Effects of Aerobic Conditioning at Intensities Corresponding to Lactate Threshold Plus Reduced Energy Intake in College-age Females

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The effects of a 15-wk aerobic conditioning (4.2 ± 1.3 d/wk) plus energy restriction (25 kcal/kg/d diet) program on anthropometric and physiologic attributes were studied in 16 obese women between the ages of 18 and 24. The women were divided into either an experimental (E, n = 10) group or a control (C, n = 6) group. The exercise + diet (E) group demonstrated significant reductions in body weight, both absolute and relative body fat, Katsura index, and serum triglycerides, and increases in oxygen uptake relative to lactate threshold (LT), maximal oxygen uptake, and the ratio of high-density lipoprotein cholesterol to total cholesterol. In the C group, none of the variables measured in this study remained unchanged. Thus the benefits of weight reduction without any change in fat free weight following the program were pronounced in the female university-age group that we studied. In conclusion, the highly structured aerobic conditioning at intensities corresponding to LT together with a proper dietary regimen is considered optimal with respect to favorable changes in various anthropometric and physiologic attributes. The feasibility of treating obese individuals with manifestation of medical and/or psychological problems in a school setting should be a significant matter in future research. (Ann. Physiol. Anthrop. 13(5): 245-252, 1994)

Key words: Maximal oxygen uptake, Body composition, Serum lipids, Obesity, Energy restriction

Obesity, which is the resultant condition of a chronic disequilibrium between energy intake and energy expenditure, can undoubtedly be considered a hazard to health and a detriment to well-being. Analysis of recent data from the Framingham Study (Hubert, 1984) indicates that individuals who possessed more than 130% of desirable weight suffered a greater incidence of cardiovascular disease, in both sexes and in two different age groups, than those who possessed less than 110% of desirable weight. While obesity may be linked to physical inactivity, this does not necessarily imply that merely by increasing physical activity one can prevent a disease if the disease is already present. However, it appears likely that promoting an active and positive life-style in order to prevent obesity is a good choice for gaining health-related benefits. In fact, regular participation in physical activity has been found to lead to significant alterations in body composition and cardiorespiratory function even among younger generations (Malina et al., 1982; Montoye, 1986; Tanaka et al., 1988; Tanaka et al., 1989a; Wells, 1986).

The chronic disequilibrium between energy
intake and energy expenditure theoretically results from either excessive intake or deficient expenditure, or both. In treating obesity, therefore, the emphasis must be placed upon both decreasing energy intake and increasing energy expenditure (Dudleston and Bennion, 1970; Hagan et al., 1986; Sopko et al., 1985; Tanaka et al., 1986a; Weltman et al., 1980; Zuti and Golding, 1976). As compared with decreasing energy intake by diet restriction alone, increasing energy expenditure through aerobic exercise such as jogging, cycling, swimming or dancing, or through anaerobic exercise, has the advantage of allowing the person to eat a relatively high energy and nutritious diet.

Moreover, exercise not only increases energy expenditure but may even alter body composition to increase energy expenditure further. Energy restriction without any exercise appears to characteristically result in substantial protein loss (visceral or muscle tissue), which is evidenced by an early onset of a negative nitrogen balance, while exercise probably stimulates protein synthesis and forestalls a protein wasting process (McMurray et al., 1986; Rennie et al., 1981; Tanaka et al., 1986a).

With the above in mind, it is reasonable to assume that participating in aerobic exercise continuously together with decreased energy intake could beneficially result in the prevention of further fat gain and reduce the risk of cardiovascular disease. Such an approach along with the scientifically established fact that adolescents and children can alter their body composition, blood lipid and lipo-protein profiles, and cardiorespiratory system should be an important matter in health education at school for their sound growth and development.

The purpose of this study was to evaluate the effects of aerobic conditioning (the exercise at lactate threshold) plus energy restriction on alterations in body composition and physiological variables of obese young women. The reason why we selected lactate threshold (LT) as the intensity for conditioning is that constant-load exercise relative to the LT appears to be sustainable for a prolonged period of time and can be an effective and safe level of conditioning intensity (Tanaka et al., 1989b). The other unique aspect of this program shall be described in the Methods section.

METHODS

1. Subjects

Sixteen obese women between the ages of 18 and 24 years volunteered to participate in this study. They were all classified as Grade I according to the ranges of body mass index or Quetelet's index (QI = Wt/Ht², Grade I corresponds to 25.0-29.9) (Garrow, 1981). The 16 women were categorized into either an experimental (E, n=10) group or a control (C, n=6) group. The age of Groups E and C averaged 20.7±1.4 years and 20.9±1.7 years, respectively. The subjects were fully informed of the nature of the experimental protocol and the aerobic conditioning plus energy restriction program. A complete medical check-up including family history, physical examination, and basic laboratory measurements was conducted prior to the initiation of the study. Statements of written informed consent were then obtained from each subject.

2. Aerobic Conditioning

The E group participated in a supervised aerobic conditioning program 4.2±1.3 d/wk for 50 to 60 min each session. The program included a 5-min calisthenic warm-up; 40 to 50 min of continuous cycling between a heart rate (HR) corresponding to LT and the HR that was approximately 20 b/min above the HRLT; and a 5-min cool-down including walking and stretching. On the average, the subjects trained for a period of 15.2±1.8 weeks. This program was considered ideal as the major component of a weight-loss exercise regimen, since extra energy of 250-400 kcal was expected to be expended per session. The HR was continuously determined in all phases of the program in order to get accurate estimates of the exercise intensity. None of the
subjects had previously been prescribed medications. Breathing pattern and perceived exertion (Borg 6-20 scale) were periodically monitored as sensitive training indicators. The intensity of cycling exercise was gradually increased from the beginning to the end of the study on the basis of changes in exercise HR at the individual LT.

3. Energy Restriction

Subjects completed a three-day dietary record that they considered representative of their own average intake. The subjects were given oral and written instructions and a sample dietary record to enable them to be as explicit as possible with regard to quantities, the manner of food preparation, and brand names. Details regarding the diet instructions are published elsewhere (Tanaka et al., 1986a).

All subjects in the E group were advised to initiate attempts at energy restriction of 25 kcal/kg/d that corresponded to approximately 1500-1700 kcal/d, since these women had consumed an average of 1948±205 kcal/d prior to this study. The subjects were also required to attend a 10- to 15-min diet meeting once a week after the exercise program during which body weight and/or skinfold thickness were individually measured and their progress was discussed. Also included in the meeting were detailed instructions on the selection of relatively low energy foods, on the avoidance of high energy foods, on the restriction of palatable foods, on the prevention of exercise-induced (or iron-deficient) anemia, and/or on the consumption of necessary quantities of vitamins, minerals and protein. The control group did not alter their daily dietary patterns nor the sedentary lifestyle.

4. Assessment of Body Composition

Body composition and anthropometric characteristics were assessed by measurement of stature (Ht), weight (Wt), skinfold thickness, and body density (Db) before the onset of exercise training. Subcutaneous skinfold fat measurements at the triceps, subscapular and abdominal sites were made using an Eiken skinfold caliper with a jaw pressure of approximately 10g/mm².

Db was determined from underwater weighing in a stainless steel tank in which a swing seat was vertically suspended from a strain guage system (Tanaka et al., 1989b; Nakadomo et al., 1990). Wt under the water was measured consistently in the fasting state. Residual volume was measured prior to the measurement of underwater weight by a closed-circuit helium-dilution technique. Percentage of body fat (%BF) was derived from Db (Brozek et al., 1963), %BF = (4.570/Db−4.142)100.

5. Assessment of Lactate Threshold and Maximal Aerobic Capacity

Submaximal aerobic capacity of the subjects was evaluated by the oxygen uptake corresponding to lactate threshold (\(\dot{V}O_{2LT}\)) and maximal aerobic capacity by the maximal oxygen uptake (\(\dot{V}O_{2max}\)). Both \(\dot{V}O_{2LT}\) and \(\dot{V}O_{2max}\) were measured by a cycling exercise test on a Monark cycle ergometer. Following 4 min of unloaded warm-up cycling at 60 revolutions per minute, a work load of 15 watts was administered and thereafter increased 15 watts every minute until the subjects could no longer turn the pedals at the prescribed cadence. All metabolic measurements of expiratory gases were determined by standard techniques of open-circuit spirometry with Mijnhardt Oxycon System (Tanaka et al., 1986b).

The LT was defined conceptually as the point at which the rate of La production and diffusion exceeded the rate of its removal, and was detected as the point in exercise of increasing intensity at which La concentration abruptly increased in a non-linear (disproportionately high) fashion. For discerning the point at which the increase of La concentration became non-linear, the log-log transformation method was used (Beaver et al., 1985).

A series of blood samples for determination of blood lactate concentration (La) were drawn from
the antecubital vein every minute during exercise. The La determination was performed by the enzymatic-electrode method with an Omron-Toyobo lactate analyzer (Nakadomo et al., 1985).

6. Analysis of Serum Lipids, Serum Iron, and Hematological Variables

Blood samples of approximately 7 ml were drawn from each subject in the morning after an overnight fast of at least 12 hours. Serum was then separated for determination of triglycerides (TG) (Fossati and Prencipe, 1982), cholesterol (CHOL) (Allain et al., 1974), and high-density lipoprotein cholesterol (HDLC) (Nomura et al., 1979). Low-density lipoprotein cholesterol (LDLC) was calculated as LDLC = CHOL - HDLC - TG/5 (Friedewald et al., 1972). Serum total iron concentration (TI) and total iron-binding capacity (TIBC) were assayed using a colorimetric technique (Carter, 1971). Hematological variables such as red blood cell count (RBC), hemoglobin concentration (Hb), and hematocrit (Hct) were determined by Coulter counter (S-Plus II).

7. Data Analysis

Data analyses included the t-test for paired data and the product-moment correlation test. Significant differences and significant correlations were only accepted when P values were less than 0.05. Values are expressed as mean and standard deviation (SD).

RESULTS

Following the aerobic conditioning plus energy restriction program, the mean Wt and %BF in the E group decreased significantly from 64.6 to 60.2 kg and 33.5 to 29.1%, a 6.8% and a 13.1% decrease respectively from baseline. Accordingly, absolute fat weight and Katsura index fell significantly in this group. Fat free weight (FFW), the difference between Wt and fat weight remained essentially unchanged (Table 1).

Mean VO₂LT and VO₂max values in the E group at the end of the program were 22.1 and 36.2 ml/kg/min respectively, a 22.1% and a 13.1% increase from baseline. Likewise, VE₇₅ and VE₇兮 values increased significantly from the pre- to post-program, while HR values at the occurrence of LT and at exhaustion remained unchanged (Table 2).

The E group participants also demonstrated a significant reduction in TG (18.8%) and a significant rise in HDLC/CHOL (9.5%). Hematological and iron status did not change significantly following the program (Table 3). In the C group, none of the variables tested in this study changed significantly.

The relationships between alterations in aerobic capacity, anthropometric and body composition characteristics, and serum lipid and lipoprotein profiles were also investigated in the E group. However, none of the relationships were significant, indicating exercise- and/or diet-induced alterations in these variables occurred independently.

| Table 1 Effects of cycling exercise plus energy restriction on anthropometric and body composition characteristics |
|--------------------------------------------------|------------------|------------------|------------------|------------------|
|                     | Group E | Group C |                     | Group E | Group C |                     |
|                     | Pre     | Post    | Pre     | Post     | Pre     | Post    |                     |
| Height, cm          | 157.4±4.0| 157.5±4.0| 155.8±3.8| 155.7±3.7|                     |
| Weight, kg          | 64.6±3.8| 60.2±3.6*| 62.7±4.3| 62.8±4.7|                     |
| Katsura Index        | 125.1±4.9| 116.4±5.2*| 125.0±3.9| 125.2±4.2|                     |
| Body Fat, %          | 33.5±3.2| 29.1±3.4*| 33.3±1.8| 33.2±2.1|                     |
| Body Fat, kg         | 21.7±3.0| 17.5±3.1*| 20.9±1.9| 20.8±2.2|                     |
| Fat Free Weight, kg  | 42.9±2.8| 42.7±3.0| 41.8±3.0| 42.0±3.2|                     |

*Significant difference in paired t-test between pre and post mean values

Katsura Index (a modified Broca Index) was calculated as \( Wt/((Ht-100)/0.9) \).
Table 2  Effects of cycling exercise plus energy restriction on submaximal and maximal aerobic capacities

<table>
<thead>
<tr>
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<th>Group E</th>
<th>Group C</th>
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<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>lactate threshold</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VO₂LT, ml/kg/min</td>
<td>18.1±3.5</td>
<td>22.1±4.1*</td>
</tr>
<tr>
<td>VELT, l/min</td>
<td>25.7±4.2</td>
<td>31.4±4.0*</td>
</tr>
<tr>
<td>HRLT, b/min</td>
<td>124.6±13.5</td>
<td>128.3±11.9</td>
</tr>
<tr>
<td>maximal value</td>
<td></td>
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<tr>
<td>VO₂max, ml/kg/min</td>
<td>32.0±4.4</td>
<td>36.2±4.3*</td>
</tr>
<tr>
<td>VEmax, l/min</td>
<td>65.3±12.4</td>
<td>76.0±9.6*</td>
</tr>
<tr>
<td>HRmax, b/min</td>
<td>188.5±9.2</td>
<td>187.6±9.0</td>
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</tbody>
</table>

*Significant difference in paired t-test between pre and post mean values

Table 3  Effects of cycling exercise plus energy restriction on blood lipids and hematological variables

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<thead>
<tr>
<th></th>
<th>Group E</th>
<th>Group C</th>
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<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>TG, mg/dl</td>
<td>89.7±34.0</td>
<td>72.8±23.7*</td>
</tr>
<tr>
<td>CHOL, mg/dl</td>
<td>186.8±32.5</td>
<td>180.3±27.9</td>
</tr>
<tr>
<td>HDLC, mg/dl</td>
<td>57.6±11.8</td>
<td>60.4±10.3</td>
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<tr>
<td>LDLC, mg/dl</td>
<td>108.3±36.4</td>
<td>103.5±33.0</td>
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<tr>
<td>HDLC/CHOL</td>
<td>0.31±0.07</td>
<td>0.34±0.07*</td>
</tr>
<tr>
<td>TI, ug/dl</td>
<td>112.6±20.6</td>
<td>114.9±22.1</td>
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<tr>
<td>TIBI, ug/dl</td>
<td>285.2±42.6</td>
<td>290.5±45.3</td>
</tr>
<tr>
<td>RBC, x 10^6/ul</td>
<td>4.33±0.23</td>
<td>4.31±0.20</td>
</tr>
<tr>
<td>Hb, g/dl</td>
<td>12.9±0.7</td>
<td>12.9±0.5</td>
</tr>
<tr>
<td>Hct, %</td>
<td>39.1±1.8</td>
<td>39.0±1.7</td>
</tr>
</tbody>
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*Significant difference in paired t-test between pre and post mean values

DISCUSSION

Cardiovascular diseases constitute the leading cause of deaths in highly industrialized nations, accounting for 1/3 to 1/2 of the total annual mortality in each nation. The prevalence of cardiovascular diseases is more frequently associated with excess body fat and elevated lipid and lipoproteins. Although cardiovascular diseases are commonly found among middle-aged and older persons, their origins begin in childhood (Kannel and Dawber, 1972). Recent epidemiologic surveys indicate the increasing incidence of this disease even in young people (Kannel and Dawber, 1972; Keys, 1975; Tanaka et al., 1981). Since obesity can be a precipitating factor of cardiovascular diseases, treatment for this attribute in early life can be of great importance. Unfortunately, there does not appear to be a universally standardized or accepted course of treatment for obese individuals.

In this study, we attempted to determine the effects of an aerobic conditioning plus energy restriction program on obesity of college-age females. Analyses of data showed the 4.2-d/wk (± 1.3) cycling training plus energy restriction (about 25 kcal/kg/d) program over a 15-wk period induced a 22.1% increase in VO₂LT, a 13.1% increase in VO₂max, a 9.5% elevation in HDLC/CHOL, a 18.8% reduction in TG, and a 19.4% loss in body fat; while FFW and hematological variables such as RBC, Hb, and Hct remained essentially unaltered. Most of the above effects found in this study are in accordance with previous studies (Dudlestone and Bennion, 1970; McMurray et al., 1986; Tanaka et al., 1986a; Tanaka et al., 1989b; Weltman et al., 1980) in which middle-aged individuals or those who were older than the present subjects were examined. Thus, it is of some interest that the profound effects of our aerobic conditioning plus energy restriction pro-
gram can be observed even among younger women. The desirable effects obtained in this study may be attributed to the continuation of physical training over an extended period of time and to an appropriate amount of protein intake during the program. In fact, analysis of the 3-d dietary records indicated that, in the E group, the amount of dietary protein intake was increased from 0.9±0.2 to 1.3±0.3 g/kg/d, despite the fact that the amount of dietary cholesterol and fat were altered from 355 g and 72 g to 294 g and 63 g, respectively. We suggest that aerobic capacity, body composition, and serum lipid and lipoprotein profiles can all change favorably, provided that aerobic conditioning is of sufficient intensity to increase the HR to the level at or slightly above LT and coincidently that energy intake is slightly or moderately restricted to approximately 25 kcal/kg/d.

Our findings indicate obese or overweight girls can be treated in a school setting without experiencing severe hunger pangs and physical exhaustion, the latter of which is usually associated with high-intensity exercise. While heredity, race, gender, and age are factors associated with cardiovascular disease and cannot be controlled, other factors such as obesity, physical inactivity, and lipid and lipoprotein profiles can be relatively easily altered at any age level. However, the feasibility of treating a number of inactive, obese or overweight girls with various medical and/or psychological problems in a school setting should be a significant matter in future research.

CONCLUSION

The recent upsurge in attention to the potential health benefits of increased physical activity in conjunction with sound dietary intake has been accompanied by a growing body of research evidence that generally supports a beneficial role for exercise plus diet in maintaining wellness or well-being. Following a unique program that combines aerobics-type physical activity and restriction in energy intake, remarkable effects can be expected to occur. We actually demonstrated the feasibility of treating obesity among college-age students, which may lead to an earlier onset of various manifestations of cardiovascular diseases. The program has the great advantage of allowing the individual to avoid suffering from severe hunger pangs and physical exhaustion. It is suggested that the unique aerobic conditioning (4–5 d/wk on the average) plus energy restriction (~25 kcal/kg/d diet) program offered in this study should be prescribed to obese individuals, over an extended period of time, in order to give optimal health-related benefits.

REFERENCES


Effects of Exercise at Lactate Threshold Intensity


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