The Effects of Exercise on Blood Cholesterol in Middle-aged Men

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RECENT research suggests a relationship between high blood cholesterol and early onset of atherosclerosis.[1-5] The specific factors which control blood serum concentrations of cholesterol have been reviewed elsewhere.[2,4,6] Most of the investigations to date have been in the area of dietary control. This approach appears promising, but limitations are already evident. Apparently there has been little study of the role of physical exercise in the regulation of blood cholesterol concentrations.

REVIEW OF PREVIOUS STUDIES

Chailley-Bert and co-workers[7] studied the concentrations of blood cholesterol immediately before and after exercise. An increase in blood cholesterol following exercise was observed for 5 subjects and no change in blood cholesterol with exercise for 1 subject. The authors concluded that the increased concentration of cholesterol in blood serum following exercise may have been associated with the first steps in the metabolism of cholesterol. Evidence that cholesterol is eliminated by the skin and the lungs was discussed. The conclusion was drawn that exercise may increase cholesterol metabolism by stimulating endocrine gland activity, hence increasing perspiration and respiration. Thus there may be an eventual lowering of the pre-exercise cholesterol level.

The authors also compared 10 sedentary subjects in middle age with 7 active subjects of approximately the same age. The active group had lower blood serum cholesterol values. The difference between the two groups was quite large. Although no statistical analysis was made, it appeared that the difference would be significant. In another part of the study, three sedentary middle-aged workers (two females and one male), whose blood cholesterol was reasonably high, were placed on a conditioning program consisting of daily 5 km walks and exercises involving rapid and deep respiration or cycling. After the conditioning program, the blood cholesterols were appreciably lower in all three subjects. The period of conditioning was six months in one case, two months in the second, and four months in the third case.

Mann[8] reported the results of a study of 3 subjects. Doubling the calorie supply had no effect on serum lipids as long as the excess of energy was dissipated through exercise. When exercise was restricted and fat deposition occurred, the serum cholesterol concentrations were doubled. Weight reduction by food restriction promptly returned the serum elevations to their original values. Both of these studies, although limited, indicate that a pro-

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gram of exercise tends to lower blood cholesterol values.

On the other hand, Keys and co-workers[3] failed to find that physical activity per se was related to differences in blood serum cholesterol of various population groups. They also found no effect of exercise on blood cholesterol in nine young men who were in caloric balance.[9]

Animal work points to a reduction of total blood cholesterol with exercise. Although Wong, Simmons, and Hawthorne[10] observed no reduction in blood cholesterol when cholesterol-fed chicks were exercised, the experiment was complicated by the administration of testosterone propionate to the cockerels. In a later experiment[11] when androgen treatment was omitted, exercise was effective in reducing blood cholesterol levels of chicks on a high cholesterol diet. Brown and co-workers[12] also reported a reduction in serum cholesterol by exercising cholesterol-fed rabbits daily.

PROCEDURE

The subjects were 31 adult males who were members of the Michigan State University faculty. They were divided into a control group and an exercise group. The control group was composed of 15 subjects who followed their customary routine of activity throughout the experiment. There were 16 men in the exercise group. These subjects were given supervised exercise for a period of three months. Four of the exercise subjects continued participation for a period of six months. For statistical calculations, these 4 subjects (hereafter referred to as the select group) are also included in the general exercise group.

A sample of venous blood was taken from the antecubital vein in the early morning when the subject was in a postabsorptive state. This was repeated twice more at weekly intervals at the beginning and again at the end of the experiment. Serum was separated from the cells by centrifugation.

Free and total cholesterol were determined by the procedure of Schoenheimer and Sperry[13] as modified by Sperry[14] and Foldes and Wilson.[15] The initial total blood serum cholesterol for each subject was compared with the mean values for men of similar age according to the frequency distribution reported by Keys.[16] If the serum cholesterol for an individual subject was greater than the mean plus one standard deviation for men of comparable age, the subject was considered to have a "high" blood serum cholesterol. Five of the 31 subjects were judged in this manner to have elevated blood serum cholesterol concentrations.

It was possible to record resting electrocardiograms before and after the three-month experimental period on eight of the exercise and seven control subjects. All records were obtained on a Model 77, four-channel Sanborn direct-writing recorder by the same operator. Three leads were taken simultaneously in the following order: three standard leads; three aV leads; V_1, V_2, and V_3; and finally V_4, V_5, and V_6. Respiration was recorded on the fourth channel throughout. All records were studied by a cardiologist* and individual written reports for each record of each individual were made by him. These analyses included P-R, QRS, axis deviation, rhythm, and Bazzet's index, plus a general interpretation.

In addition, a statistical analysis was made of the following measurements: pulse rate, P-R interval, QRS duration, Q-T interval, QRS and T frontal-plane vectors (amplitude and direction), amplitude and direction of frontal-plane ventricular gradients and angle between the spacial QRS and T vectors. The latter employed the method of Langner.[17]

All electrocardiogram measurements were made according to the recommendations of the original Committee of the American Heart Association and the Cardiac Society of Great Britain and Ireland and the most recent report of the Committee of the American Heart Association for the standardization of precordial leads.

Each subject in the experiment was given a medical examination by a physician† of the University Health Service before being assigned to either the exercise or control group. If assigned to the control group, the subject was

* We are indebted to Dr. Robert Stow for this part of the work.

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asked to continue his activities as before, and, in every instance, this was a rather sedentary life with no moderate or vigorous exercise taken regularly.

This was based upon the results of the written questionnaire filled in by the subjects. Some of the subjects reported that they took considerable exercise during the summer months but during the rest of the year except for occasionally shoveling snow, no appreciable physical exercise was taken around the home on weekends or after working hours. Some of the subjects had hobbies but none of these involved vigorous physical activity. With one exception, the men all rode back and forth to work. No further records of their activities were maintained. Since the experiment was conducted during the winter and spring months, which in this part of the country affords little opportunity for outdoor work around the home, it was felt that these men changed their activities very little. However, the experiment would have been strengthened by maintaining records of physical activity other than the regularly supervised exercise.

If the subject was assigned to the exercise regimen, a program of activities was prescribed after consultation with the examining physician. The exercise program consisted of two phases: an individual program outlined to meet the specific needs of each subject and a general program in which all subjects followed a single exercise routine. However, the emphasis in the exercise phase of the study was placed on the supervised portion participated in by all subjects as soon as they were considered physically capable. At the start, all subjects were cautioned against all-out efforts in any of the exercises for several weeks. The program was a supervised noon-hour calisthenics-swimming class to which the subjects reported as often as possible Monday through Friday.*

Under supervision the group performed six calisthenic exercises for one minute each. The number executed during the one-minute period was recorded daily. Following the calisthenics the subjects swam in the pool. The number of laps which could be swum continuously was recorded daily. Most of the subjects had difficulty swimming more than two or three laps (25 yards per lap) at the beginning, whereas three months later they were routinely completing 20 to 30 laps. A record of attendance at the noon-hour supervised programs was kept for each subject, and the means and ranges in attendance are presented in Table I. There were days when circumstances prevented the subjects from reporting. These absences were included in computing the averages and, of course, resulted in lower means than would otherwise have been the case.

TABLE I

Frequency of Participation in Supervised Exercise Program

	General exercise group		
	First period: January–March	Second period: April–June	Select group: January–June
Number of subjects	7	9	4
Frequency per week			
Mean	2.70	2.58	2.56
Range	2.2–3.6	2.0–3.4	2.0–3.1

The exercise program employed in this study represents about what is possible in an ordinary routine. It would be difficult for the average man to maintain an exercise schedule of more than two or three one-hour exercise periods per week. No doubt greater conditioning would have been achieved if the men had been exercising more often, but such an artificial program would have indicated little of the effect of a practical exercise schedule. From the standpoint of medical considerations, it is also necessary to approach regular exercise moderately at first when dealing with middle-aged men who are used to a sedentary life.

RESULTS

Student's t distribution was employed in studying the changes in the various electrocardiogram measurements. The t's comparing the differences in the changes between the exercise and control groups ranged from -1.07 to $+1.73$, none of which was significant at a probability of 0.10 or less. None of the 5 high blood cholesterol subjects individually showed a significant change.

* One subject could not be present at the noon hour and a gymnasium-type program was carried on instead.

TABLE II

Changes in Total and Free Blood Serum Cholesterol in Normal Subjects

Group	No.	Age mean and (range)	Mean total blood cholesterol (mg/100 ml) Before	After	t^a	Mean free blood cholesterol (mg/100 ml) Before	After	t^a	Mean body weight change[b] (kg)
Exercise	13	43.1 (32–54)	189.5	187.1	0.20	63.0	58.1	0.91	−0.6
Control	13	40.5 (31–51)	194.6	196.6	−0.16	63.5	63.9	−0.08	−0.9
Select	4	42.8 (38–48)	175.3	173.6	0.06	57.9	55.8	0.16	−1.2

[a] None of these Student t's were significant at the 5% level.

[b] Number of subjects for weight change respectively: exercise, 12; control, 8; select, 4.

In the present study, there were no appreciable differences in blood serum cholesterol between the mean initial and final values in either the "normal" control group or the "normal" exercise group (see Table II). This was true also for the four "normal" subjects in the select group who were studied for a total period of six months.

When the difference between the exercise and control groups was analyzed, statistically insignificant Student t values of 0.43 ($p = 0.7$) for changes in total blood serum cholesterol and 1.09 ($p = 0.3$) for changes in free blood serum cholesterol were obtained.

The decrease in total and free cholesterol among those with "high" levels is shown in Figure 1. However, because of the small number of such cases and because the controls as well as exercise subjects showed a decrease, each individual subject was studied further. The analysis appears in Table III. The intra-individual variance used in determining the Student t values was the variation between blood samples taken about one week apart at a testing period. This was compared to variations in mean values between two testing periods. As can be seen in the table, one of the three exercise subjects showed a statistically significant decrease ($p < 0.05$), while none of the controls showed a significant decrease.

Because some of the normal subjects on exercise showed no decrease or even an increase in blood cholesterol and because in some of the controls a decrease occurred, change in body weight in the subjects was studied. Table II reveals that the mean weights of both normal cholesterol groups decreased. The difference in weight loss was not significant ($t = 0.32$). Although members of the control group were not taking regular exercise, the fact that they were participating in the experiment perhaps made them more conscious of their general physical fitness and may have resulted in a limited amount of dieting. Evidence for this is contained in Figure 2, where weight changes of the subjects in all groups are plotted against changes in total serum cholesterol. The subject showing the largest *increase* in blood cholesterol was in the exercise group. This discrepancy and the others can now be understood by the statistically significant correlation ($p < 0.01$) between cholesterol change and body weight change. The high blood cholesterol subjects are also plotted on this graph. The three high cholesterol subjects on exercise lost on the average 1.8 kg of body weight as com-

TABLE III

Changes in Total and Free Blood Serum Cholesterol in Initially High Level Subjects

Subject	Age	Total blood cholesterol (mg/100 ml) Before	After	t	p	Free blood cholesterol (mg/100 ml) Before	After	t	p	Body weight change (kg)
1 (Exercise)	38	261.0	236.9	1.32	0.29	115.4	97.7	1.62	0.21	−2.6
2 (Exercise)	35	216.6	167.9	2.56	0.07	66.3	45.9	2.96	0.04	−1.4
3 (Exercise)	32	224.7	193.2	1.86	0.15	61.7	57.2	0.64	0.28	−1.4
4 (Control)	35	239.3	216.6	1.29	0.27	84.1	66.3	1.58	0.19	−3.5
5 (Control)	31	258.1	247.7	0.30	0.40	100.3	93.3	0.82	0.45	0.0

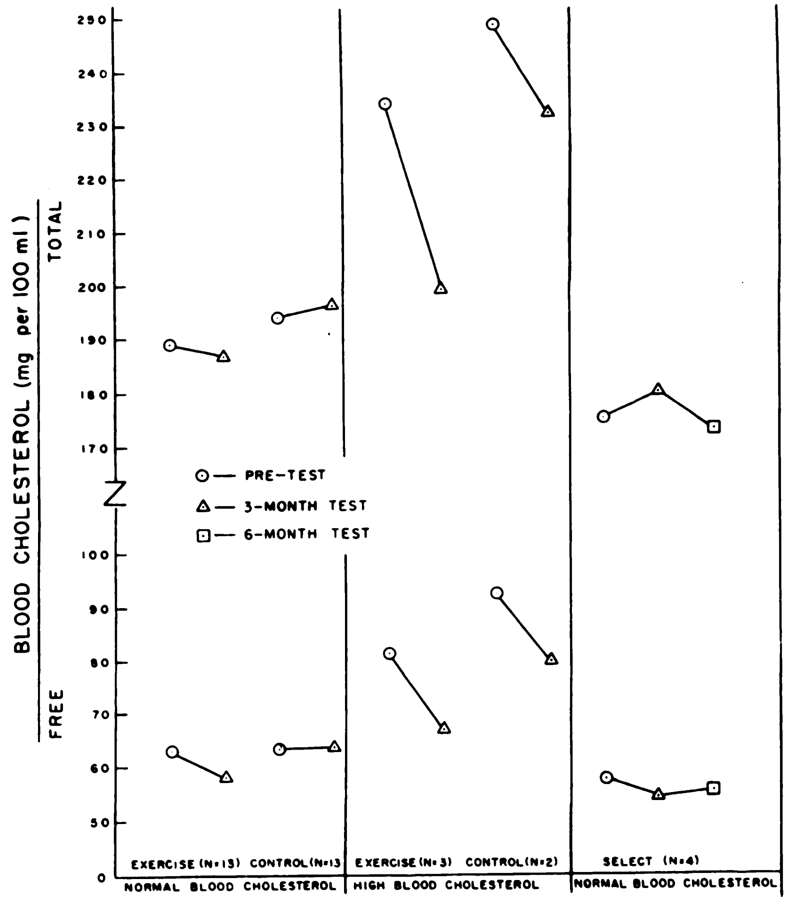

Fig. 1. Changes in blood serum cholesterol.

pared to a mean of 0.6 for the entire exercise group. These subjects also showed above-average decreases in blood cholesterol. The one high-cholesterol control subject whose cholesterol was lowered considerably (subject 4, Table III) lost 3.5 kg of body weight as compared to 0.9 kg for the entire control group. The other high-cholesterol control whose level did not change appreciably (subject 5, Table III), did not change in body weight.

It is unfortunate that accurate diet recall records were not available on the subjects. However, it is doubtful that the percentage of fat or cholesterol in the diets was changed appreciably because the men were all eating at home, they were cautioned not to change their dietary habits, and the experiment was of short duration. If the decrease in blood cholesterol in some subjects is to be attributed to changes in diet, this factor should also be responsible

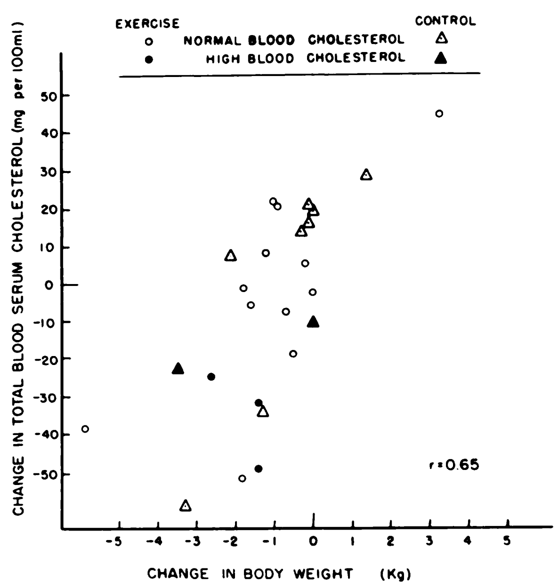

Fig. 2. Relationship between change in blood serum cholesterol and change in body weight.

for the increases in the remaining subjects (almost half of the total). This does not appear logical, although without substantiating diet records, it cannot be ruled out as a possibility.

Changes in free cholesterol were also plotted against weight change and, although the trend was similar to total cholesterol, the relationship was not as close ($r = 0.41$, $p = 0.05$). A ratio of total to free cholesterol was computed for each subject at each testing period. The changes in these ratios were plotted against weight changes, but no statistically significant trends were observed ($r = 0.23$, $p = 0.10$).

In view of the small number of cases, the results should not be considered conclusive. Nevertheless, the results (see Fig. 2) suggest that the effects of exercise are indirect in that they are present only when associated with a weight loss. This agrees with the work of Mann,[8] whose subjects were overfed without exhibiting an increase in blood cholesterol provided the daily energy expenditure was increased sufficiently to compensate for the increased food intake. It also explains why Taylor and collaborators[9] found no significant change in blood cholesterol in subjects who exercised but who were maintained in caloric balance. It is unfortunate that other human studies and those with animals did not include data on body weight or fat changes.

It is possible that a closer relationship could be shown between changes in total serum cholesterol and change in body fat than with body weight in the present study, but it was not possible to secure accurate specific-gravity data on the subjects.

The relatively simple explanation of cholesterol change suggested here probably does not explain the abnormal lipid metabolism which occasionally appears. However, it is not out of line with the data utilized by insurance companies for many years which show clearly a correlation between excess body weight and incidence of heart disease.

SUMMARY

The effects of supervised exercise (three months) on total blood serum cholesterol were studied among 31 sedentary middle-aged men. No effect was observed among subjects with "normal" initial serum levels. However, three "high" level subjects showed an appreciable decrease following exercise compared with two controls with high initial levels. When the subjects of both groups were combined, change in total serum cholesterol generally accompanied a change in body weight regardless of whether the subject was in the exercise or control group. Exercise, therefore, was effective in decreasing total blood serum cholesterol in some subjects, but this effect appeared to be indirect by decreasing body weight. Free serum cholesterol showed the same trends, but the relationship with body weight changes was not as close.

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