Exercise intensity does not affect the composition of diet- and exercise-induced body mass loss

Douglas L Ballor, John P McCarthy, and E Joan Wilterdink

ABSTRACT The effect of caloric restriction (1200 kcal/d intake) in combination with high (High) (80–90% of peak VO2) or low (Low) (40–50% of peak VO2) exercise work rates on the composition of lost body mass was determined in 27 obese women (percent fat, 36.7 ± 4.2%; x ± SD). All subjects trained 3 d/wk for 8 wk, with the High (n = 14) and Low (n = 13) groups exercising for 25 and 50 min/d, respectively. After posttesting there were no differences between the groups with respect to pre- to posttest changes (mean of combined groups) in body mass (−7%), fat-free mass (−10%), fat mass (−16%), percent fat (−10%), and sum of five skinfold-thickness measurements (−16%). This study suggests that with regard to conservation of fat-free mass, the selection of an exercise intensity for a diet and exercise regimen may be left to the preference of the clinician and/or dieter.

KEY WORDS Body mass loss, exercise, exertion, diet, fat-free mass, caloric restriction

Introduction

Calorically induced body mass loss generally includes both fat and fat-free masses (1–3). If a portion of the reduced caloric intake is replaced by increased energy expenditure via exercise, the percentage of body mass lost as fat increases. For example, Weltman et al (4) found that the percentage of body mass lost as fat was greater (79% vs 68%) for diet plus exercise (DE) than for diet alone (D). Likewise, Zuti and Golding (3) found higher fat mass losses for DE (109%) than for D (79%).

In contrast, if the exercise is added to a constant dietary restriction such that it results in a greater body mass loss for the DE group, conservation of fat-free mass as a percentage of lost body mass may not occur. Hagan et al (2) found that adding exercise to a caloric-restriction regimen did not increase the percentage of body mass lost as fat for obese men (DE, 69% vs D, 70%) or women (DE, 79% vs D, 89%). Thus, if exercise is added to a diet program, thereby increasing the total body mass loss, the sparing effect of exercise on fat-free mass may be lost.

Exercise type, duration, frequency, and intensity may differentially affect the composition of calorically induced body mass loss. The effect of exercise intensity on the composition of lost body mass is of particular interest, in part, because of the variance in the metabolic responses to high- and low-intensity exercise. As exercise intensity (work rate) increases from ~50% of maximum oxygen uptake (VO2max) to maximal levels, the percentage of energy supplied via carbohydrates increases progressively (5). Blood catecholamine (6) and lactate concentrations (7) increase exponentially with increases in exercise intensity (starting from ~50% of VO2max) and are thought to be partially responsible for the stimulation of glycolysis.

Thus, during high-intensity exercise (> 80% of VO2max), a large portion of the required energy is derived from carbohydrate sources. In dieting individuals, where carbohydrate and protein intake is limited, high-intensity exercise may increase the rate of gluconeogenesis and consequently the loss of fat-free mass.

In contrast, low-intensity exercise stimulates β-oxidation while carbohydrate metabolism is suppressed. Furthermore, low-intensity exercise can be performed daily with minimal risk of overtraining or muscle and joint injury and places less stress on the cardiorespiratory system. Because a large portion of the overweight population is older (8) and has a relatively high incidence of cardiovascular disease (9), exercise of low-intensity may be preferable for use with caloric-restriction programs.

There appear to be no studies in the literature directly comparing the effects of different intensities of exercise at the same total caloric expenditure on the composition of lost body mass. The purpose of this study was to compare the effects of high- and low-intensity exercise on the composition of calorically induced body mass loss.

Subjects and methods

Subjects

Twenty-seven sedentary obese females (body mass, 78.6 ± 7.4 kg (x ± SD); % fat, 36.7 ± 4.2; height, 167.6 ± 3.8 cm; age, 31.9 ± 5.1 y) volunteered to participate in an 8-wk body mass loss study. The study was approved by the University of Wisconsin institutional review board. The subjects were randomly assigned to one of two exercise groups: High (Hi) or Low (Lo). The Hi group was composed of participants who trained at 80–90% of their estimated VO2max, while the Lo group trained at 40–50% of their estimated VO2max. Both groups trained 3 d/wk for 8 wk. The Hi group trained 25 min/d, while the Lo group trained 50 min/d.
Physical characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>Group†</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Difference‡</th>
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<tbody>
<tr>
<td>Body mass</td>
<td>High</td>
<td>79.1 ± 8.4</td>
<td>73.1 ± 8.2</td>
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<td>Low</td>
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<td>72.6 ± 6.8</td>
<td>-5.6 ± 1.8§</td>
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<tr>
<td>Fat-free mass</td>
<td>High</td>
<td>50.3 ± 3.6</td>
<td>48.8 ± 3.8</td>
<td>-1.4 ± 1.1§</td>
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<td>48.8 ± 3.5</td>
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<td>-0.9 ± 1.2§</td>
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<tr>
<td>Fat mass</td>
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<td>24.3 ± 7.2</td>
<td>-4.5 ± 2.1§</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>29.4 ± 4.3</td>
<td>24.7 ± 4.5</td>
<td>-4.7 ± 1.3§</td>
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<tr>
<td>Percent fat</td>
<td>High</td>
<td>36.1 ± 5.0</td>
<td>32.7 ± 7.0</td>
<td>-3.4 ± 2.6§</td>
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<td></td>
<td>Low</td>
<td>37.5 ± 3.2</td>
<td>33.8 ± 3.5</td>
<td>-3.7 ± 1.4§</td>
</tr>
<tr>
<td>Sum of five skinfold-thickness measurements (mm)</td>
<td>High</td>
<td>135.4 ± 43.6</td>
<td>115.9 ± 44.7</td>
<td>-19.5 ± 1.2§</td>
</tr>
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<td>125.8 ± 35.1</td>
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<td>Peak VO2 (L/min)</td>
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<td>2.7 ± 0.5</td>
<td>0.4 ± 0.4§</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>2.3 ± 0.2</td>
<td>2.4 ± 0.3</td>
<td>0.1 ± 0.2§</td>
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<tr>
<td>Peak VO2 (mL·kg⁻¹·min⁻¹)</td>
<td>High</td>
<td>29.5 ± 4.9</td>
<td>37.1 ± 8.3</td>
<td>7.6 ± 5.1§</td>
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<tr>
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<td>Low</td>
<td>29.6 ± 2.9</td>
<td>33.3 ± 4.5</td>
<td>3.8 ± 3.0§</td>
</tr>
<tr>
<td>Peak heart rate (beats/min)</td>
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<td>179.6 ± 8.1*</td>
<td>-1.7 ± 5.1</td>
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<tr>
<td></td>
<td>Low</td>
<td>187.5 ± 6.2*</td>
<td>188.5 ± 7.2*</td>
<td>1.1 ± 4.5</td>
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</tbody>
</table>

*± SD.
† High group, n = 14; low group, n = 13.
‡ Posttest value minus pretest value.
§ Pretest significantly different from posttest (within groups, ie, high pretest different from high posttest), p < 0.025.
|| High change (prepost) significantly different from low change, p < 0.05.
† High significantly different from low, p < 0.05.

Wisconsin—Madison Center for Health Sciences Human Subjects Committee. After informed written consent and pretesting, subjects were randomly assigned to one of two groups: 1) caloric restriction and high-intensity exercise (High) (n = 14) or 2) caloric restriction and low-intensity exercise (Low) (n = 13). With the exception of peak heart rate, there were no statistically significant between group pretest differences for any of the variables measured (body mass, body composition, peak VO2). The pretest characteristics of the subjects are shown in Table 1.

Experimental design

All subjects followed the same dietary protocol and exercised 3 d/wk on a cycle ergometer at either a high or low work rate for a total of 8 wk. The subjects were instructed (and agreed) not to participate in any exercise training outside of that undertaken as part of this study. The duration of exercise was such that the total caloric expenditure per session was similar between the High and Low groups. Body composition and peak VO2 determinations were made at the beginning and conclusion of the study. In addition, peak VO2 was reassessed at the end of the fourth week. Training work loads were then recalculated by using the new peak VO2. Heart rate and energy expenditure during exercise training was also determined for each individual. This was done during the fifth week of the study immediately after the reassessment of peak VO2.

Dietary intervention

A modified version of the American Diabetes Association Caloric Exchange Program (10) was used. Subjects were assigned quantities of food to eat from specific food categories but were allowed individual choices within those categories. The nutritionally balanced diet of 1,200 kcal/d consisted (as a percentage of total kcal) of 52% carbohydrate, 20% protein, and 28% fat and met the Recommended Dietary Allowance (RDA) for vitamins and minerals (11).

Subjects attended weekly meetings with a dietary counselor. At these meetings, body mass changes were recorded, dietary compliance evaluated (via food diaries), and strategies developed to improve individual success.

Exercise program

The Low and High groups were assigned cycle ergometer work rates that were intended to represent 42.5% and 85% of their peak VO2, respectively. The Low group exercised for 50 min and the High group for 25 min, three times per week. The cycle ergometry work rates in kilogram meters per minute (kpm) were estimated (12) as a percentage of peak VO2 where
\[ \text{kpm} = \frac{(\text{desired exercise percentage} \times \text{peak VO2 (mL/min)})}{3.5 \text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \times \text{body mass}} \times 2 \text{kpm} \cdot (\text{mL O}_2)^{-1} \cdot \text{min}^{-1} \]

All exercise sessions were supervised by qualified personnel.

Body composition

Body mass was measured to the nearest 60 g with a beam balance scale. Body density was determined via hydrostatic weighing as described by Katch et al (13). Twelve repeat weighings were made and the average of the last three weighings chosen to represent the true underwater weight (13). Residual lung volumes were determined by using the closed circuit oxygen dilution technique as described by Wilmore (14) with the subjects in the same bent-forward position used in the underwater
density determinations. The average of three residual volume measurements were used in the body composition determinations. Body density was converted to percent fat by using the Siri equation (15). Fat mass was calculated by multiplying body mass by percent fat. Fat-free mass was determined by subtracting fat mass from body mass.

Anthropometrics

Five skinfold-thickness measurements (thigh, abdominal, iliac, tricep, subscapula) were made according to the procedure described by Behnke and Wilmore (16). All pre- and posttest measurements on an individual were made in duplicate by the same investigator.

Peak VO₂

Open-circuit spirometry was used to determine peak VO₂. Expired gases were collected and analyzed for percent oxygen and percent carbon dioxide. Oxygen uptake was calculated by using the volume of expired air and the above gas percentages as described by McArdle et al (17). All values represent 1-min averages.

The seat height of the cycle ergometer was adjusted for each subject before testing. The subjects initially started exercising at between 300 and 600 kpm with work rates increased by 300 kpm every 3 min until the subject would no longer maintain the work rate. In a few selected instances the work rate in the last stage was increased by 150 kpm when in the opinion of the test director the subject could not have tolerated a 300-kpm increase. Peak VO₂ was the highest VO₂ elicited during the test. This always occurred during the last or next-to-last test minute. Peak heart rate was the heart rate associated with the peak VO₂ and was determined with a model 8799 Uniq Heart Watch (Computer Instruments Corp, Hempstead, NY). This type of heart rate monitor has been shown to yield results similar to those of ECG monitoring (18).

Physiological responses to exercise

During the 5th wk the heart rates and energy output for the High and Low subjects were determined. Expired gases were collected in meteorological balloons for 1 min at minutes 5, 10, 15, 20, and 25 and at minutes 10, 20, 30, 40, and 50 for the High and Low groups, respectively. These gases were analyzed as described previously to determine VO₂ and respiratory exchange ratio (RER). The mean of these five measurements was used to represent the average response to the exercise. Caloric expenditure was determined by multiplying the VO₂ by the kcal/L equivalent associated with the RER (17).

Statistical analyses

Paired and unpaired t tests were used where appropriate to determine between- and within-group differences. Between-group changes represent a comparison of the pre- and post-test difference scores whereas within-group changes are a comparison of the pretest to posttest value for a single group. All values are reported as the mean ± SD.

Results

Table 1 contains the anthropometric and physiological responses to the diet and exercise intervention. Both groups exhibited statistically significant (p < 0.05) pretest to posttest within-group changes for body mass (High, −6.0 ± 1.9; Low, −5.6 ± 1.8 kg), fat-free mass (High, −1.4 ± 1.1; Low, −0.9 ± 1.2 kg), fat mass (High, −4.5 ± 2.1; Low, −4.7 ± 1.3 kg), percent fat (High, −3.4 ± 2.6; Low, −3.7 ± 1.4), and sum of five skinfold thickness measurements (High, −19.5 ± 12.5; Low, −26.1 ± 15.2 mm). There were no statistically significant between-group differences for any of the above variables. Thus, exercise intensity does not seem to affect the composition or rate of body mass loss.

The absolute peak VO₂ (L/min) pretest to posttest change was statistically different between the groups with the High group increasing more (17%) than the Low group (4%). A similar finding was obtained when the High and Low groups were compared for changes in relative peak VO₂ (mL·kg⁻¹·min⁻¹) with the High group change (26%) significantly (p < 0.05) larger than the Low group change (13%). The High group exhibited a statistically significant within-group increase for both absolute and relative peak VO₂ whereas the Low group increased significantly only in the latter. There were no differences between the groups with respect to changes in peak heart rate.

Table 2 contains the mean physiological responses found during the 25- and 50-min cycle ergometer exercise bout for the High and Low groups, respectively. Although the body composition analysis yielded no between-group differences, there were numerous differences between the groups with respect to the physiological responses during exercise. Oxygen uptake, percentage of peak VO₂, heart rate, RER, caloric expenditure (per min), and assigned exercise work rates (kpm) are all significantly higher for the High group (p < 0.01). The High and Low groups exercised at ~85% and 51% of peak VO₂, respectively. A similar difference was observed in peak heart rate with the High group exercising at 91% of peak heart rate and the Low group at 68%. The total caloric expenditure per exercise session was not different (p > 0.05) between the groups (High, 260 ± 36; Low, 283 ± 28 kcal).

There was very little drift in the VO₂, heart rate, and RER
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During either the 25- or 50-min monitored exercise sessions. The VO2 increased from 2.03 to 2.16 L/min (6% over 25 min) and from 1.11 to 1.19 L/min (7% over 50 min) for the High and Low groups, respectively. Likewise, the heart rate increased from 160 to 171 beats/min (7%) for the High group and from 123 to 132 beats/min (7%) for the Low group. In contrast, RER declined from 0.95 to 0.89 (6%) for the High group and from 0.81 to 0.79 (2%) for the Low group. Adherence to the assigned exercise was quite high. The 27 subjects missed only a combined total of 23 (3.7%) of the 621 possible exercise sessions.

Discussion

During the exercise sessions, estimated carbohydrate utilization (based on RER) was 74.1% of the energy expenditure for the High group and 33.4% for the Low group. It was postulated that exercise that emphasized the use of fat as fuel (Low) would result in additional fat mass losses, or alternatively, that exercise that resulted in increased carbohydrate utilization would promote the loss of fat-free mass. The Low group would then lose a higher percentage of body mass as fat compared with the High group.

In this study, however, the effects of high- and low-intensity exercise on the magnitude and composition of calorically induced body mass loss were not different (Table 1). The percentage of body mass lost as fat for the 27 women (mean of both groups, 80%) was similar to that found by Hagan et al (males, 70%; females, 79%) (2), Weltman et al (males, 79%) (4), and Kenrick et al (mixed sexes, 78%) (19) during various combinations of diet and exercise. Thus, the choice of which type of cycle ergometry exercise (high- or low-intensity) to include in a diet and exercise program can be left to the preference of the clinician or dieter.

The lack of significant differences between the groups with respect to the composition of the body mass loss may have occurred because the frequency and duration of exercise were not of sufficient quantity. Thus, the demands that the high- and low-intensity exercise placed on the carbohydrate and fat reserves, respectively, may not have been large enough to result in measurable differences between the High and Low groups. The 3 d/wk of exercise resulted in a caloric expenditure of ~800 kcal/wk, which represents only ~5% of a subject’s weekly caloric expenditure (assuming a daily caloric expenditure of 2200 kcal). Over the duration of the study the Low group expended, as a result of the exercise, only 2900 kcal more as fat than did the High group. This could, at most, account for a 0.4-kg difference in fat mass loss (2900 kcal/7700 kcal per kg fat). Alternatively, the High groups increased carbohydrate utilization via exercise (~300 kcal/wk more than the Low group) may not have been large enough to necessitate significant additional gluconeogenesis. The moderate level of caloric restriction (1200 kcal/d intake) also likely reduces the possible effect of exercise intensity on the composition of lost body mass because greater opportunities exist for obtaining carbohydrates via feeding.

Peak VO2 increased significantly on both an absolute (L/ min) and on a relative to body mass basis (mL·kg⁻¹·min⁻¹) for the High group and on a relative basis for the Low group. Increases in absolute and relative peak VO2 during periods of moderate caloric restriction have also been demonstrated by others (2). The failure of the Low group to achieve a significant increase in absolute peak VO2 is consistent with a number of studies that use calorically unrestricted subjects that show that low-intensity exercise does not elicit statistically significant increases in peak VO2 over relatively short training periods (20). The statistically significant increase in relative peak VO2 is a function of the significant decrease in body mass but does represent an important improvement in functional capacity.

Although exercise intensity did not elicit differing changes in the magnitude or composition of body mass loss, the subjects did respond differently to the exercise. The subjects in the Low group tolerated the exercise much better than did the High group, especially initially. In contrast, the subjects in the High group initially had labored breathing and were forced to split the exercise into two or more segments, especially during the early training sessions, because they could not complete the assigned exercise in one bout. After several weeks of training, however, the High group progressed to the point where they could tolerate the work rates without undue difficulty.

Although no differences exist between the High and Low groups with respect to the composition of lost body mass, we suggest that low-intensity exercise may be more appropriate for inclusion in diet and exercise programs than high-intensity exercise especially during the early phases of the regiment. Low-intensity exercise can be done daily, does not usually require expensive medical screening before participation, and elicits the same body mass changes as diet and high-intensity exercise. High-intensity exercise did, however, result in greater gains in cardiorespiratory fitness (peak VO2) than did low-intensity exercise and should be considered when improvements in peak VO2 are desired.

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References