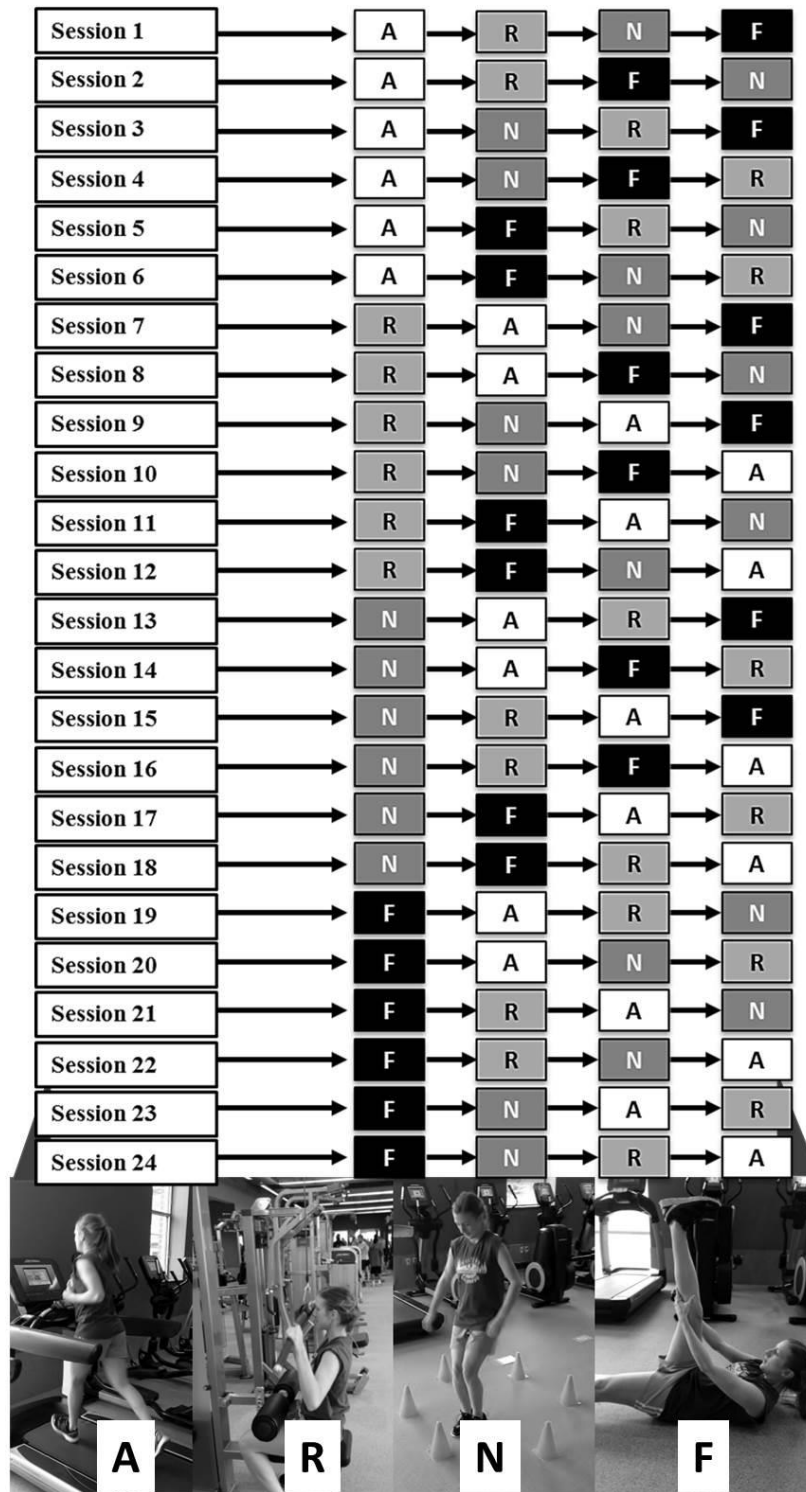
maximum weight participant can lift was established with 3 minutes between each attempt.

- b. If first 1-RM lift deemed unsuccessful by the researcher, weight was decreased until participant successfully lifted the heaviest weight possible.

There were 3 minutes rest between 1-RM attempts and a maximum of 5 1-RM attempts. There were 5 minutes of rest between the 1-RM testing of each resistance exercise.

### **Exercise sessions**

After baseline testing, participants performed an ExRx that consisted of 24 standardized exercise sessions adhering to current ACSM ExRx guidelines for cardiorespiratory, resistance, flexibility, and neuromotor exercise<sup>6,9</sup>. The exercise sessions were performed in all possible sequences using the counterbalanced experimental design displayed in Figure 1. Each training session was separated by a minimum of 48 hours and no more than 7 days. All exercise sessions were directly supervised by a member of the research team.

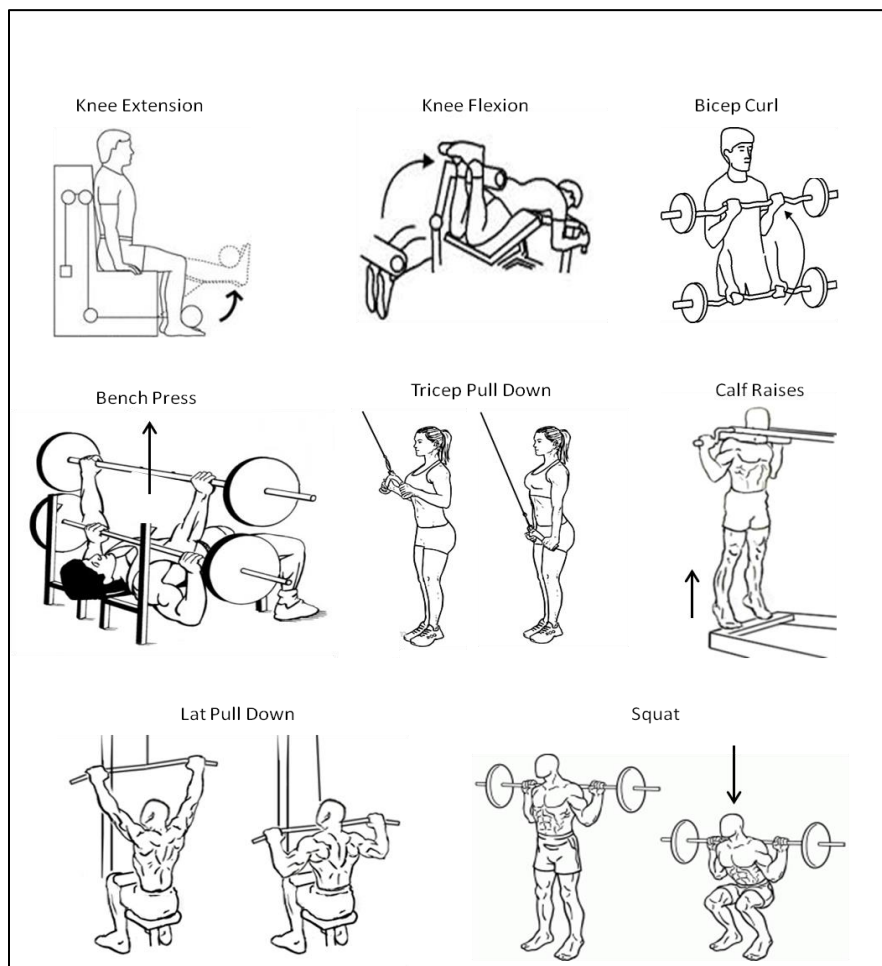


**Figure 1.** Counterbalanced experimental design for all possible exercise sequences. A represents cardiorespiratory exercise, R represents resistance exercise, N represents neuromotor exercise and F represents flexibility exercise.

### Cardiorespiratory exercise

The cardiorespiratory exercise component of the ExRx consisted of 30 minutes of treadmill exercise. For cardiorespiratory exercise, participants started with a five-minute 3.5 mph warm up at 0% incline. After the warm up, treadmill speed was gradually titrated over the first five minutes to elicit a moderate-intensity (50-60% HRR) heart rate response. Participants maintained this

treadmill workload for a total 20 minutes. After 20 minutes participants then cooled down for five minutes at 3.5 mph. Exercise HR was recorded at five-minute intervals throughout the cardiorespiratory exercise session. The mean HR from these recorded values was used for data analysis. The same treadmill workload was subsequently used for all exercise sessions.



**Figure 2.** Exercises performed for the resistance exercise component of the ExRx.

### Resistance exercise

The resistance exercise component of the ExRx consisted of eight different resistance exercises: bench press, lateral pull downs, tricep pull downs, bicep curls, squats, knee extension, knee flexion, and calf raises

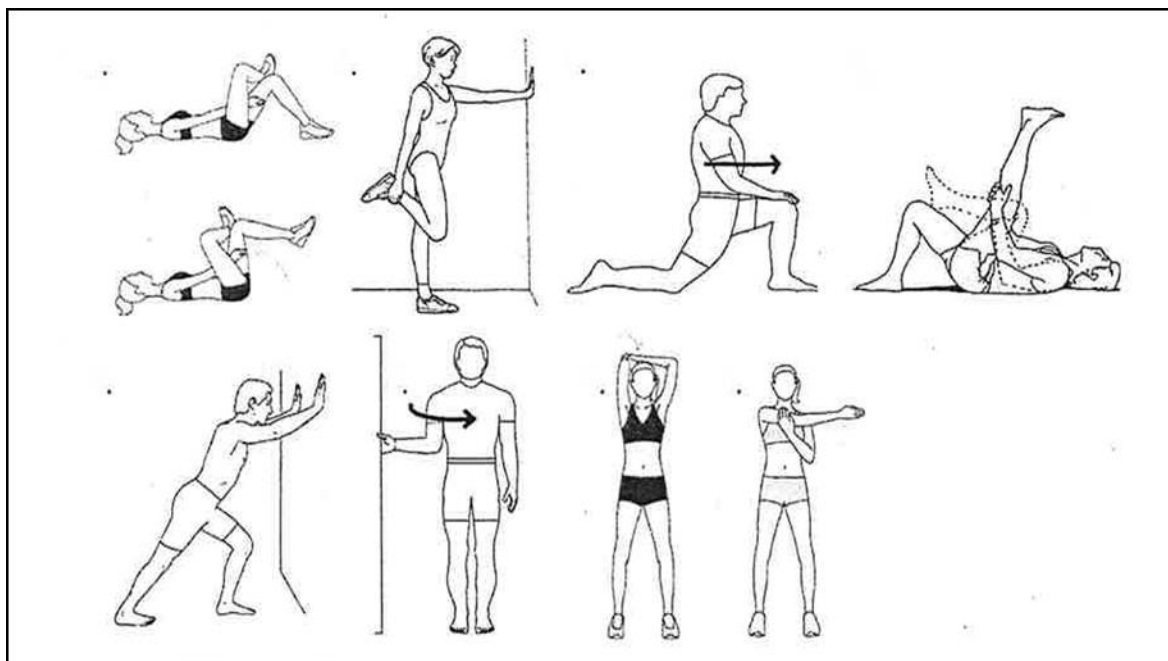
(Figure 2). Participants performed 2 sets of 12 repetitions for each exercise at a

resistance equating to 60% 1-RM. There were 1-minute rest periods between each exercise and a 2-minute rest period between sets. At the conclusion of the resistance exercise component participants were asked to provide a session rating of perceived exertion (RPE) as described elsewhere<sup>17</sup>.

### Flexibility exercise

The flexibility exercise component of the ExRx consisted of eight different flexibility exercises. The flexibility exercises included lying gluteal stretch, standing quadriceps stretch, hip flexor stretch, lying hamstring

stretch, standing calf stretch, chest stretch, triceps stretch, and shoulder stretch. Each stretch was performed on both sides of the body for 2 sets of 20 seconds. Participants were instructed to perform all stretches to a point of mild discomfort. At the conclusion of the flexibility exercise component participants performed the sit-and-reach test. The protocol for the sit-and-reach test is described in detail elsewhere<sup>6</sup>. The sit-and-reach test was performed three times with one-minute rests between each trial. The average of all three trials was used in later data analysis.



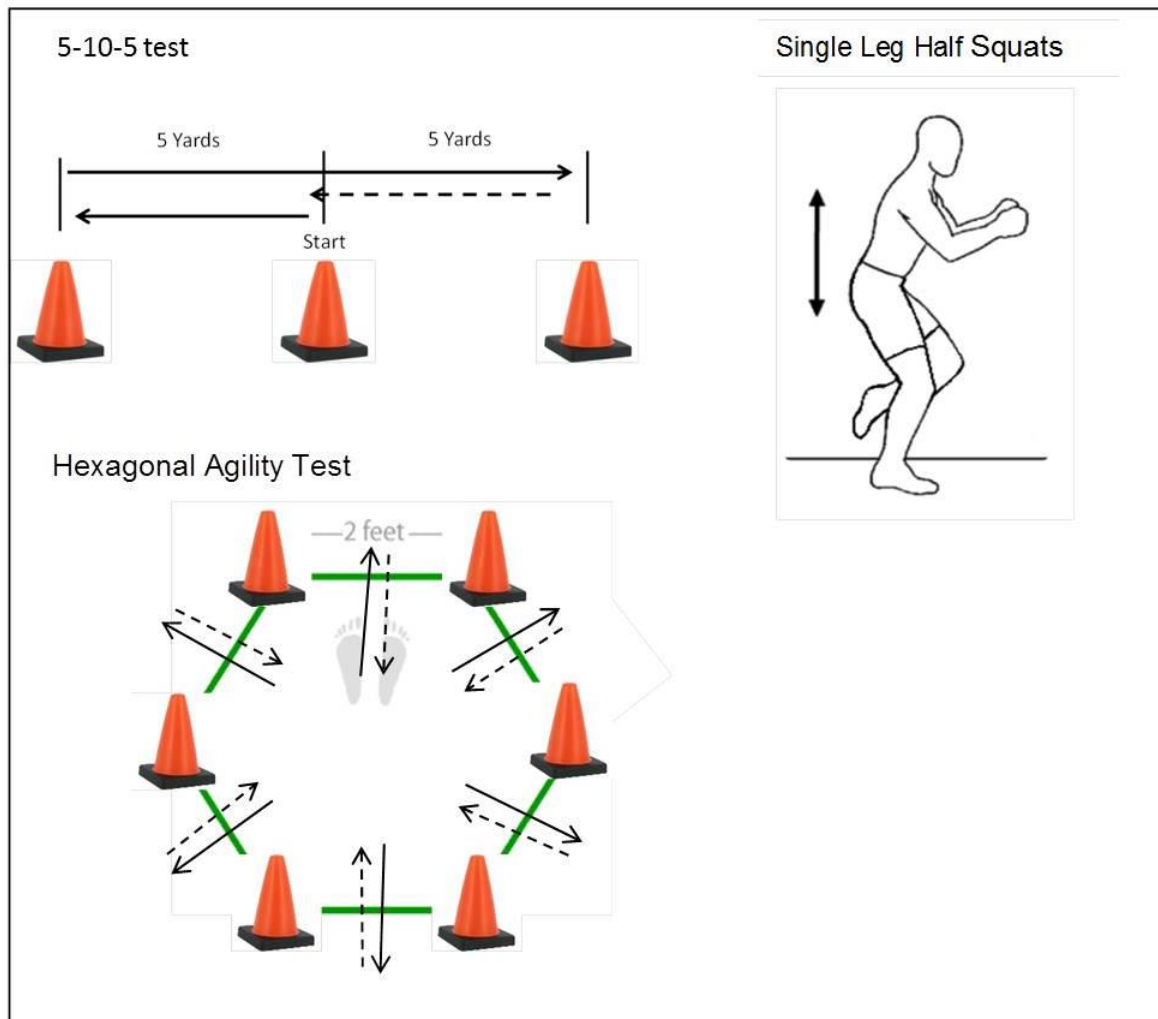
**Figure 3.** Exercises performed for the flexibility exercise component of the ExRx.

### Neuromotor exercise

The neuromotor exercise component (Figure 4) of the ExRx consisted of three different exercises: the 5-10-5 shuttle run, the hexagonal agility test, and single leg squat test (a measure of dynamic balance). Participants performed each of the three

neuromotor exercises with 90 seconds rest between each exercise. Participants then completed a second set of each neuromotor exercise with 90 second rests between exercises. The mean of the two trials for each neuromotor exercise was recorded.





**Figure 4.** Example diagrams of neuromotor exercises for the neuromotor training.

#### *5-10-5 shuttle run*

The 5-10-5 shuttle run was set up by placing three cones five yards apart. The participant initiated the protocol when the tester indicated and sprinted from the center cone to the left side cone, turned, sprinted to the furthest right cone, turned, and sprinted back to the center cone. The 5-10-5 shuttle run was timed by a researcher.

#### *Single leg squat test*

Participants were instructed to stand on one

leg while the other leg was lifted off the ground in front of the body so that the hip was flexed to approximately 45° and the knee of the non-stance leg flexed to approximately 90°. Participants were also instructed to hold arms straight out in front, with the hands clasped together. From this starting position, participants were instructed to squat down until about 60° knee flexion, then return to the start position. Participants completed as many repetitions as possible. The exercise was

completed on both legs. The overall number of repetitions performed by participants was recorded by a researcher.

#### *Hexagonal test*

The hexagonal test was set up with cones two feet apart at an angle of 120° from the adjacent cones. The participant commenced the protocol when the tester indicated. The participant started in the center of the hexagon and jumped to each corner, returning to the center each time. The hexagonal test was timed by a researcher.

#### **Statistical analyses**

All analyses were performed using SPSS Version 22.0 (Chicago, IL) and GraphPad Prism 6.0. (San Diego, CA). Measures of centrality and spread are presented as mean  $\pm$  standard deviation (SD). All physiological and psychological responses (i.e., the dependent variables) to the 24 exercise order combinations were pooled into one of four possible sequences. For example, all the heart rate responses to cardiorespiratory exercise when cardiorespiratory exercise was sequenced first in the exercise session were combined. Similarly, heart rate responses to cardiorespiratory exercise were also combined when cardiorespiratory exercise was sequenced second, third, and fourth, respectively. This was done for each the four types of exercise (cardiorespiratory,

resistance, flexibility, and neuromotor). Polynomial trend analyses were then performed to determine if there was a linear pattern to dependent variables with each sequence of exercise type. Additionally, a one-way analysis of variance (ANOVA) with repeated measures was used to examine differences in all dependent variables (cardiorespiratory heart rate; resistance exercise RPE; neuromotor 5-10-5 test score, left leg squat test score, right leg squat test score, and hexagonal agility test score; sit-and-reach test score). If a significant F ratio was obtained, Tukey's post hoc tests were used to locate differences between means. The probability of making a type I error was set at  $p < 0.05$  for all statistical analyses.

#### **Results**

The ExRx was well tolerated with 100% adherence for the 20 of 24 participants who completed the study. Four participants were unable to complete the study for the following reasons: injury outside the study ( $n = 2$ ), illness ( $n = 1$ ), and personal reasons ( $n = 1$ ). All analyses and data presented in the results are for those participants who completed the study. The physical and physiological characteristics of participants are presented in Table 1. Physiological and psychological responses to all exercise order combinations are shown in Table 2.

**Table 1.** Physical and physiological characteristics of the participants.

| <b>Outcome variable</b>                                       | <b>Men<br/>(N=10)</b> | <b>Women<br/>(N=10)</b> | <b>Combined<br/>(N=20)</b> |
|---|-----------------------|-------------------------|----------------------------|
| Age (yrs)   | 21.0±1.6 <sup>a</sup> | 27.1±7.0                | 24.1±5.9                   |
| Height (cm)   | 177.5±6.4             | 164.6±6.8               | 171.1±9.2                  |
| Weight (kg)   | 80.8±13.2             | 64.1±8.6                | 72.5±13.8                  |
| Rest HR (bpm)   | 69.9±12.1             | 76.7±11.6               | 73.3±12.1                  |
| Maximal HR (bpm)  | 193.8±6.0             | 182.4±10.7              | 188.1±10.3                 |
| HRR (bpm)   | 123.9±13.6            | 105.7±13.9              | 114.8±16.3                 |
| VO <sub>2</sub> max (mL·kg <sup>-1</sup> ·min <sup>-1</sup> ) | 49.6±8.0              | 38.7±4.5                | 44.2±8.4                   |
| Bench press 1-RM (lbs)  | 192.5±46.6            | 86.6±29.1               | 139.6±66.2                 |
| Squat 1-RM (lbs)  | 263.0±83.2            | 141.7±65.4              | 202.4±95.8                 |
| Knee extension 1-RM (lbs)                                     | 205.0±37.3            | 110.0±55.2              | 157.5±66.9                 |
| Knee flexion 1-RM (lbs)                                       | 136.3±10.9            | 92.7±38.9               | 114.5±35.7                 |
| Bicep curl 1-RM (lbs)   | 87.5±13.8             | 31.2±9.8                | 59.4±31.1                  |
| Tricep pull down 1-RM (lbs)                                   | 88.5±6.3              | 42.6±13.7               | 65.5±25.8                  |
| Lat pull down 1-RM (lbs)                                      | 138.0±23.9            | 74.5±36.1               | 106.2±44.2                 |
| Calf raise 1-RM (lbs)   | 580.0±160.5           | 294.2±194.5             | 437.1±227.2                |

<sup>a</sup>Mean ± SD.

**Table 2.** Physiological responses to cardiorespiratory (A), resistance (B), neuromotor (C), and flexibility (D) exercise for all orders of exercise.

| Sequence | Order of Exercises     |           |           |            |          |         |         |            |          |                      |                            |
|----------|------------------------|-----------|-----------|------------|----------|---------|---------|------------|----------|----------------------|----------------------------|
| 1        | A                      |           |           | B          |          |         | C       |            |          | D                    |                            |
|          | 137.5±9.4 <sup>a</sup> |           |           | 5.2±0.9    |          |         | 5.7±0.7 | 15.7±6.5   | 15.7±4.6 | 4.7±0.8 <sup>b</sup> | 30.4±9.5                   |
| 2        | A                      |           |           | B          |          |         | D       |            |          | C                    |                            |
|          | 137.9±9.1              |           |           | 5.2±0.8    |          |         |         | 30.8±9.1   |          | 5.6±0.6              | 17.4±9.3 16.9±6.1 3.9±0.7  |
| 3        | A                      |           |           | C          |          |         | B       |            |          | D                    |                            |
|          | 135.8±15.7             |           | 5.5±0.5   | 21.2±10.4  | 21.6±9.9 | 3.8±0.6 |         | 6.0±1.5    |          |                      | 30.2±8.9                   |
| 4        | A                      |           |           | C          |          |         | D       |            |          | B                    |                            |
|          | 136.5±11.2             |           | 5.6±0.5   | 17.9±9.2   | 19.0±9.3 | 3.5±0.6 |         | 31.0±9.6   |          |                      | 5.9±1.3                    |
| 5        | A                      |           |           | D          |          |         | B       |            |          | C                    |                            |
|          | 139.4±12.6             |           |           | 30.4±9.9   |          |         |         | 5.8±1.1    |          | 5.5±0.8              | 20.0±9.3 18.8±9.9 3.5±0.5  |
| 6        | A                      |           |           | D          |          |         | C       |            |          | B                    |                            |
|          | 137.5±14.8             |           |           | 30.9±9.9   |          |         | 5.7±0.9 | 19.1±10.2  | 20.4±8.2 | 3.6±0.6              | 6.1±1.4                    |
| 7        | B                      |           |           | A          |          |         | C       |            |          | D                    |                            |
|          | 5.1±1.1                |           |           | 145.9±10.9 |          |         | 5.5±0.5 | 19.9±8.9   | 18.5±7.7 | 3.8±0.7              | 30.4±8.4                   |
| 8        | B                      |           |           | A          |          |         | D       |            |          | C                    |                            |
|          | 5.0±1.1                |           |           | 149.1±9.8  |          |         |         | 31.5±8.3   |          | 5.4±0.6              | 20.4±8.9 21.6±8.1 3.6±0.5  |
| 9        | B                      |           |           | C          |          |         | A       |            |          | D                    |                            |
|          | 4.8±1.2                |           | 5.4±0.5   | 20.5±8.9   | 20.0±9.2 | 3.7±0.6 |         | 150.0±10.0 |          |                      | 30.0±8.2                   |
| 10       | B                      |           |           | C          |          |         | D       |            |          | A                    |                            |
|          | 4.8±1.3                |           | 5.3±0.5   | 20.2±9.1   | 21.0±9.4 | 3.5±0.4 |         | 30.0±7.1   |          |                      | 149.6±13.7                 |
| 11       | B                      |           |           | D          |          |         | A       |            |          | C                    |                            |
|          | 4.5±1.4                |           |           | 29.2±7.8   |          |         |         | 145.5±13.9 |          | 5.4±0.5              | 21.0±10.6 21.1±8.0 3.3±0.5 |
| 12       | B                      |           |           | D          |          |         | C       |            |          | A                    |                            |
|          | 4.7±1.4                |           |           | 30.8±9.5   |          |         | 5.2±0.5 | 19.4±9.9   | 20.4±8.9 | 3.3±0.4              | 148.1±11.9                 |
| 13       | C                      |           |           | A          |          |         | B       |            |          | D                    |                            |
|          | 5.5±0.5                | 22.8±12.7 | 22.7±11.4 | 3.5±0.5    |          |         |         | 144.0±13.1 |          | 5.3±1.2              | 31.4±9.0                   |
| 14       | C                      |           |           | A          |          |         | D       |            |          | B                    |                            |
|          | 5.5±0.5                | 23.1±10.8 | 23.7±9.3  | 3.4±0.5    |          |         |         | 140.9±13.1 |          | 31.6±9.1             | 5.2±1.5                    |
| 15       | C                      |           |           | B          |          |         | A       |            |          | D                    |                            |
|          | 5.7±0.7                | 22.6±10.3 | 23.0±9.1  | 3.5±0.7    |          |         |         | 4.6±1.2    |          | 149.9±13.9           | 31.3±8.3                   |
| 16       | C                      |           |           | B          |          |         | D       |            |          | A                    |                            |
|          | 5.5±0.5                | 21.9±10.8 | 23.0±9.6  | 3.3±0.6    |          |         |         | 4.6±1.4    |          | 32.2±8.7             | 147.9±17.1                 |
| 17       | C                      |           |           | D          |          |         | A       |            |          | B                    |                            |
|          | 5.5±0.6                | 21.9±11.5 | 21.6±9.3  | 3.6±0.5    |          |         |         | 31.0±8.3   |          | 145.9±15.1           | 5.6±1.4                    |
| 18       | C                      |           |           | D          |          |         | B       |            |          | A                    |                            |
|          | 5.5±0.7                | 22.4±10.4 | 22.9±9.5  | 3.7±0.6    |          |         |         | 31.2±9.2   |          | 5.2±1.2              | 149.9±12.9                 |
| 19       | D                      |           |           | A          |          |         | B       |            |          | C                    |                            |
|          | 31.8±9.6               |           |           | 141.9±12.8 |          |         |         | 4.9±1.0    |          | 5.3±0.6              | 23.5±8.0 24.1±7.6 3.6±0.6  |
| 20       | D                      |           |           | A          |          |         | C       |            |          | B                    |                            |
|          | 32.2±10.4              |           |           | 142.8±10.9 |          |         | 5.2±0.7 | 25.0±6.8   | 21.2±9.1 | 3.4±0.7              | 5.0±1.3                    |
| 21       | D                      |           |           | B          |          |         | A       |            |          | C                    |                            |
|          | 32.3±9.7               |           |           | 4.5±1.0    |          |         |         | 145.0±15.5 |          | 5.4±0.6              | 24.0±7.6 22.6±6.6 3.4±0.6  |
| 22       | D                      |           |           | B          |          |         | C       |            |          | A                    |                            |
|          | 32.4±9.6               |           |           | 4.4±1.0    |          |         | 5.3±0.6 | 24.9±5.8   | 24.5±6.7 | 3.4±0.5              | 148.9±12.8                 |
| 23       | D                      |           |           | C          |          |         | A       |            |          | B                    |                            |
|          | 32.2±9.8               |           | 5.3±0.6   | 21.5±10.3  | 21.9±8.5 | 3.5±0.6 |         | 142.8±13.2 |          |                      | 5.6±1.1                    |
| 24       | D                      |           |           | C          |          |         | B       |            |          | A                    |                            |
|          | 31.6±9.6               |           | 5.4±0.7   | 22.2±10.0  | 22.8±8.1 | 3.5±0.6 |         | 5.4±1.6    |          |                      | 151.8±12.8                 |

<sup>a</sup>Mean ± SD.

<sup>b</sup>Mean ± SD for neuromotor performance measures, including 5-10-5 shuttle test, left leg squat test, right leg squat test, and hexagonal agility test.

### Cardiorespiratory exercise

The mean heart rate response to cardiorespiratory exercise was significantly different ( $p < 0.05$ ) across exercise sequence positions. Post hoc tests showed that all mean heart rate responses across the four possible exercise sequence positions were significantly different from each other. There was a 12 beats per minute (bpm) difference in mean HR response to cardiorespiratory exercise when cardiorespiratory exercise was sequenced first when compared to last in the ExRx. When cardiorespiratory exercise was performed first, the HR response equated to 56% HRR (i.e., moderate-intensity exercise). In contrast, the mean HR response equated to 66.7% HRR (i.e., vigorous-intensity exercise) when cardiorespiratory exercise was sequenced last in the exercise session. Trend analysis showed that the mean heart rate response to cardiorespiratory exercise continued to increase in a linear manner the further cardiorespiratory exercise was prescribed in the exercise session (Figure 5).

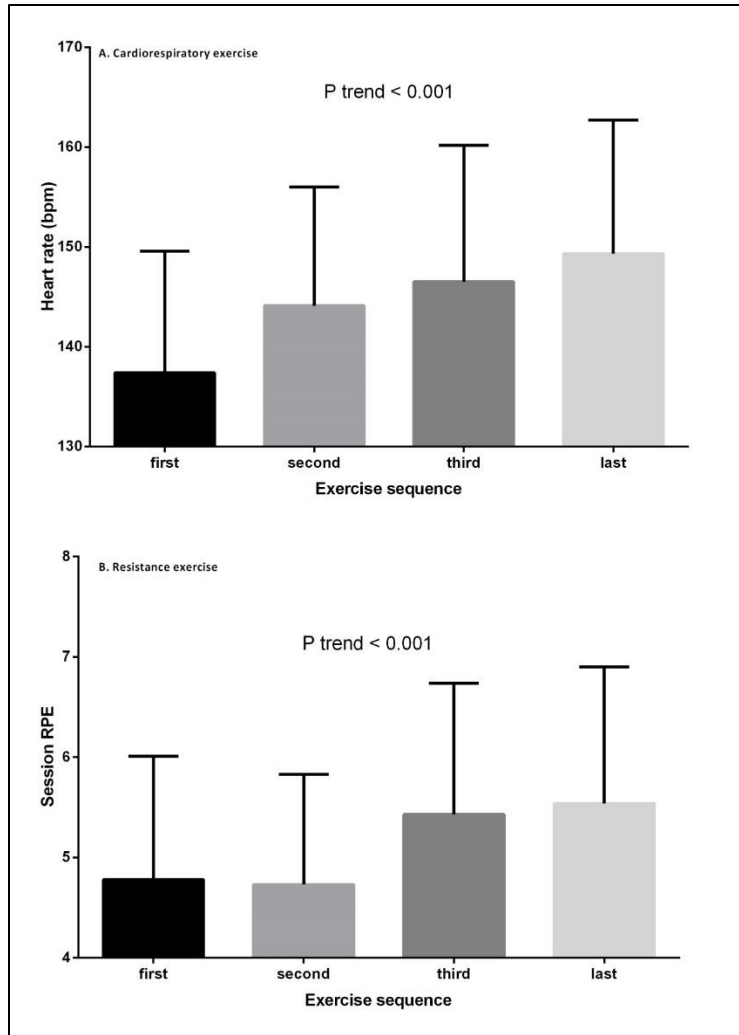
### Resistance exercise

The mean resistance exercise RPE was

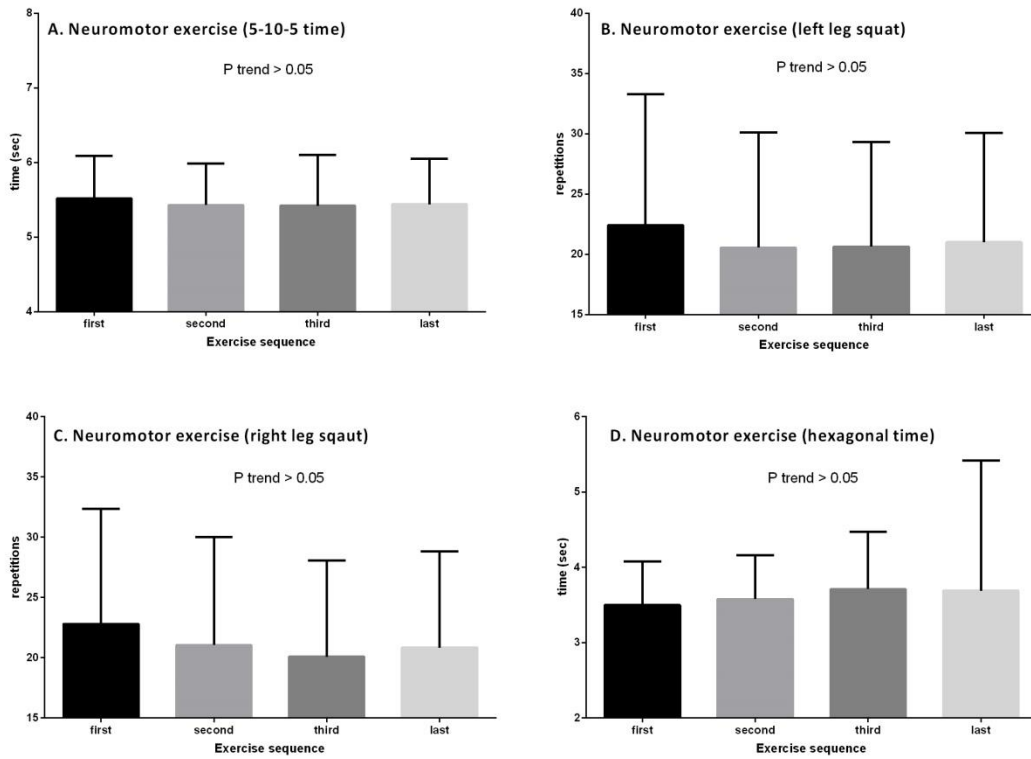
significantly different ( $p < 0.05$ ) across exercise sequence positions. Mean resistance exercise RPE was similar ( $p > 0.05$ ) when resistance exercise was positioned either first or second in the ExRx; however, post hoc tests showed mean resistance exercise RPE was significantly higher ( $p < 0.05$ ) when the resistance exercise component was positioned third or fourth in the ExRx when compared to first or second. Trend analysis showed there was a linear increase in mean resistance exercise RPE the further in that resistance exercise was prescribed in the ExRx (Figure 5).

### Neuromotor and flexibility exercise

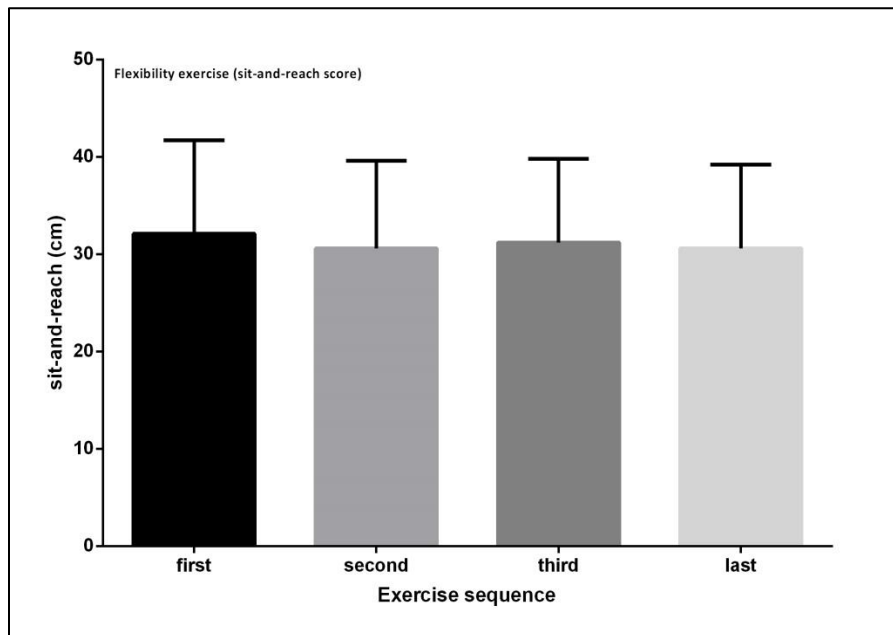
There was no significant difference ( $p > 0.05$ ) in the physiological response to either neuromotor or flexibility exercise across all exercise sequence positions. Likewise, trend analyses exhibited no change (increase or decrease) in any of the neuromotor or flexibility measures when these types of exercise were prescribed at a later point in the ExRx (Figures 6 and 7).



**Figure 5.** Heart rate response to cardiorespiratory exercise (A) and resistance exercise RPE (B) across exercise sequence. Columns, means; error bars, SDs.



**Figure 6.** Physiological responses to neuromotor exercise: 5-10-5 time (A), left leg squat (B), right leg squat (C), and hexagonal time (D) across exercise sequence. Columns, means; error bars, SDs.



**Figure 7.** Sit-and-reach scores across exercise sequence. Columns, means; error bars, SDs.

## Discussion

The main finding of the present study is that exercise order has a significant effect on the acute physiological and psychological responses to an exercise session. Heart rate responses to cardiorespiratory exercise and resistance exercise RPE values were significantly higher when these types of exercise were sequenced later in the exercise session. In contrast, physiological responses to flexibility and neuromotor exercise were not influenced by exercise order. Although it is well-established that regular exercise confers numerous health benefits, the effect of exercise order on physiological and psychological measures when combining all four exercise types recommended in the most recent ACSM guidelines<sup>6</sup> within the same session has not, to our knowledge, been previously scientifically explored. As such, the results of this novel study are encouraging and provide important preliminary data towards formulating recommendations denoting an optimal sequence for cardiorespiratory, resistance, flexibility, and neuromotor exercise for the ExRx.

Despite a large body of evidence demonstrating the beneficial health effects linked to the development and maintenance of cardiorespiratory, resistance, flexibility, and neuromotor exercise, there is currently limited data on the best strategy for the ExRx when all 4 types of exercise are combined within a single exercise session. Previous

research<sup>14,18</sup> on concurrent exercise programs have reported significant effects on the sequencing of cardiorespiratory and resistance exercise training within the same training session. For example, Drummond et al. (2005) showed a higher heart rate response when cardiorespiratory exercise followed rather than preceded resistance exercise (172 versus 161 bpm;  $p < 0.05$ )<sup>18</sup>. Our findings were comparable as heart rate responses were consistently higher when cardiorespiratory exercise was sequenced further in the exercise session. When cardiorespiratory exercise was sequenced last, as compared to first, in the exercise session, the exercise intensity exceeded the prescribed moderate intensity threshold and subsequently fell within the vigorous exercise intensity domain. Given that the cardiorespiratory ExRx in the present study called for moderate intensity exercise this finding was unexpected; this may have important practical implications for exercise professionals and the ExRx. First, although overall adherence in the present study was high, previous research has reported that individuals may adhere to moderate-intensity exercise to a greater extent when compared to vigorous intensity exercise<sup>9</sup>. As such, the higher than prescribed heart rate response (i.e., vigorous exercise intensity) to cardiorespiratory exercise when sequenced at a latter point in the exercise session may, over the long-term, result in poorer adherence to regular exercise training. Second, unexpected



vigorous-intensity exercise may contribute to increased musculoskeletal injury. Furthermore, it has also been reported that acute myocardial infarction and sudden cardiac death can be triggered by unaccustomed vigorous physical exertion<sup>19</sup>. Although the likelihood of the latter scenario is rare, it nonetheless highlights the possible consequences of an incorrectly prescribed exercise order. Taken together, the present findings placed in the context of the cited literature supports the recommendation for cardiorespiratory exercise to be sequenced first overall in the exercise order when multiple types of exercise are performed in the same session.

Previous research has found that resistance exercise was negatively impacted, possibly due to muscle fatigue, when sequenced after cardiorespiratory exercise<sup>14</sup>. Conversely, results from the present study showed similar resistance exercise RPE values when resistance exercise was performed after, when compared to before, a bout of cardiorespiratory exercise. Moreover, resistance exercise RPE values were also similar when resistance exercise was sequenced after, when compared to before, either a bout of flexibility or neuromotor exercise. However, when resistance exercise was performed after two or three previous bouts of exercise (i.e., third or fourth in the overall sequence of exercise types), and despite the fact that the same standardized resistance

exercise workload was performed for all exercise sessions, it was found that resistance exercise RPE was significantly higher. An interference phenomenon is the most common reason offered for an order effect when multiple types of exercise are combined within a single session<sup>20</sup>. It has been reported that residual fatigue from the first bout of exercise can compromise tension development of the skeletal muscles specific to the muscles involved in the later bouts of exercise<sup>21</sup>. Unlike the physiological and psychological responses to cardiorespiratory and resistance exercise, the present study showed similar flexibility and neuromotor exercise responses regardless of location in the exercise session. Collectively, these findings suggest resistance exercise should be sequenced second in the exercise session, with flexibility and neuromotor exercise interchangeable as the third and fourth bouts of exercise when all types of exercise are combined within a single session.

### **Conclusion**

The ACSM recommends a comprehensive program of exercise including cardiorespiratory, resistance, flexibility, and neuromotor exercise of sufficient volume and quality as outlined below in Table 3 for apparently healthy adults of all ages<sup>9</sup>. An exercise program that meets these criteria will improve overall physical and mental health in most persons. Yet for the frequency recommendations of each

type of exercise to be satisfied it should be evident from Table 3 that individuals will need to perform at least two (or more)

types of exercise the same day, and most likely within the same exercise session.

**Table 3.** Frequency, intensity, and time guidelines for cardiorespiratory, resistance, flexibility, and neuromotor exercise.

| Type of exercise         | Frequency   | Intensity  | Time   |
|--------------------------|---|--|--|
| <b>Cardiorespiratory</b> | 5 days/wk moderate intensity; 3 days/wk vigorous intensity; or combination of both. | Moderate intensity corresponds to brisk walk with noticeable ↑ heart rate. Vigorous intensity equivalent to jogging resulting in significant ↑ heart rate and quick breathing. | For moderate intensity activities, accumulate at least 30 min/day; for vigorous intensity activities, accumulate at least 20/min day |
| <b>Resistance</b>        | 2-3 days/wk   | A resistance exercise that permits 8 to 12 reps, equivalent to ~ 60% to 80% of one repetition maximum.   | Complete 2 to 4 sets for each muscle group. Permit 2 to 3 min rest intervals between each set.                                       |
| <b>Flexibility</b>       | 2-3 days/wk   | Exercises should be performed to the point of mild discomfort within the natural range of motion.  | Complete up to 4 reps per muscle group, 15-60 sec per static stretch. Overall duration at least 10 min.                              |
| <b>Neuromotor</b>        | 2-3 days/wk   | Currently unknown  | ≥ 20-30/day may be needed  |

Modified from Garber et al. 2011.

However, when combining all four exercise type components into the same session, there are no clear guidelines for the most appropriate sequencing of activities. In the present study, individuals performed 24 exercise sessions consisting of all the possible exercise sequence combinations of cardiorespiratory, resistance, flexibility, and neuromotor exercise. The ExRx for each session was designed to ensure current evidence-based guidelines for frequency, intensity, and time (see Table 3) were fulfilled for each type of exercise. Results from the

current study provide important preliminary data towards formulating recommendations for an optimal sequence of cardiorespiratory, resistance, neuromotor, and flexibility exercise for the ExRx. The safety and effectiveness of each exercise session can be maximized by adhering to the following 3 exercise order guidelines:

1. ***Cardiorespiratory exercise should always be sequenced first in the exercise order.***

Findings from the present study showed a

significantly higher heart rate response to cardiorespiratory exercise (into the vigorous exercise intensity domain) when it was sequenced further in the exercise session. Unaccustomed vigorous-intensity exercise may lessen adherence, increase the risk of musculoskeletal injury, and increase the risk of acute cardiac events. Given that the health benefits accrued from engaging in regular cardiorespiratory exercise far exceed those received from other types of exercise, it would appear unwarranted to possibly compromise an individual fulfilling weekly cardiorespiratory exercise recommendations on a regular basis by prescribing an incorrect exercise order.

## ***2. Resistance exercise should be sequenced second in the exercise order and follow cardiorespiratory exercise.***

Our findings showed resistance exercise RPE was similar when resistance exercise was performed either first or second in the exercise order. However, when resistance exercise was performed third or fourth in the exercise order, resistance exercise RPE was significantly higher. Long-term, a greater level of physical strain may impact exercise adherence. Additionally, there is a mistaken belief that a cardiorespiratory-resistance exercise order will negatively impact muscular fitness development. However, this perception is unsupported by the scientific literature. In fact, a recent study clearly showed that intra-session sequencing of aerobic and resistance

activities does not negatively influence the change in muscular fitness. At the conclusion of a 3-month investigation, it was reported that the improvements in maximal muscular strength, strength endurance, and explosive strength and power were comparable between aerobic-resistance and resistance-aerobic groups<sup>22</sup>.

## ***3. Flexibility and Neuromotor exercise conclude the exercise session***

Unlike cardiorespiratory and resistance exercise which were significantly impacted by sequence of exercise, results from the present study found no order effect for either flexibility or neuromotor exercise. Given the fact that flexibility and neuromotor exercise were performed equally well regardless of overall position in the exercise order, the general recommendation can be made to order these types of exercise third and/or last in the exercise session.

### **Competing interests**

This investigation was supported financially by the American Council on Exercise (ACE). The American Council on Exercise (ACE) was not involved in development of the study design, data collection and analysis, or preparation of the manuscript. There are no other potential conflicts of interest related to this article.

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