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Research Article

Acute Impact of Moderate-Intensity and Vigorous-Intensity Exercise Bouts on Daily Physical Activity Energy Expenditure in Postmenopausal Women

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This study determined whether performing a single moderate- or vigorous-intensity exercise bout impacts daily physical activity energy expenditure (PAEE, by accelerometer). Overweight/obese postmenopausal women underwent a 5-month caloric restriction and moderate- ($n = 18$) or vigorous-intensity ($n = 18$) center-based aerobic exercise intervention. During the last month of intervention, in women performing moderate-intensity exercise, PAEE on days with exercise (577.7 ± 219.7 kcal·d^{-1}) was higher ($P = .011$) than on days without exercise (450.7 ± 140.5 kcal·d^{-1}); however, the difference (127.0 ± 188.1 kcal·d^{-1}) was much lower than the energy expended during exercise. In women performing vigorous-intensity exercise, PAEE on days with exercise (450.6 ± 153.6 kcal·d^{-1}) was lower ($P = .047$) than on days without exercise (519.2 ± 127.4 kcal·d^{-1}). Thus, women expended more energy on physical activities outside of prescribed exercise on days they did NOT perform center-based exercise, especially if the prescribed exercise was of a higher intensity.

1. Introduction

Obesity is associated with numerous chronic diseases and, currently, its prevalence is 34% in US adults [1]. Excess fat storage is the result of greater energy intake than expenditure for a period of time; thus, increasing energy expenditure is an important strategy to treat obesity. Approximately 20–45% of total daily energy expenditure is due to physical activity [2]. Physical activity energy expenditure (PAEE) can be further divided into energy expended during structured exercise and during activities of daily living other than structured exercise [2].

There has been extensive research investigating the effects of various exercise and/or caloric restriction interventions for inducing weight loss. In general, these programs are successful at inducing weight loss; however, there is some evidence showing that increases in total daily energy expenditure during prescribed exercise interventions are less than expected given the amount of energy expended during the prescribed exercise sessions [3–8]. In support of this, one study showed that accelerometer counts from physical activities outside of structured exercise decreased by 8% after a 12-week training period [8]. This suggests that PAEE outside of the structured exercise may decrease as a result of the exercise treatment.

All of these prior studies examined the chronic or longer-term effects of exercise interventions on PAEE. However, it is also important to determine whether there are potential changes in PAEE acutely on days in which the exercise is performed. Yet, to date, only one small study examined this acute effect of exercise on daily PAEE [8]. It reported that accelerometer counts from nonexercise activities were lower

on days with, than without, structured exercise during a 12-week exercise program. Thus, the purpose of the present study was to determine whether performing a single exercise bout impacts daily PAEE in postmenopausal women and to determine whether the intensity of the exercise bout plays a role in any potential changes in daily PAEE.

2. Methods

2.1. Study Design and Participants. Women in this study are a subset of those enrolled in a randomized clinical trial that was designed to determine whether intensity of aerobic exercise affects the loss of abdominal adipose tissue and improvement in cardiovascular disease risk factors in postmenopausal women with abdominal obesity (Clinicaltrials.gov: NCT00664729). The detailed inclusion and exclusion criteria were published previously [9]. Briefly, they were: (1) older postmenopausal (age: 50–70 yr), (2) overweight or obese (BMI: 25–40 $kg \cdot m^{-2}$ and waist circumference >88 cm), (3) nonsmoking, (4) not on hormone therapy, and (5) sedentary (<15 minutes of exercise, two times per wk) in the past 6 months before enrollment. The study was approved by the Wake Forest University Institutional Review Board, and all women signed an informed consent form to participate in the study according to the guidelines for human research.

Data used for the current analyses are from women who were randomized to caloric restriction plus moderate-intensity aerobic exercise (moderate-intensity) or caloric restriction plus vigorous-intensity aerobic exercise (vigorous-intensity) and completed the study interventions. There were 18 women in the moderate-intensity and 18 women in the vigorous-intensity groups who had PAEE data available from before the intervention and from days with and without center-based exercise in the last month of intervention.

2.2. Intervention. Both the moderate-intensity and vigorous-intensity interventions were 5 months, and the energy deficit was designed to be approximately 2100 $kcal \cdot wk^{-1}$ from caloric restriction and 700 $kcal \cdot wk^{-1}$ from center-based exercise. Individual energy needs for weight maintenance were calculated from each woman's resting metabolic rate (indirect calorimetry after an overnight fast by using a MedGraphics CCM/D cart and BREEZE 6.2 software, MedGraphics, St. Paul, MN) and an activity factor based on self-reported daily activity (1.2-1.3 for sedentary lifestyle).

Individual diets were developed by a registered dietitian according to each woman's choices from a menu designed by a registered dietitian. Throughout the course of the 5-month intervention, all women were provided with daily lunch, dinner, and snacks prepared by the General Clinical Research Center (GCRC) metabolic kitchen. Women purchased and prepared their breakfast meals from a provided menu plan. They were asked to eat only the food that was given to them or that was approved from the breakfast menu. Energy make-up of the diet was approximately 25% from fat, 15% from protein, and 60% from carbohydrate. Women were allowed to consume as many noncaloric, noncaffeinated beverages as they liked. They were also allowed 2 free days per month during which they were not provided food but were given guidelines for diet intake at their prescribed energy level. All women were provided with daily calcium supplements (500 mg, 2 $times \cdot d^{-1}$). They were asked to keep a log of all foods consumed, and the records were monitored by the dietitian to verify compliance.

The exercise interventions were center-based walking on treadmills (LifeFitness 9500HR, Life Fitness Co., IL) on 3 $d \cdot wk^{-1}$ under the supervision of an exercise physiologist. Exercise progressed from 20–25 min the first week to 55 minutes by the end of the sixth week for the moderate-intensity (45–50% of maximum oxygen consumption, VO_2max) group and it progressed from 10–15 minutes the first week to 30 min by the end of the sixth week for the vigorous-intensity (70–75% of VO_2max) group. The target exercise intensity was determined based on each woman's target heart rate calculated from the Karvonen equation [(HRR $\times$ intensity) + resting heart rate] [10], where HRR is the maximal heart rate, obtained from each woman's maximum exercise test, minus resting heart rate. Treadmill speed and grade were adjusted on an individual basis to ensure women exercised at their prescribed exercise intensity. Blood pressure was taken before and after each exercise session. Heart rate readings (by Polar heart rate monitors; Polar Electro Inc, Lake Success, NY) were taken before, at least 2 times during (to monitor compliance to the prescribed exercise intensity), and after the exercise.

2.3. Physical Activity Energy Expenditure (PAEE) Measurements. PAEE was measured using an RT3 triaxial accelerometer (Stayhealthy, Inc., Monrovia, CA). It is about the size of a pager and is worn by clipping onto the waist. It collects 3-dimensional data at one minute intervals and stores such data for 7 days. Data were collected in units of acceleration. Activity energy expenditure was computed using the manufacturer's software from the integrated acceleration and body mass with formula developed by the manufacturer. Daily PAEE was calculated using the average calories expended per minute times 1440 minutes a day.

Women were asked to wear the accelerometer before and each month during the intervention, for 5–7 days including week days and weekend days. Women were instructed not to change their activities while wearing the accelerometer at all times, except while sleeping and bathing. Data collected from RT3 monitors were included only when there were valid data from both before the intervention and during the last month of intervention. During the last month of intervention, RT3 data were considered valid when data were collected from at least 2 days with center-based exercise and at least 2 days without center-based exercise. The average PAEE from days with and without center-based exercise were used for the current analyses. Of note, the average daily PAEE from days with center-based exercise included the energy expended during the exercise sessions, and none of the women performed structured exercise at baseline.

Treadmill readings during the exercise sessions were recorded for each woman as a measure of energy expended during center-based exercise. Height and weight were measured before and after the 5-month intervention with shoes and jackets or outer garments removed.

2.4. Statistics. All analyses were performed using SAS software, version 9.1 (SAS Institute, Cary, NC). Continuous variables are presented as mean ± SD. Analysis of variance was used to compare values between groups. Paired t-tests were used to compare values within the same group at different measurement points. An alpha level of 0.05 was used to denote statistical significance.

3. Results

As shown in Table 1, there were no differences in baseline characteristics such as age, racial distribution, body weight, and body mass index between the moderate-intensity and vigorous-intensity groups. Daily PAEE was also similar between the two groups at baseline.

The total amount of weight loss during intervention was similar between the moderate-intensity and vigorous-intensity groups (12.9 ± 4.2 kg or 14.6 ± 4.8% and 12.6 ± 5.1 kg or 13.5 ± 4.6%, resp.). During the last month of intervention, PAEE on days with center-based exercise was significantly higher in women performing moderate-intensity exercise than in women performing vigorous-intensity exercise ($P = .052$). In contrast, PAEE on days without exercise was not statistically different between the two groups ($P = .135$).

In the moderate-intensity group, 13 of the 18 women had higher PAEE on days with than without center-based exercise (Figure 1), and the average PAEE on days with exercise (577.7 ± 219.7 kcal·d^{-1}) was higher than on days without exercise (450.7 ± 140.5 kcal·d^{-1}, $P = .011$) (Table 1). Yet, the difference (127.0 ± 188.1 kcal·d^{-1}) was much smaller than the energy expended during exercise (325.0 ± 79.6 kcal·d^{-1}) (Figure 2), suggesting that, during the 5th month of exercise training, women expended less energy on activities outside of the structured exercise when they exercised during the day. In support of this, PAEE on days with center-based exercise was not different from baseline PAEE (520.8 ± 206.5 kcal·d^{-1}; $P > .05$ for both) in women performing moderate-intensity exercise even though energy expended during exercise was included in the daily PAEE on days with exercise.

On the other hand, in the vigorous-intensity group, 12 of the 18 women had lower PAEE on days with than without center-based exercise during the last month of the intervention (Figure 1). The average daily PAEE on days with exercise (450.6 ± 153.6 kcal·d^{-1}) was lower than on days without exercise (519.2 ± 127.4 kcal·d^{-1}) (difference = −68.6 ± 136.1 kcal·d^{-1}, $P = .047$) again even though energy expended during exercise (296.8 ± 93.0 kcal·d^{-1}) was included in daily PAEE on days with exercise (Figure 2). This indicates that, during the 5th month of exercise training, women performing vigorous-intensity exercise were expending more total calories on nonexercise days than on exercise days. In addition, PAEE on days without exercise was not different from baseline daily PAEE (543.2 ± 164.0 kcal·d^{-1}; $P > .05$); however, PAEE on days with exercise (which included energy expended during center-based exercise) was significantly lower than baseline PAEE ($P = .020$).

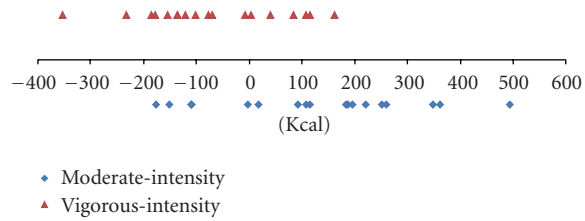

Figure 1: The difference between daily physical activity energy expenditure during days with and without center-based exercise (PAEE on days WITH exercise minus PAEE on days WITHOUT exercise). In the moderate-intensity exercise (moderate-intensity) group, majority of the women had higher PAEE during days WITH center-based exercise. In contrast, in the vigorous-intensity exercise (vigorous-intensity) group, majority of the women had higher PAEE during days WITHOUT center-based exercise.

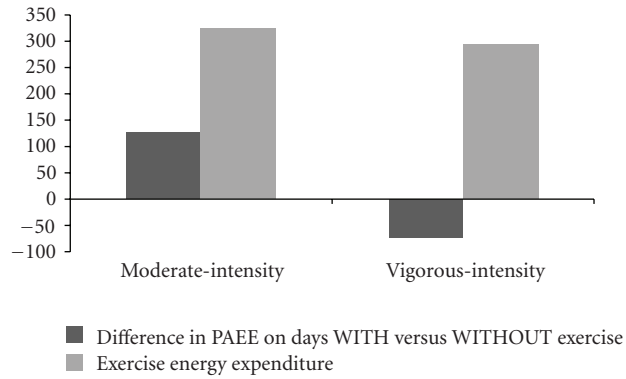

Figure 2: The difference between daily physical activity energy expenditure during days with and without center-based exercise (PAEE on days WITH exercise minus PAEE on days WITHOUT exercise) and energy expended during center-based exercise by group. In women performing moderate-intensity exercise (moderate-intensity), PAEE was higher on days with center-based exercise; however, the difference was much lower than the energy expended during exercise. In contrast, in women performing vigorous-intensity exercise (vigorous-intensity) group, PAEE was lower on days with center-based exercise, even with exercise energy expenditure included in PAEE.

4. Discussion

This study adds information to the literature regarding how acute exercise sessions affect daily PAEE and whether the intensity of exercise influences the effects. We found that, during the last month of a 5-month moderate-intensity exercise training intervention, the daily PAEE during days WITH center-based exercise was higher than days WITHOUT exercise by an amount much smaller than the exercise energy expenditure. During the 5th month of

Table 1: Participant characteristics at baseline.

Characteristics	Moderate-intensity (n = 18)	Vigorous-intensity (n = 18)
Age (yrs)	58.7 ± 5.9	58.1 ± 5.4
Non-White (n, %)	6, 33.3%	4, 22.2%
Body weight (kg)	88.9 ± 8.5	91.1 ± 12.9
Body mass index ($kg \cdot m^{-2}$)	33.3 ± 3.1	33.3 ± 3.8
PAEE at baseline ($kcal \cdot d^{-1}$)	520.8 ± 206.5	543.2 ± 164.0
PAEE on days with exercise in last month ($kcal \cdot d^{-1}$)	577.7 ± 219.7	450.6 ± 153.6*
PAEE on days without exercise in last month ($kcal \cdot d^{-1}$)	450.7 ± 140.5†	519.2 ± 127.4‡

PAEE: physical activity energy expenditure.
*P = .052 versus moderate-intensity group; †P = .011 versus PAEE on days with exercise in last month; ‡P = .047 versus PAEE on days with exercise in last month.

a vigorous-intensity exercise training intervention, daily PAEE during days WITH center-based exercise was lower than days WITHOUT center-based exercise sessions, even with energy expended during the exercise sessions included in PAEE. Therefore, there was a reduction in PAEE outside of the center-based exercise sessions in both intervention groups, and this reduction appeared to differ based on the intensity level of the center-based exercise because it was greater in women performing vigorous-intensity, compared to moderate-intensity, exercise.

Our findings are in line with those of Meijer et al. [8], who found that accelerometer counts of total physical activity were similar between days with and without training, and that after energy expenditure during the training session was subtracted out, accelerometer counts were significantly lower on training days. In their study, the training program included one aerobic exercise of 60 minutes and one cardio- and weight-stack machine exercise of 90 minutes each week for 12 weeks in men and women of 55 years and older. We cannot directly compare the magnitude of the PAEE responses in our study to their study because the intensity of the exercises was not specified and only accelerometer counts were reported in their study.

We also showed that exercise at vigorous intensity induced greater compensation in PAEE than moderate-intensity exercise. Of note, both exercise programs in our study are consistent with the current physical activity guidelines for adults [11, 12]. The frequency of the exercise sessions was the same for the moderate-intensity and vigorous-intensity exercise groups, and the volume of exercise was also similar. However, this does not exclude the possibility that volume or frequency of exercise of an exercise program may affect the "chronic" response in PAEE to the program. Further studies are needed to address these questions because these are important factors to consider when designing exercise programs to better meet an individual's goal for participating exercise.

In this study, PAEE was measured in the last month of the 5-month training program. Thus, women were relatively trained so that PAEE responses to acute exercise may be somewhat different from those if women were untrained. However, we suspect that the compensation in PAEE is likely lower in the trained state. In other words, for a person who does not participate in regular exercise, an acute session of exercise may induce greater compensation in PAEE. On the other hand, the information found in this study may be more important because with the epidemic of obesity, many individuals participating in exercise programs may think that would satisfy the goal of weight control. Thus, we should educate and encourage them to maintain higher daily activities while participating in exercise programs at the same time.

The results of this study should be interpreted in light of a few considerations. The daily PAEE during days with and without center-based exercises was the average of at least two days. Although this provides a good measure of activity energy expenditure, it would be better if data from more days were available. Second, all exercise sessions were during the week. For PAEE during days without exercise, we did not have enough data to determine whether there was a difference in PAEE between those weekdays and weekend days. Third, we used treadmill readings as the energy expended during exercise sessions. These are not accurate measures of energy expenditure; however, we believe this will not affect our conclusion given the big difference shown between exercise energy expenditure and the difference between PAEE during days with and without exercise sessions (Figure 2).

In summary, the main finding of this study is that women expended more energy during physical activities outside of prescribed exercise sessions on days they did NOT perform center-based exercise, especially if the prescribed exercise was of a higher intensity. More research is needed to determine what exercise prescription can minimize this "compensation". This phenomenon may have biological and behavioral reasons, and future research investigating the underlying mechanisms is warranted. Thus, health professionals should encourage individuals who are participating in exercise programs to maintain levels of activity in addition to the program, so that greater weight loss can be achieved.

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