THE EFFECTS OF RESISTANCE AND AEROBIC EXERCISE SEQUENCE ON ENERGY EXPENDITURE

Nicholas M. Beltz¹, Joel Woldt², David Clark ², Jason Tilque², Jacob St. Mary ², Jeffrey M. Janot², Gary P. VanGuilder³

¹University of New Mexico, Department of Health, Exercise, and Sports Sciences, Albuquerque, NM, USA
²University of Wisconsin-Eau Claire, Department of Kinesiology, Eau Claire, WI, USA
³South Dakota State University, Department of Health and Nutritional Sciences, Brookings, SD, USA

ABSTRACT

Beltz NM, Woldt J, Clark D, Tilque J, St. Mary J, Janot JM, Van Guilder GP. The Effects of Resistance and Aerobic Exercise Sequence on Energy Expenditure. Journal of Undergraduate Kinesiology Research 2014; (9)2:31-39. Purpose: There has been little research to determine the optimal order of aerobic and resistance exercise with respect to the amount of calories expended, which may provide a rationale for considering the sequence of exercise when designing exercise programs. Our experiment was designed to examine the effects of exercise sequence on energy expenditure during a single exercise bout. Methods: Ten physically active young adults (age: 21.3 ± 1.6 years; 5 male, 5 female) participated in this study. Participants were randomized to perform two, 1-hour exercise sessions (sequence 1: resistance-aerobic and sequence 2: aerobic-resistance) separated by 7 days. The resistance session entailed 2 sets of 10 repetitions of 8 separate resistance exercises performed at 75% 1 repetition maximum (1RM) with 90-sec rest period. The aerobic session consisted of 30 min of aerobic exercise performed at 70% VO₂ reserve. Portable indirect calorimetry was used to estimate exercise session energy expenditure for both exercise sequences. Results: Total energy expenditure for sequence 1 (599.2±204.9 kcals) was significantly higher (P=0.04) when compared to sequence 2 (572.6±185.0 kcals). Energy expenditure was ~35 kilocalories higher (P <0.05) during the aerobic exercise session that was performed in sequence 1 in relation to sequence 2. In contrast, there were no differences in resistance exercise energy expenditure between sequence 1 (189.2±106.1 kcals) and sequence 2 (181.5±71.2 kcals). Conclusion: Energy expenditure is higher when aerobic exercise is performed after a sequence of whole body resistance exercise. These findings may be partially attributable to poor mechanics in running economy resultant of the preceding resistance exercise session. This finding provides useful insight from a program design perspective when the main outcome goal is energy expenditure.

Key Words: Kilocalories, Oxygen Consumption, Metabolism, Running Economy, Exercise Prescription
INTRODUCTION

It is recommended practice for an individual exercise prescription to include both aerobic and resistance exercise to maximize health benefits. Due to time constraints and convenience it is common to perform both aerobic and resistance exercise in a single session, a strategy known as concurrent exercise (1,2). It is believed that resistance and aerobic training done separately will cause significant increases in energy expenditure (3). Performing high intensity resistance exercise promotes greater energy expenditure during a subsequent aerobic session; however, it remains unclear as to how reversing the exercise order may affect energy expenditure during resistance exercise (4). Currently, little evidence exists for clear recommendations on sequence of aerobic and resistance exercise for increasing energy expenditure. The focus of the current study is to provide insight into whether energy expenditure is influenced by the sequence of aerobic and resistance exercise.

Some of the benefits of aerobic and resistance exercise include decreased low-density lipoprotein cholesterol, increased high-density lipoprotein cholesterol, decreased blood pressure, improved body composition, and increased bone mineral density. (5,6,7,8). The American College of Sports Medicine (ACSM) recommends that aerobic activity of approximately 45-minutes per day (200-300 min/week) can facilitate weight loss and prevent weight regain. The ACSM also recommends an intensity level that will expend a minimum of 150 to 400 kcals per day from physical activity and a minimum of 1,000 kcals weekly. Expenditure of 1,000 kcals weekly from physical activity is associated with a 20-30% reduction in all-cause mortality. However, the amount of energy expenditure required for weight loss nears 2,000 kcals weekly (9). With such high amounts of energy expenditure necessary for weight loss, it is essential to identify innovative ways to enhance energy expenditure whenever possible. A potential solution to expending extra calories could lie within the determinants of running economy.

Running economy can be impaired for up to eight hours following a single session of resistance exercise. Due to this impairment sub-maximal oxygen consumption during a subsequent running session is significantly greater and leads to an increased rate of energy expenditure (10). Studies investigating the effect of aerobic training before resistance training have demonstrated that the body is mechanically more efficient in performing aerobic exercise when compared to performing resistance training first. This may be due to blood flow dynamics and the absence of muscle fatigue induced from prior resistance training. Running before resistance training has also been shown to elicit less consumption of oxygen, which ultimately leads to less total energy expenditure (3,11,12,13). There is also a notable difference in the amount of calories expended during aerobic exercise when compared to resistance exercise, given they are performed independently on two separate occasions. For example, caloric expenditure for trained men during a single bout of aerobic cycling exercise for 30 min elicits a much higher caloric expenditure than a 30 min intermittent squatting exercise routine consisting of the same intensity and duration (cycling 70% VO2 max = 441 kcal; free-weight squatting 70% 1RM = 269 kcal). Even though resistance training expends less calories than aerobic exercise, resistance training has still been shown to be a
value addition to weight loss programming [6]. Indeed, accumulated fatigue resulting from increased anaerobic metabolism from set to set may induce a higher VO\textsubscript{2} regardless of exercise order and this believe to be affected by the rest interval between sets during the resistance training session (14,15). Previous findings demonstrate that when resistance training is combined with aerobic training, performing the resistance exercise first can raise oxygen consumption of the subsequent bout of running. This elicits a higher caloric expenditure than running alone or running prior to resistance exercise (4). It is plausible that performing resistance exercise before running is the ideal sequence for energy expenditure during a workout that includes resistance and aerobic training. Therefore, the need exists for the current study to further evaluate and clarify the ideal sequence when designing a concurrent exercise prescription with the aim to expend calories for weight loss.

Accordingly, the specific aim of this study was to determine if varying the sequence of resistance and aerobic exercise in a single exercise bout influences total energy expenditure. We hypothesized that energy expenditure would be greater by performing resistance exercise prior to aerobic exercise when compared to performing aerobic exercise first in a single bout of training.

**METHODS**

**Participants**
Ten healthy and physically active young adults aged 20-24 years volunteered to participate in this investigation (5 males and 5 females). Participants were recruited via word of mouth and online bulletins posted around the campus community. All participants completed a Physical Activity Readiness Questionnaire to ensure that inclusion criteria were met. Participants were excluded if they had any serious medical conditions or injuries which would permit them from engaging in the exercise protocol. Prior to participation, all participants had the research study and its potential risks and benefits explained fully before providing written informed consent according to the guidelines of the University.

**Baseline Testing and Instrumentation**
The baseline assessments included body mass, height, systolic and diastolic blood pressure, resting heart rate and predicted VO\textsubscript{2}max. Body mass was measured using a medial beam balance (Seca 220, Hamburg, Germany) and height was measured using a standing stadiometer. Body mass index (BMI) was calculated as weight (kilograms) divided by height (meters) squared. The participant rested for five minutes before a 60 second resting heart rate (RHR) was taken manually at the radial artery and recorded in beats per minute. Auscultatory resting systolic (SBP) and diastolic blood pressure (DBP) were measured using a stethoscope and sphygmomanometer (Diagnostic 700 Series, American Diagnostic Corp, Hauppauge, NY). To obtain predicted VO\textsubscript{2}max, each participant completed the George 1-mile sub-maximal exercise test and the George Jog Treadmill Test. For the 1-mile run, the participant was instructed to run 1-mile on an indoor track. Once the participant completed the mile, time and heart rate were recorded and used to calculate the participant’s predicted VO\textsubscript{2}max. For the treadmill submaximal test, each participant was instructed to run at a constant speed until their
heart rate remained within 3 beats per min during 3 consecutive 30 sec intervals. Final heart rate and speed along with mass (kg) and gender were used to calculate estimated VO$_2$max. Both predicted values from the sub-maximal tests were then averaged to obtain each participant’s aerobic fitness and used in determining the speed of their aerobic exercise session. After the completion of both sub-maximal exercise protocols, each participant performed two separate maximal strength tests; one on bench press and the other on leg press. Each maximal strength test consisted of one set to technical failure, which was required to fall between 5 and 10 repetitions. These collected values (reps and weight used) were used to predict 1 repetition maximum (1RM) values for the six remaining exercises. The resistance training intensities were established by calculating 75% of the 1RM for each exercise.

**Experimental Design and Procedures**

Prior to each training session, participants were instructed to be properly hydrated and to refrain from alcohol, caffeine, and tobacco products for 24 hours. Moreover, each participant was instructed to refrain from any aerobic or resistance exercise at least 24 hours before testing and also avoid any food intake 2 hours prior to testing. We employed an exercise intervention study in which participants were randomized to perform two 60-min exercise protocols of varying sequence consisting of combined aerobic (30-min treadmill jog @ 70% predicted VO$_2$ reserve) and resistance exercise separated by one week. Values for VO$_2$ reserve were calculated by assuming a resting VO$_2$ of 3.5 ml/kg/min. Sequence 1 (resistance-aerobic) consisted of participants performing the 30-min resistance exercise protocol first, following by the 30-min aerobic protocol. Participants completed the alternate sequence (sequence 2; aerobic-resistance) on their next testing session. Utilizing each participant’s predicted VO$_2$max, we calculated the speed for the treadmill using the running and walking metabolic equations found in the seventh edition of the American College of Sport Medicine's Guidelines for Exercise Testing and Prescription [5]. The whole body resistance training protocol consisted of 2 sets of 10 repetitions of eight exercises performed at 75% of each participant’s predicted 1RM. A rest time of 90 seconds was taken in between each set. The exercises included in the protocol were performed in the following specified order: bench press, leg press, dumbbell shoulder press, walking lunge, lat pull down, triceps pushdown, EZ bar biceps curl, and standing calf raise. The order at which each exercise was performed was consistent for both sequences. Prior to beginning each exercise session, all participants completed a 5 min warm-up walk at 3.2 miles per hour on a treadmill. At the end of each protocol, a 3 min cool down period was employed in which participants walked at 3.2 miles per hour on a treadmill.

**Energy Expenditure**

To assess energy expenditure during each exercise sequence protocol, resting and exercise oxygen consumption was collected using a K4b$^2$ portable metabolic unit (COSMED Pulmonary Function Equipment, Rome, Italy). The K4b$^2$ was calibrated according to standing operating procedures provided by the manufacturer before conducting each test. Following calibration, each participant was properly fitted with the metabolic unit and a Polar heart rate monitor (Polar Electro, New York, USA). Subsequently, and following the 5-min warm up period, each participant performed the randomly assigned exercise sequence. Oxygen consumption was collected continuously
Exercise sequence and energy expenditure throughout the entire exercise session. During the transition between exercise mode (aerobic or resistance), each participant was allowed a 90-sec rest to prepare for the second portion of the exercise protocol.

**Statistical Analysis**
The primary dependent variables were total energy expenditure (kcals) for the entire 60 min exercise bout for either sequence, and the energy expenditure for the aerobic bout and the resistance bout. The independent variable was the aerobic and resistance protocol and sequence. Energy expenditure data obtained from the COSMED were downloaded to the software K4b² program provided with the device. Subsequently, energy expenditure data (calculated breath by breath) for each 30 min exercise protocol (resistance and aerobic) were separated during the 1 hour sequence of exercise with the marking device located on the COSMED. Energy expenditure data does not include the warm-up or cool down periods. The data strictly consisted of the resistance and aerobic portion of the test as well as the 90-second transition between the types of exercise. Differences in baseline characteristics between male and female participants were determined using independent sample T tests. Differences in energy expenditure between each 60 min exercise sequence, and between aerobic (sequence 1 versus sequence 2), and resistance (sequence 1 versus sequence 2) bouts were determined using a general linear model repeated measures analysis of variance and Paired T test. Data are presented as mean±SD. Statistical significance was set at \( P<0.05 \). All analyses were conducted using the Statistical Package for the Social Sciences (SPSS, Version 17; SPSS Inc., Chicago, IL.)

**RESULTS**
Baseline characteristics for all study participants are listed in Table 1. No significant differences were observed at baseline between all participants and between genders. Total energy expenditure for sequence 1 (599.2±204.9 kcals) was significantly higher (\( P=0.04 \)) compared with sequence 2 (572.6±185.0 kcals) (Figure 1). Energy expenditure increased was ~35 kilocalories higher (\( P <0.05 \)) during the aerobic exercise session that was performed in sequence 1 compared in relation to with sequence 2. (Figure 2). In contrast, there were no significant differences in resistance exercise energy expenditure between sequence 1 (189.2±106.1 kcals) and sequence 2 (181.5±71.2 kcals) (Figure 3).

**Table 1. Physical Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Total (n=18)</th>
<th>Female (n=10)</th>
<th>Male (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>21.3 ± 1.6</td>
<td>20.6 ± 1.3</td>
<td>22.3 ± 1.5</td>
</tr>
<tr>
<td>RHR (beats/min)</td>
<td>67 ± 11</td>
<td>73 ± 10</td>
<td>60 ± 6</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>118 ± 8</td>
<td>116 ± 12</td>
<td>120 ± 4</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>75 ± 5</td>
<td>78 ± 5</td>
<td>72 ± 4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.6 ± 8.3</td>
<td>169.3 ± 5.5</td>
<td>181.1 ± 6.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.8 ± 13</td>
<td>63.8 ± 6.1</td>
<td>84 ± 9.9</td>
</tr>
<tr>
<td>Pred. VO(_2)max (ml/kg(\cdot)min(^{-1}))</td>
<td>48.6 ± 5.2</td>
<td>45.8 ± 3.2</td>
<td>52.2 ± 5.2</td>
</tr>
</tbody>
</table>
Figure 1. Total Energy Expenditure in Sequence 1 and Sequence 2.

Figure 2. Total Aerobic Energy Expenditure in Sequence 1 and Sequence 2.
DISCUSSION

The main findings of the present study support our hypothesis. The results show that traditional resistance training performed prior to an aerobic training in a single session results in the greatest energy expenditure as compared to the opposite order. Previous studies have shown similar results from performing resistance exercise before aerobic exercise. It has been suggested that resistance exercise creates a mechanical inefficiency during the following bout of aerobic exercise causing a higher consumption of oxygen and ultimately larger energy expenditure (1). Another intriguing finding of this study was that the excess calories expended in the resistance first session came during the aerobic portion. It is hypothesized that these excess calories were lost due to higher levels of EPOC (excess post oxygen consumption) that come after resistance training bouts. This idea was supported in previous study (10) where it was suggested that after performing resistance training, there is an increase in oxygen consumption for up to 8 hours.

It was also found that when combining exercise, resistance VO$_2$ was lower, although not statistically significant, when resistance exercise was performed first, yet RER was higher. This signified that when resistance exercise is performed first fewer calories are expended during resistance exercise, while exerting more effort. This may also be due to blood flow dynamics. Certain amounts of aerobic exercise performed prior to resistance exercise may actually increase the caloric expenditure during the resistance portion, while lessening exertion levels (1). There was also no significant difference in energy expenditure during the resistance portion during sequence 1 and 2. Conversely, there were more calories expended during the aerobic portion of sequence 1 then expended during the aerobic portion of sequence 2. This demonstrates that the difference in total energy expenditure between the two sequences was driven by the
aerobic portion of the exercise session. The previous physiological phenomenon was not replicated for aerobic exercise. When aerobic exercise was performed second, the VO$_2$ and RER were greater when compared to being performed first. This signifies that resistance exercise performed prior to aerobic exercise not only allows for more energy expenditure during the aerobic portion, but also requires greater levels of exertion. Limitations to the present study merit discussion. First, statistical power was low due to the relatively small sample size. Additionally, there may have been errors from the predictive calculations which were used to estimate 70% of maximal intensities for both the aerobic portion and 75% 1RM for resistance exercises. If there were errors in the calculated running speed or the weight suggested from these calculations, the intensity level for each client would be inconsistent and jeopardize the results of the study. Future research may be needed to determine the extended effects of EPOC from resistance training. Measuring the effects of EPOC for an extended period of time beyond the duration of the test could ultimately lead to equal amounts of calories expended during each sequence of exercise. It would also be beneficial to perform chronic intervention study to examine possible physiological adaptations. The body may adapt to the specific training protocol and the differences energy expenditure may become minimal.

CONCLUSIONS

In conclusion, the present study demonstrated that performing 30 minutes of resistance exercise prior to 30 minutes of aerobic exercise in the same sequence may elicit a greater caloric expenditure than the opposite sequence. To add, the excess caloric expenditure during the first sequence came during the aerobic portion of the workout. The data also showed that regardless of which exercise was performed first, the second exercise of the sequence caused greater energy expenditure in comparison to when it was performed first. These findings can be an important building block in the understanding of energy expenditure in concurrent exercise prescriptions. This data helps to better understand the effects of exercise sequence on energy expenditure. This finding supports that for maximum caloric expenditure one should perform resistance exercise prior to aerobic exercise. The effects of performing the aforementioned sequence could result in a greater weight loss over a given training period.

ACKNOWLEDGEMENTS

First and foremost, we would like to thank all of the participants for volunteering. We also want to thank Dr. Don Bredle for taking the time out of their schedules to make this project possible. We would like to acknowledge the Department of Kinesiology at the University of Wisconsin-Eau Claire for the use of equipment and supplies necessary to complete our research. This study was supported by the Office of Research and Sponsored Programs.

**Address for correspondence:** Nicholas M. Beltz, MS, Department of Health, Exercise, and Sports Sciences, University of New Mexico, Albuquerque, NM, United States, 87106, Phone: (763) 607-6191; Email: nbeltz@unm.edu.
REFERENCES

Disclaimer
The opinions expressed in the *Journal of Undergraduate Kinesiology Research* are those of the authors and are not attributable to the *Journal of Undergraduate Kinesiology Research*, the editorial staff or Western State Colorado University.