Effects of Exercise Training at an Intensity Relative to Lactate Threshold in Mildly Obese Women

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To determine the effects of exercise training on the anthropometric and physiologic characteristics, twenty-eight mildly obese women were studied prior to and following a 14-week exercise training program. The present data demonstrated that regular aerobic training at an intensity corresponding to lactate threshold (LT) led to significant improvements in $\dot{V}O_2\text{max}$ (12%) and $\dot{V}O_2\text{LT}$ (16%) and significant reductions in systolic (5%) and diastolic blood pressure (9%). Weight (5%) and percent body fat (11%) decreased significantly, while LBM remained essentially unchanged. Although the change in HDLC and HDLC/TC did not reach statistical significance, the TC (8%) and LDLC (7%) decreased significantly. These alterations in cardiorespiratory, anthropometric, and metabolic characteristics clearly demonstrate that training intensity relative to LT may be appropriate for obese individuals to improve the aerobic capacity, lipid-lipoprotein metabolism, and anthropometric profile.

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Key words : Lactate threshold, $\dot{V}O_2\text{max}$, Obesity, Exercise training

It appears that obesity is to a large extent the result of reduced physical activity with a maintenance of an 'old-fashioned' appetite set for an energy expenditure well above the one typical for a sedentary individual. Overweight middle-aged women generally exhibit low levels of habitual physical activity and physical work capacity when compared to their normal-weight counterparts. Recently the possibility that habitual exercise may play an important role in the prevention or treatment of coronary heart disease (CHD) and obesity has led to a greater interest in the effects of increased physical activity in sedentary middle-aged individuals. The health-related benefits brought about by habitual physical activity are associated not only with energy turnover, modification of metabolic pathways, and improvement of physical condition but also with the facilitation of weight

reduction and loss of excess body fat plus possible reduction in susceptibility to chronic disease (Buskirk, 1986).

Previous studies suggested that serum TG and LDLC significantly decreased and HDLC significantly increased following endurance exercise training at an intensity of 70% to 85% of $\dot{V}O_2\text{max}$ (Holloszy et al., 1964; Carlson and Mossfeldt, 1964; Farrell and Barboriaka, 1980). However, for many middle-aged obese individuals, the relatively intensive exercise training may be uncomfortable and often leads to various musculoskeletal injuries. The data of Bouchard et al.'s study (1990) indicate that prolonged exercise of moderate intensity (50% of $\dot{V}O_2\text{max}$) is capable of inducing some of the known adaptations of exercise training such as a decrease in blood La concentration at a given exercise intensity and an increase in skeletal muscle oxidative capacity. It has been suggested that improvements

in lactate threshold (LT) or onset of blood lactate accumulation (OBLA) may be more important than elevating $\dot{V}O_2$ max for enhancing endurance performance (Yoshida et al., 1982; Henritze et al., 1985). For these reasons, previous investigations have suggested that $\dot{V}O_2$ or work rate corresponding to anaerobic threshold (AT) or LT could be used not only as the single best determinant of endurance performance (Tanaka and Matsuura, 1984) but also as a possible index of optimal exercise intensity as compared with $\% \dot{V}O_2$ max or HR (Kindermann et al., 1979; Tanaka et al., 1986; Kim et al., 1990). Schnabel et al. (1982) and Simon et al. (1983) also recommend the AT or LT as a better reference point to base submaximal exercise intensities and exercise prescription. However, there are few studies about the effects of endurance training relative to LT level intensity in obese women. The purpose of this study was therefore to determine the effects of aerobic exercise training at the LT level intensity on the cardiorespiratory, serum lipid and lipoprotein, anthropometric, and body composition characteristics in mildly obese women.

METHODS

Subjects. The mean age ($\pm$ standard deviation) on 28 healthy women upon entry into the study was 40.7 ± 10.7 years. The height of subjects averaged 154.1 ± 4.6 cm. The subjects were all mildly obese, with indirectly estimated body fat (BF) being 25-40%. Following a complete medical history, physical examination, and basic laboratory studies that were conducted prior to the onset of the study, only those subjects found to be free of severe clinical problems other than obesity, hypertension, and hypercholesterolemia were admitted to participate in the exercise program. Eighteen women were classified as the exercise (Ex) group. Statements of informed consent were obtained from the subjects prior to initiation of the study, after being fully informed of the nature of the experimental protocol and the exercise program. Ten women served as the control

(C) group.

Exercise Program. The training program consisted of two or three exercise sessions (50 to 60 min each) per week for 14 consecutive weeks. Exercise program was similar to that previously presented by Tanaka et al. (1989). The continuous jogging/cycling activities were considered ideal as the major component of a weight-loss exercise program. The cycling exercise was done with the use of a stationary cycling device. Subjects monitored their training HR during the steady-state exercise and adjusted the intensity accordingly. Exercise HR was telemetrically determined in all phases of the program in order to get accurate estimates of the training intensity. The intensity of jogging/cycling in the supervised program was gradually increased from the beginning to the end of the study. Additionally, all subjects in the Ex group performed unsupervised, self-controlled aerobic activities (jogging, running, walking, swimming, and/or dancing) that activate a relatively large muscle mass at least 1 d/wk and a maximum of 4 d/wk for 20-60 min each session. The self-controlled training was individualized to the specific needs and certain limitations of the subjects. On the average, the subjects trained 4.3 ± 1.2 d/wk as a whole for a period of 14 ± 2 weeks. Control group was kept at a normal activity for the same period.

Measurement of Body Composition and Aerobic Capacity. Body composition and anthropometric measures included stature, body weight (BW), triceps skinfold, subscapular skinfold, body density (Nagamine and Suzuki, 1964), and percentage of BF ($\%BF = 4.570/Db - 4.142$, where Db = body density, Brozek et al., 1963). The details of measurement of both $\dot{V}O_{2LT}$ and $\dot{V}O_{2max}$ have been described elsewhere (Tanaka et al., 1989; Kim et al., 1990).

Blood Analyses. Blood samples of 10 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), cholesterol (TC), and high-density lipoprotein cho-

lesterol (HDL). Red blood cell count (RBC), hemoglobin concentration (Hb), and hematocrit (Hct) were also determined. Low-density lipoprotein cholesterol (LDLC) was calculated from $TC - HDLC - TG/5$. The details of the analysis have been described previously (Tanaka et al., 1989).

Data Treatment. Statistical analyses included the Student's t-test for paired data and the Pearson product-moment correlation. Significant differences and significant correlations were only accepted when p values were less than 0.05. Values are expressed as mean $\pm$ SD.

RESULT

The effects of physical training on anthropometric and body composition variables are shown in Table 1. The relative and absolute fat losses and reductions in selected anthropometric variables such as BW and body mass index were observed ($p < 0.05$) for the Ex group, while no changes occurred in any of the variables for the C group (Table 2). Since the LBM remained unchanged, the decrement in BW was entirely attributed to the drop of BF.

The results of $\dot{V}O_{2\max}$, $\dot{V}O_{2LT}$, HRmax, and resting blood pressure are also shown in Tables 1 and 2. Except for HRmax, all of the variables changed significantly from pre- to post-training in the Ex group. In the C group, none of the variables changed significantly. The mean decreases from pre- to post-training in the Ex group were 8% for the TC, 14% for the TG, and 7% for the LDLC. The mean post-training levels of TC and LDLC in the Ex group were significantly lower than the mean pre-training levels. These altered serum lipid and lipoprotein values were not significantly related to the decrease in relative BF ($r = .140$ for TC, $.287$ for LDLC, and $.365$ for TG). The Ex group means of pre-training and post-training HDLC levels did not differ significantly. Since the ratio of HDLC to TC has been proposed as an important predictor of CHD, we assessed the ratio as well. Eleven subjects

demonstrated an increase in the ratio of HDLC to TC, whereas seven subjects showed a decrease. The differences in the means were not statistically significant. The changes in both FFA and BG concentration were insignificant for both groups. All hematological variables remained unchanged for

Table 1 Descriptive statistics in selected variables for exercise group.

Variable	Pre-training	Post-training
Height, cm	154.1 $\pm$ 4.6	154.2 $\pm$ 4.6
Body weight, kg	64.7 $\pm$ 5.6	61.4 $\pm$ 5.2*
Body Mass Index	26.9 $\pm$ 1.3	25.5 $\pm$ 1.2*
Katsura Index	131.1 $\pm$ 6.8	124.3 $\pm$ 6.5*
Skinfolds, mm		
Triceps	24.8 $\pm$ 5.1	22.7 $\pm$ 4.7*
Subscapular	29.6 $\pm$ 8.0	25.6 $\pm$ 6.6*
Body fat, %	36.0 $\pm$ 5.0	32.0 $\pm$ 4.6*
Body fat, kg	23.8 $\pm$ 4.5	19.8 $\pm$ 3.7*
Lean Body Mass, kg	41.3 $\pm$ 3.8	41.7 $\pm$ 3.5
$\dot{V}O_{2LT}$, ml/kg/min	13.7 $\pm$ 1.6	15.9 $\pm$ 2.0*
$\dot{V}O_{2\max}$, ml/kg/min	25.3 $\pm$ 3.4	28.3 $\pm$ 3.1*
HRmax, b/min	173.2 $\pm$ 11.5	172.9 $\pm$ 9.5
SBP, mmHg	127.4 $\pm$ 13.5	120.6 $\pm$ 11.5*
DBP, mmHg	77.3 $\pm$ 10.0	70.2 $\pm$ 8.2*
TC, mg/dl	199.5 $\pm$ 31.4	183.1 $\pm$ 29.7*
TG, mg/dl	98.8 $\pm$ 48.5	84.7 $\pm$ 32.2
HDL, mg/dl	56.8 $\pm$ 10.6	56.8 $\pm$ 9.3
LDLC, mg/dl	118.3 $\pm$ 32.4	110.0 $\pm$ 26.5*
HDL/TC, %	29.4 $\pm$ 6.8	31.4 $\pm$ 6.0
HDL/LDLC, %	46.6 $\pm$ 19.9	47.0 $\pm$ 20.0
FFA, μ Eq/ml	818.3 $\pm$ 373.2	935.0 $\pm$ 263.5
BG, mg/dl	79.6 $\pm$ 10.9	75.4 $\pm$ 10.2
WBC	4688 $\pm$ 134	4765 $\pm$ 87
RBC, $\times 10,000$	404 $\pm$ 36	419 $\pm$ 34
Hb, g/dl	12.2 $\pm$ 1.1	12.7 $\pm$ 0.8
Hct, %	36.0 $\pm$ 4.0	38.1 $\pm$ 2.5
Grip strength, kg		
Right	31.3 $\pm$ 5.1	31.5 $\pm$ 4.5
Left	29.8 $\pm$ 5.8	29.5 $\pm$ 5.8
Back strength, kg	96.9 $\pm$ 21.0	94.8 $\pm$ 20.2
Trunk flexion, cm	11.8 $\pm$ 7.7	13.1 $\pm$ 7.2*
Trunk extension, cm	38.1 $\pm$ 7.0	41.6 $\pm$ 8.0*
Vertical jump, cm	27.6 $\pm$ 6.1	30.2 $\pm$ 5.7*
Side step, step/20 sec	30.9 $\pm$ 5.7	34.5 $\pm$ 4.6*

Values are mean $\pm$ SD

*Significantly different from the pre-training ($p < 0.05$).

Table 2 Descriptive statistics in selected variables for control group.

Variable	Pre-training	Post-training
Height, cm	152.9±2.5	152.8±2.8
Body weight, kg	60.4±3.6	60.4±3.6
Body Mass Index	25.8±1.4	25.8±1.5
Katsura Index	127.0±7.3	127.0±8.1
Skinfolds, mm		
Triceps	23.0±3.9	23.0±4.1
Subscapular	28.3±7.3	28.4±7.6
Body fat, %	33.9±6.8	34.0±6.8
Body fat, kg	20.6±4.9	20.6±4.8
Lean Body Mass, kg	40.0±3.8	39.9±4.0
$\dot{V}O_2$ LT, ml/kg/min	14.9±2.8	14.9±2.3
$\dot{V}O_2$ max, ml/kg/min	26.5±6.8	26.3±6.1
HRmax, b/min	172.8±30.5	172.7±29.5
SBP, mmHg	125.4±21.2	123.7±21.0
DBP, mmHg	78.7±12.0	77.0±10.6
TC, mg/dl	196.3±22.4	193.4±20.6
TG, mg/dl	99.4±34.2	98.0±35.5
HDLc, mg/dl	57.8±15.7	58.8±16.8
LDLc, mg/dl	119.1±25.0	114.9±26.5
HDLc/TC, %	30.0±9.4	30.8±9.5
HDLc/LDLc, %	52.3±22.7	47.0±24.7
FFA, uEq/ml	793.2±352.0	837.2±249.0
BG, mg/dl	84.0±8.3	84.6±6.9
WBC	4767.0±200.0	4600.0±100.0
RBC, ×10,000	427.0±53.0	428.0±41.0
Hb, g/dl	12.3±2.6	12.5±1.9
Hct, %	36.7±6.4	37.9±6.5
Grip strength, kg		
Right	31.0±3.1	30.4±3.6
Left	29.1±3.8	29.5±3.4
Back strength, kg	90.6±15.2	88.9±16.3
Trunk flexion, cm	10.0±8.9	11.5±11.5
Trunk extension, cm	35.1±7.6	34.6±6.9
Vertical jump, cm	29.3±7.9	29.6±7.4
Side step, step/20 sec	31.3±8.1	31.3±8.9

Values are mean ± SD

both Ex and C groups (Tables 1 and 2).

DISCUSSION

Eighteen mildly obese women participated in a controlled, supervised training program that improved the anthropometric, lipid, and physical fitness profile including aerobic work capacity. Previ-

ous investigators (Girandola, 1976; Smith and Stransky, 1976) suggested that, in the absence of adequate dietary control, reductions in BW and/or %BF may not be a consistent result, even in the presence of improved cardiorespiratory endurance. However, the present investigation was able to demonstrate alterations in both BW and absolute and relative BF following the 14-wk training relative to the LT intensity (Table 1). The finding that the weight loss was almost entirely attributed to the reduction in fat mass is interesting.

One of the adaptations in muscle induced by endurance exercise may be increased fat utilization during submaximal exercise. The relative exercise intensity determines to what extent energy can be mainly supplied from carbohydrate or fat. It was found that increasingly more energy was derived from fat combustion during endurance exercise at relative intensities < 65-70% of $\dot{V}O_2$ max but no fat adaptation was seen at intensities > 75% of $\dot{V}O_2$ max (Christensen and Hansen, 1939; Pruett, 1970). In addition, the respiratory exchange ratio after light intensity training was significantly lower than after high intensity training (Seals et al., 1984), reflecting a shift in substrate utilization towards an increased use of fat. These metabolic adaptations of muscle to endurance exercise could enhance the ability to exercise at a higher percent of $\dot{V}O_2$ max in the trained state, by slowing glycogen depletion and reducing La accumulation (i. e., raising LT). To our knowledge, no information is available concerning the effect of training on the rate of intramuscular lipid utilization during exercise, but we could predict on the basis of the above previous findings, that the trained individual obtains a greater proportion of her energy requirement during training program from intramuscular lipid stores. From these reasons, moderate intensity training at LT corresponding to 52% of $\dot{V}O_2$ max might be efficient for the mobilization and release of fat.

The present study shows that relatively low intensity (52% $\dot{V}O_2$ max) training lasting 14 wk causes a

significant increase in both $\dot{V}O_{2\max}$ and $\dot{V}O_{2LT}$ by an average of 11.9% and 16.1% respectively. It is of interest that, although the training intensity was moderate, the increase in both $\dot{V}O_{2\max}$ and $\dot{V}O_{2LT}$ was significant ($p < 0.05$) (Fig. 1). This increase in aerobic capacity as a response to training was similar (or even greater) to that described by other authors under comparable conditions (Rowell, 1974; Tanaka et al., 1986).

Fig 1 Effect of physical conditioning on the $\dot{V}O_{2LT}$ and $\dot{V}O_{2\max}$.

Recent studies (Denis et al., 1982; Henritze et al., 1985; Tanaka et al., 1986) have reported greater relative changes in La-related variables as compared with changes in $\dot{V}O_{2\max}$ as a result of endurance training. It is well established that regularly performed endurance-type training will induce significant adaptations at the systemic as well as at the muscle cell level. An alternative explanation for the improvement in LT with training involves an improved metabolic efficiency in the exercising muscles associated with a greater oxygen extraction from arterial blood (Saltin et al., 1986). Orlander et al. (1977) have reported a positive relationship between %ST and the increase in $\dot{V}O_{2\max}$ observed in sedentary men after 7 wk of low intensity training. The present data suggest that the significant increase in aerobic work capacity could be achieved

Fig 2 Relationship between $\dot{V}O_{2LT}$ and $\dot{V}O_{2\max}$ values before and after physical conditioning.

even by the low-intensity conditioning relative to LT.

It has been known that the correlation between $\dot{V}O_{2\max}$ and $\dot{V}O_{2LT}$ is relatively high (Davis et al., 1979). Of interest is the finding that the correlation ($r = 0.490$) between $\dot{V}O_{2\max}$ and LT at the post-training was much smaller than the correlation at the pre-training ($r = 0.801$) (Fig. 2). This finding would provide further support for the concept that the metabolic responses to LT and $\dot{V}O_{2\max}$ are to some degree dependent on different physiological mechanisms. In other words, the peripheral factors such as capillary density or enzyme activities of skeletal muscles may determine the submaximal La response, while $\dot{V}O_{2\max}$ is preferentially related to and limited by the central circulation. LT measured during submaximal exercise seems to be more sensitive to endurance training-induced adaptations than $\dot{V}O_{2\max}$.

In addition, other physical fitness elements of previously sedentary obese women were improved following the regular aerobic exercise program

(Table 1). Results from the present investigation indicate there were significant improvements on flexibility and jumping power, but not on static muscle strength. The insignificant grip and back strength changes in both Ex and C groups may be that strength is maintained somewhat equally for both groups due to participation in normal household chores or other activities of daily living which involve use of the hands and wrists.

It is well documented that an extended period of aerobic training results in the improvement in lipid and lipoprotein profiles. TG tended to decrease from the pre- to post-training. In a group of men trained by cycling exercise, the capacity of quadriceps muscle to incorporate fatty acids into TG was increased (Morgan et al., 1971). The present data could not confirm the possibility that the lower TG after physical training may come from the decreased weight reduction. Similarly, there were no relationship between the reduction in BW and the changes in other lipoprotein variables. Lewis et al. (1976) suggested that when plasma TG values were within the normal range they were not lowered by BW reduction resulting from increased physical activity and/or caloric restriction.

Although an alteration in the post training HDLC levels was not significant, the change in both TC and LDLC was statistically significant ($p < 0.05$). The study by Thompson et al. (1980) reported an increase in HDLC with 14 wk of exercise training programs in initially sedentary people ($p < 0.05$), while Moll et al. (1979) found no change in HDLC levels in a group of women who exercised for 6 wk, despite improved aerobic capacity. These conflicting results may be explained by a difference in the degree of obesity and the threshold intensity, duration and frequency of exercise required to change plasma lipid and lipoprotein levels. Intensity and/or duration of the training prescribed in the present study might have not been enough to induce marked changes in HDLC. One of the other factors which may have contributed to the lack of change in

HDLC may be the sex difference. Women have higher levels of HDLC than their male counterparts (Gordon et al., 1977), and sedentary women are more resistant to the effect of exercise on HDLC than men due to higher initial HDLC concentrations.

In summary, our findings indicate that the adaptations necessary to produce the attenuated La response can be elicited even by moderate intensity (i. e., LT level) conditioning. The moderate intensity prolonged exercise corresponding to LT level also resulted in decreases in TC and LDLC. Although the change in HDLC was not significant, the most important functional response to exercise conditioning was a significant increase in aerobic work capacity accompanying with an improvement in the anthropometric profile.

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