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THE EFFECT OF ACUTE AND CHRONIC ENDURANCE EXERCISE ON HIGH DENSITY LIPOPROTEIN CHOLESTEROL AND THE HDL-CHOLESTEROL : TOTAL SERUM CHOLESTEROL RATIO

by

Douglas Edward Barre

Honours B.Sc., Queen's University, 1977

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University of Ottawa

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UNIVERSITÉ D'OTTAWA
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SIGNATURE PAGE

DEDICATION

This thesis is dedicated to my parents, Dr. and Mrs. Maurice Barre. Their continued support has very much assisted in the completion of this study.

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ABSTRACT

The primary objective of this study was to determine if acute ergometric exercise performed at a heart rate of 140-160 beats per minute for one hour by physically untrained males (aged 19-51 years) has a time course effect on the serum concentration of High Density Lipoprotein cholesterol (HDLc), Low Density Lipoprotein cholesterol (LDLc), Total Serum Cholesterol (TSC), Total Serum Triglycerides (TSTGL) and on the HDLc:TSC ratio. The secondary objective of this study was to compare the changes in these parameters after 1 and 3 sessions of acute ergometric exercise performed at a heart rate of 140-160 beats per minute.

The 31 subjects who participated in this study were normolipidaemic (TSC: 2.59-6.48 mmol/l; TSTGL: 0.79-2.82 mmol/l), untrained ($\dot{V}O_2max < 50.0$ ml./kg./min.) males without diabetic tendencies, with clinically normal blood pressure ($< 140/90$ mm. Hg.) and no clinical evidence of coronary heart disease (CHD), myocardial infarction (MI), electrocardiogram (EKG) abnormalities, respiratory or other uncontrolled chronic disease.

All subjects conformed to a sedentary lifestyle carried throughout the study. The subjects were asked to keep written records of diet, alcohol and cigarette consumption during the course of the study. Variable compliance with this request to submit dietary (including alcohol) diaries made interpretation of the impact of exercise more difficult.

Significant differences were determined by comparing the change in all possible combinations of any two post-

exercise points in the treatment group and comparing it to the difference over the comparable period in the control group.

The HDLc:TSC ratio increased (.317 to .338) and the Low Density Lipoprotein cholesterol concentration decreased (2.33 to 2.20 mmol/l), significantly ($p < .05$), in going from immediately post- to 1 hour post-exercise in the acute treatment group when 30 subjects were considered. The biochemistry of these changes is discussed. All results were linearly corrected for changes in hematocrit. However, significant changes were lost when 2 control subjects taking propranol were dropped and when the groups were matched on the basis of age, weight and Body Mass Index (BMI).

Thus, while the trends toward an increased HDLc:TSC ratio and decreased LDLc at one hour post-exercise remained the same regardless of the method of grouping and matching subjects, it is concluded that a single bout of acute exercise does not significantly affect the HDLc:TSC ratio and LDLc.

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CHAPTER I

THE PROBLEM

Introduction and Rationale

The search for ways to increase the serum concentration of High Density Lipoprotein cholesterol (HDLc) has received much attention since Miller and Miller (1975) suggested an inverse relationship between HDLc* and coronary atherosclerotic heart disease (CASHD). CASHD is the major cause of death in many western countries (Benditt 1977).

This effort is based on the observation that HDL decreases the availability of cholesterol to the arterial wall. Glomset (1968) suggested that HDL removes cholesterol from the arterial wall via the action of lecithin cholesterol acyl transferase (LCAT). HDL is proposed to carry the cholesterol to the liver where the cholesterol is metabolised. Further, HDL inhibits the internalization of Low Density Lipoprotein (LDL) by porcine smooth muscle cells and human endothelial cells in culture (Carew et al 1976, Stein and Stein 1976, and Steinberg et al 1976). Thus, any process which augments HDL and its ability to decrease the availability of cholesterol to the arterial wall to form plaques should theoretically result in a reduction of the risk for developing CASHD (Miller and Miller 1975).

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*All references are to serum enzyme activities, lipid and lipoprotein concentrations except where noted otherwise.

Chronic endurance exercise as a possible agent in the management of CASHD has received much attention in the past 25 years. While chronic exercise appears to increase HDLc (Wood et al 1976, 1977), it may, given the proposed role of HDL in CASHD, have the more important effect of increasing the HDLc:Total Serum Cholesterol (TSC) ratio (Murdoch 1980). Thus, the proportionate amount of cholesterol available for deposition in vascular walls is reduced.

The cumulative effects of a number of acute endurance exercise sessions repeated over a short term is not well documented. Erkelens et al (1979) found that HDLc increased significantly after one week of moderate exercise. This result combined with acute studies which showed a significant increase in HDLc suggests that the summation of acute effects is possible.

Chronic endurance exercise is essentially an accumulation of the acute effects of stimuli provided through intermittent and regular acute exercise. Acute exercise, however, has received relatively little attention with regard to its singular and cumulative effects on the distribution of cholesterol among the lipoprotein fractions.

An increase in HDLc may be a post- acute exercise (recovery) phenomenon. This increase may be mediated by lipoprotein lipase (LPL). HDLc and TSTGL are inversely related, the explanation for which may be the reaction:

$$VLDL + HDL_3 \xrightarrow{LPL} HDL_2 + LDL$$ Kinnunen (1979).

LPL removes fatty acids, by hydrolysis, from the triglyceride (TGL) associated with the Very Low Density Lipoprotein (VLDL) fraction. VLDL is the major carrier of TSTGL. Given that skeletal muscle triglyceride falls with prolonged acute aerobic exercise (Oscai et al 1978, Lithell 1979a) and that this TGL must be repleted, perhaps from fatty acids (FA) from TSTGL, it follows that there must be a pattern of depletion-repletion in that tissue. Aerobic exercise recruits mostly slow oxidative muscle fibres (Gollnick et al 1972, 1973 and Edgerton et al 1975) which have the greatest oxidative capacity among human fibre types (Karlsson et al 1978). Froberg et al (1978), using 13 male MI survivors and 14 males from a lipid clinic population in resting studies, found that there was a correlation of r= -0.62 between the k2 (fractional removal rate from plasma of intravenously (IV) injected Intralipid*) and the TGL concentration of the muscle.

This suggests a higher skeletal muscle LPL activity following acute exercise that recruits slow oxidative tissue. Perhaps, given the reaction of Kinnunen (1979) outlined above, an increase in LPL may lead to an increase in HDLc. Then as the muscle fibres are repleted with TGL it would appear that k2 decreases. This suggests a drop in LPL activity which in turn implies that HDL production slows down and that the serum levels of these lipoproteins may eventually return to their

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*Intralipid is a soybean oil emulsion stabilized with 10% egg lecithin.
Intralipid contains triglycerides and is used as a fat tolerance test (Boberg et al 1969)

pre-acute exercise levels. The work of Kekki (1980) supports this theory. He noted that LPL activity and k2 correlated $r= +0.91$ and $r= +0.90$ respectively with HDLc in normolipaemic adults.

Furthermore, if LCAT activity increases it is also possible that HDLc will increase. Schmitz et al (1982) found that, in vitro, LCAT was responsible for the HDL_3 to HDL_2 conversion and that over time the cholesterol ester content of HDL_3 decreased while that of HDL_2 increased as the result of that enzyme's activity. Consequently, one might suggest that an increase of cholesterol carried by HDL or its major subfraction, HDL_2, is possible with acute and/or chronic exercise.

There is little evidence in the current literature to confirm or reject significant redistribution of cholesterol among the lipoprotein fractions in untrained adult males as the result of exposure to 1 hour of endurance exercise. Enger et al (1980), Thompson et al (1980), and Dufaux et al (1982) observed a significant redistribution of cholesterol among the lipoprotein fractions on each of two successive days following acute exercise that lasted longer than one hour. The occurrence of peak HDLc levels well into the post-exercise period might explain the delay in the occurrence of a peak in the HDLc:TSC ratio and may be due to a lag in the peak rate of activity of LPL and/or LCAT. If TSC remains constant or falls simultaneously (Enger et al 1980, Thompson et al 1980) with an increase in HDLc during the post-exercise period then the HDLc:TSC ratio may also rise.

Statement of the Problem

The primary objective of this study was to determine if acute exposure to continuous bicycle ergometer exercise performed for one hour has an effect on the immediate and extended post-exercise profile of lipoprotein cholesterol fractions in untrained adult males. Specifically, this study was designed to determine if one hour of cycling at a heart rate of 140 to 160 beats per minute (bpm) affects the immediate, 1 hour, 2 hour and 24 hour post-exercise measurements of serum HDLc, TSC, TSTGL, the HDLc:TSC ratio and the calculated LDLc in 19 to 51 year old untrained males.

A secondary objective of this study was to examine the post-exercise profiles in subjects who have either experienced or not experienced three bouts of exercise in the preceding 6 days.

Delimitations

The subjects volunteered and were selected on the basis of availability, willingness and scheduling compatability. Therefore, the results from this experiment are only applicable to this experimental population. Risk factors associated with CASHD such as diabetes, hyperlipidaemia, and hypertension ($>$ 140/90 mm Hg) were not considered. Furthermore, the subjects demonstrated no clinical evidence of coronary heart disease (CHD), myocardial infarction (MI), electrocardiogram

(EKG) abnormalities, respiratory or other uncontrolled chronic disease.

Hypothesis

On the basis of information in the introduction, measurable concomitant trends will be seen in increased HDLc and decreased TSC in the post-exercise period. These trends should affect the HDLc:TSC ratio. It is further hypothesized that an additive effect of these acute trends will not be significant after 3 exercise sessions.

Limitations of the Study

Interpretations of the data must consider that:

1. Increased HDLc concentration does not necessarily suggest an increase in the number of HDL particles. It may mean an increased cholesterol content of each particle due to an increased total or apo A-I protein content of that micelle or an enhanced ability of that particle to bind cholesterol. A summary of lipoprotein metabolism occurs in Appendix I.

2. The proposed intensity (target heart rate) for exercise is likely only an approximation of the point where the muscle lactate of some subjects begins to pass in significant quantities into the blood. Therefore the level

of exercise stressor presented to each subject is only approximately equal and may not be sub-anaerobic threshold in all cases. Generally speaking, however, the intensity should be below that threshold.

3. The Friedwald formula was used to calculate LDLc on the assumption that VLDLc was equal to TSTGL/5. As this assumption is not always valid, the use of LDLc comparisons is limited. However, as the relationship of HDL to CASHD is thought to be independent of that of the LDL-CASHD relationship, this study is not invalidated.

4. Ultracentifugation is the technique of choice for lipoprotein analysis. The technique used in this study correlates r= +0.82 with the former method (Lopes-Virella et al 1977). Since any change in the specified variables would likely be small, one must be sure that every change is outside the range of error of the biochemical determinations before suggesting a statistically significant change.

5. There was no strict control on diet, caloric intake or alcohol consumption. These factors affect lipoprotein cholesterol metabolism (Appendix II).

Definition of Terminology

The following terms are used in this study:

1. Serum Lipoproteins: Since lipids are insoluble in serum they must be conjugated with soluble proteins in order to be carried in the blood. Triglycerides (TGL),

phospholipids, cholesterol, and cholesteryl esters are transported by serum lipoproteins (Eisenberg 1979). The cholesterol concentration of a lipoprotein includes the free and esterified forms of that sterol. Some of the characteristics of the lipoproteins are defined in Table I.

2. High Density Lipoprotein (HDL or alpha(α)-lipoprotein):

HDL_2, a major subfraction of HDL, is thought to be antiatherogenic (Gofman et al 1966, Hammett et al 1979) while HDL_3, the other major HDL subfraction, appears to play no role in the CASHD process. HDL_2c is disproportionately decreased relative to HDL_3c in CASHD (Gofman et al 1966). Hammett et al (1979) found a more marked reduction in HDL_2c than in HDL_3c in patients with angiographically determined CASHD. Further, there is little or no difference in HDL_3c between the age-matched sexes, yet females of child bearing age demonstrate a reduced risk of CASHD but much higher levels of HDL_2c than do age-matched males (Miller and Miller 1981). CASHD risk factors are associated with a disproportionate decrease in HDL_2c relative to the decrease in HDL_3c (Miller and Miller 1981). Further, the cholesterol:protein ratio is greater in HDL_2 than in HDL_3 (Nichols 1967). This may suggest that HDL_2 has a better binding capacity for cholesterol and hence is the better subfraction for the removal of cholesterol at the

TABLE I (Morrisett et al 1977)

COMPOSITION AND PROPERTIES OF HUMAN PLASMA LIPOPROTEINS

Properties	Chylomicrons	VLDL	LDL	HDL
Density, g/ml	< 0.95	0.95–1.006	1.006–1.063	1.063–1.210
Molecular weight	$> 0.4 \cdot 10^9$	$5 \cdot 10^6 - 10 \cdot 10^6$	$2.7 \cdot 10^6 - 4.8 \cdot 10^6$	$1.8 \cdot 10^5 - 3.6 \cdot 10^5$
Major apoproteins	apoB	apoB	apoB	apoA-1
	apoC-I	apoC-I		apoA-II
	apoC-II	apoC-II		
	apoC-III	apoC-III		
		apoE		
Minor apoproteins	apoA-I	apoA-I		apoC-I
	apoA-II	apoA-II		apoC-II
		apoD		apoC-III
				apoD
				apoE
Major lipids	triglyceride	triglyceride	cholesteryl esters	phospholipids
			phospholipids	cholesteryl esters
Minor lipids	phospholipids	phospholipids	free cholesterol	free cholesterol
		cholesteryl esters	triglyceride	

arterial wall. This conflicts, perhaps, with the fact that HDL_2 has less apoprotein in terms of percentage of total weight and in absolute terms (Cheung and Albers 1977).

3. Low Density Lipoprotein (LDL or Beta(β)-lipoprotein): see Table I.

4. Very Low Density Lipoprotein (VLDL or pre β-lipoprotein): see Table I.

5. Total Serum Cholesterol (TSC): The total amount of the sterol carried in the fasting blood. Normal TSC levels in adult humans are 4.92 mmol/l with a range of 2.59-6.48 mmol/l. Serum cholesterol occurs in free and esterified form in a ratio of 1:3.

6. Total Serum Triglycerides (TSTGL): The total amount of triacylglycerols in fasting serum. In adult humans, the concentration range is normally 0.79-2.82 mmol/l with a mean of 1.81 mmol/l. Endogenous TSTGL is carried by VLDL.

7. Lipoprotein Lipase (LPL): catalyzes the hydrolysis of fatty acids from TSTGL and perhaps participates in the reaction:

$$VLDL + HDL_3 \xrightarrow{LPL} LDL + HDL_2$$

The enzyme is activated by apoprotein C-II which is found in VLDL and HDL. Acute exercise appears to result in Kinetic induction (eg increases in the serum insulin: glucagon ratio) of enhanced LPL activity. Chronic exercise appears to increase the synthesis of new enzyme protein leading to enhanced enzyme activity by increased enzyme concentration in the case of LPL and Lecithin cholesterol acyl transferase

8. <u>Lecithin Cholesterol Acyl Transferase (LCAT):</u> esterifies cholesterol in serum HDL_2 and may participate in the conversion of HDL_3 to HDL_2. It is activated by apoprotein A-I which is found in HDL and VLDL.

9. <u>$\dot{V}O_2$ max ($M\dot{V}O_2$):</u> the maximal rate of oxygen uptake that can be achieved by an exercising animal or person.

10. <u>Friedwald equation:</u> LDLc = TSC-(TSTGL/5)-HDLc
This formula is not accurate if TSTGL exceeds 4.52 mmol/l. VLDLc is inaccurately estimated as TSTGL/5. LDLc values determined by this formula reflect those determined by ultracentrifugation (Friedwald et al 1972).

11. <u>Acute Exercise:</u> a single session of continuous exercise on one day as opposed to chronic exercise which is a series of distinct exercise sessions over a period of days, months, or years.

12. <u>Aerobic Exercise (or endurance exercise):</u> exercise which is performed at a sub-anaerobic threshold level. Anaerobic threshold (A.T.) usually occurs between 60 and 80% $\dot{V}O_2$ max.

CHAPTER II

REVIEW OF THE LITERATURE

The focus of this review is to outline the exercise approaches used in an attempt to manipulate the distribution of serum cholesterol among the lipoprotein fractions. This chapter is broken down into 4 sections (see Table II).

The first section discusses the proposed relationships between lipoproteins and CASHD pathology. These relationships are linked in the next part to the metabolism of lipoproteins. The following section deals with the relationship between lipoprotein metabolism and exercise studies. The exercise studies are subdivided into acute (including an interpretation of the state of the art) and chronic exercise studies. The chronic exercise section is further divided into cross-sectional and longitudinal studies. The penultimate section deals with chronic exercise and its impact on LCAT and LPL activities. These are thought to be the two key enzymes in lipoprotein metabolism as it pertains to exercise. Finally, there is an interpretation of the state of the art of chronic exercise studies.

CASHD Pathology and Lipoproteins

Epidemiological studies have demonstrated a negative correlation between serum concentrations of HDL (or HDLc) and CASHD risk (Medalie et al 1973, Berg et al 1976a, b, Miller and Miller 1975, Rhoads et al 1976a, Castelli et al 1975, 1977a, Yaari et al 1981). Bondjers et al (1976) found a

TABLE II

FLOW CHART FOR THE REVIEW OF THE LITERATURE

CASHD[1] pathology and lipoproteins

↓

lipoprotein lipase, lecithin cholesterol acyl transferase and lipoprotein metabolism (relation to CASHD pathology)

↓

EXERCISE STUDIES

1)* acute exercise and lipoprotein profiles (includes summary of the state of the art)

2)* chronic exercise
   a) cross-sectional studies and lipoprotein profiles
   b) longitudinal studies and lipoprotein profiles
   c) human LPL[2] and LCAT[3] studies
   d) summary of the state of the art

[4]changes in hematocrit
[4]changes in weight
[4]changes in adiposity

[4]alcohol
[4]medications
[4]diet
[4]cigarettes

* sections deal in part with lipoprotein metabolism

1) CASHD - Coronary Atherosclerotic Heart Disease

2) LPL - Lipoprotein Lipase

3) LCAT - Lecithin Cholesterol Acyl Transferase

4) Factors affecting concentration of cholesterol in lipoprotein fractions.
   In many studies these factors are not adequately controlled and thus the state of the art is not as refined as it could be. The current study controls for changes in hematocrit, weight, adiposity and cigarette consumption. Poor subject cooperation made control of the other factors impossible.

significant correlation of r= -0.80 between HDLc and the cholesterol content of mesenteric arterial tissue in 13 severely obese humans. As with all correlations, causality was not proven. Some authors (Carew et al 1976, Stein and Stein 1976, Steinberg et al 1976) have discovered that HDL inhibits the internalization of LDL by porcine smooth muscle cells and human endothelial cells in culture. However, most authors (Burke 1980, Hsia et al 1975, Miller and Miller 1975, Havel 1979, and Stein et al 1975a, 1975b) view HDL as a cleaning agent which picks up cholesterol from the arterial wall and transports it to the liver where it is catabolized. According to these notions, as the serum HDL concentration increases, the capacity to control cholesterol levels in the arterial walls perhaps increases.

Williams et al (1979) found the HDLc:TSC ratio to be one of the most powerful predictors of atherosclerosis in humans. This observation of Williams et al (1979) may be related to CASHD in that there is a high positive correlation between TSC and LDL. LDL is thought to deposit cholesterol on the arterial walls (Goldstein and Brown 1975, Stein and Stein 1976, and Stein et al 1975a) thereby promoting the formation of atheromae and partial or complete occlusion of the lumen. An increased HDLc:TSC ratio, therefore, suggests a reduced availability of cholesterol for LDL and hence a reduced CASHD risk.

As Miller and Miller (1975) have indicated, the HDL/LDL concept of cholesterol removal/deposit is the only theory which so thoroughly takes into account the positive risk factors of hypercholesterolemia+*, hypertriglyceridemia+*, obesity*, diabetes mellitus+, and perhaps the negative risk factor of physical activity, while accounting for the higher incidence of CASHD in men than in women (Aldersberg 1957, Ho et al 1960). All of these major positive risk factors or conditions are associated with a lower level of HDL or HDLc.

A number of authors have demonstrated a relation between the angiographically determined extent of CASHD and both lipid and lipoprotein parameters (Pearson et al 1979, Jenkins et al 1978, Milne et al 1981, Papadopoulous et al 1973, and Crowley 1971). Papadopoulous et al (1973) and Crowley (1971) found significantly elevated TSTGL and TSC in CASHD diagnosed by coronary angiography. These findings may be related to the lipoprotein theory of atherogenesis in that there is a significant high positive correlation (r= +0.88) between Beta-lipoprotein and TSC (Castelli et al 1977b) and an inverse relation between HDLc and VLDL-TGL in man (Nikkila 1978a). Elevated TSTGL may reflect low LPL activity which would reduce HDL production (Kinnunen 1979). Pearson et al (1979) reported lower total HDL in patients with CASHD. The lower HDL levels in the afflicted group support the antiatherogenic concept of HDL. A study by Milne et al (1981), however, demonstrated a significant inverse relation between

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*major positive risk factors for the development of clinical CASHD (i.e. myocardial infarction, sudden death, and angina pectoris-Simborg (1970))
+major positive risk factors for the development of clinical CASHD-Hurst et al (1974)

the severity of coronary artery disease and the HDLc:TSC ratio but not between CASHD and HDLc. Interestingly, Gordon et al (1977) suggested that the HDLc:TSC ratio may be a more powerful negative risk factor than HDLc.

HDL (or HDLc) has an inverse relationship, and LDLc a direct relationship with clinically diagnosed CASHD (Berg et al 1976a, Zilversmit 1977, Robinson et al 1979, Castelli et al 1977a, and Brunner et al 1979).

The angiography work of Pearson et al. (1979), Jenkins et al (1978), Papadopoulous et al (1973), and Crowley (1971) and the clinical studies of Berg et al (1976a) and Zilversmit (1977), showing that HDL (or HDLc) has an inverse relationship, and LDLc a direct relationship with clinically diagnosed CASHD, are supported by in vitro studies (Carew et al 1976, Hsia et al 1975). These studies suggested that HDL and LDL respectively, have a cholesterol removal and deposit function for the arterial wall. While HDLs carry cholesterol, one of their features that makes them antiatherogenic is their lack of apo-B which gives LDL the ability to bind to the negatively charged glycosaminoglycans that are present in the arterial intima (Havel 1979, Camejo et al 1980).

Burke (1980) has suggested that the lipid (lipoprotein) theory has not been proven and that prospective studies are required to determine its validity. This view is supported by the Ontario Ministry of Health et al (1980).

The question of the carrying capacity and the saturation kinetics of HDL is also important in determining the validity of the proposed protective effect of HDL against CASHD. Hsia et al (1975) reported that, normally, lipoproteins are not saturated with cholesterol. They found that when cholesterol pulverized by sonication was mixed with human serum, the HDL fraction solubilised 29% of the serum cholesterol binding reserve (SCBR) of the original serum. SCBR is the ability of human serum to solubilise exogenous cholesterol in the in vitro medium in addition to its endogenous cholesterol content (i.e. the cholesterol already associated with the lipoproteins). Further, patients with clinically diagnosed CASHD demonstrated a significant lesser regression line slope, relative to non-cases, with TSC (abcissa) compared to the SCBR (ordinate). This suggests the possibility that in non-cases there is an increasing number of HDL particles with increasing TSC if one assumes the same or approximately the same saturation levels of cholesterol for a given HDL molecule. The negative regression line slope in CASHD patients might be explained by the finding of Berg et al (1976a) that CASHD patients have significantly less total HDL than asymptomatic controls. That is, as TSC increases in CASHD patients, the ability of HDL to bind that cholesterol is reduced if one assumes the same or approximately the same levels of cholesterol saturation for HDL. This may explain the finding of Castelli et al (1977a) that CASHD patients, across all ages, had significantly higher TSC and LDLc but lower HDLc than non-CASHD patients. The significantly higher levels of total HDL in asymptomatic controls (Berg et al 1976a) might, in part, explain the positive correlation between TSC and

SCBR in non-CASHD subjects (Hsia et al 1975). These results of Hsia et al (1975), Berg et al (1976a), and Castelli et al (1977a) combine to support the antiatherogenic concept of HDL.

The large support for the HDL/LDL hypothesis of cholesterol removel/deposit is found in coronary angiography studies, HDLc and LDLc levels in clinically diagnosed CASHD, and <u>in vitro</u> studies. Kinnunen (1979), however, has suggested that HDL may not be antiatherogenic. He argues that the atherogenicity of low HDL does not apply to Tangier disease. Tangier disease is characterized by the absence of HDL_2 and HDL_3 but the presence of a particle (HDL_T). Further, in Tangier disease there are low levels of LDLc (1.35 mmol/l) and TSC (2.13 mmol/l) and an HDLc of 0.05 mmol/l thus giving an HDLc:TSC ratio of .02 (Matthes et al 1981). The low TSC and LDLc suggest that there is a reduced need for HDL to decrease the uptake or promote reverse cholesterol transport. Thus, low HDLc in Tangier disease does not seem to conflict with the HDL/LDL concept of cholesterol removal/deposit at the arterial wall. Indeed, Fredrickson et al (1978) have stated that the limited number of older subjects with this disease "precludes firm conclusions regarding premature atheroscletosis" in such people.

HDL and LDL are thought, respectively, to remove and deposit cholesterol from the arterial wall (Glomset 1968, Hsia et al 1975, Miller and Miller 1975, Havel 1979, Stein et al 1975a, and Goldstein and Brown 1975). Alternatively, HDL inhibits the internalization of Low Density Lipoprotein (LDL) by porcine smooth muscle cells and human endothelial cells in culture (Carew et al 1976, Stein and Stein 1976, and Steinberg et al 1976). These concepts seem possible in view of the findings by Berg et al (1976a,b), Papadopoulous et al (1973), and Crowley (1971) that HDL (or HDLc) has an inverse relationship, and LDLc a direct relationship with clinically diagnosed CASHD.

These relationships between the lipoproteins and CASHD will be elaborated upon in the next section which will deal with the key enzymes in lipoprotein metabolism.

Lipoprotein Lipase, Lecithin Cholesterol Acyl Transferase, and Lipoprotein Metabolism

LPL, LCAT, and lipoprotein metabolism have been extensively investigated since the early 1950s when the serum lipoproteins were first suggested to have some relation to CASHD (Gofman et al 1950, Russ et al 1951, Jencks et al 1956). LPL, which acts at, and is bound to the luminal surface (endothelium) of the capillary walls of extrahepatic organs, is significant because of its proposed role in the apparently irreversible (Patsch et al 1978) reaction:

$$HDL_3 + VLDL \xrightarrow{LPL} HDL_2 + LDL \text{ (Kinnunen 1979)}$$

HDL_2 is thought to be the antiatherogenic subfraction of HDL (Miller and Miller 1981).

Eisenberg et al (1975) reported that LPL leads to the rapid hydrolysis of the triglyceride of VLDL (supported by

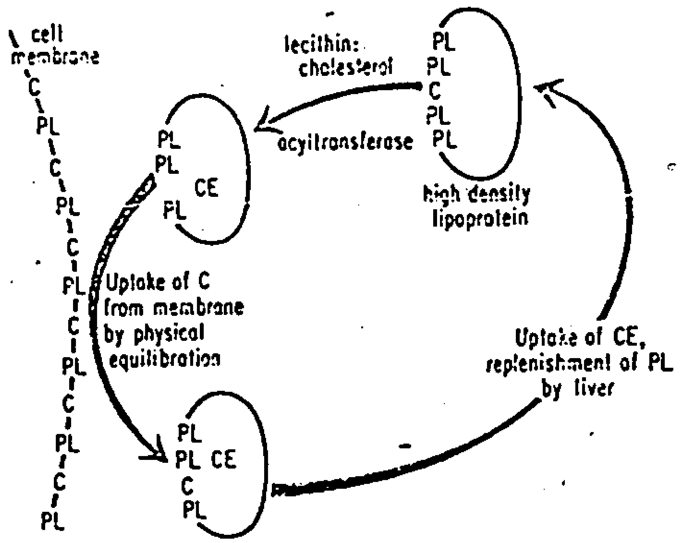
Musliner et al 1979) and the transfer of Apo C-I, II, and III to HDL. Eisenberg et al (1975) also noted that most of the esterified and unesterified cholesterol, removed from VLDL as the result of LPL activity, is transferred to HDL.

The nature of the relationship between LPL and fatty acid hydrolysis from VLDL-triglyceride (VLDL-TGL) is quite clear, however the nature of the contribution of LPL to protein transfer between lipoproteins is not well defined. What is certain is that LPL is an essential requirement for the reaction proposed by Kinnunen (1979) to proceed when HDL_3 and VLDL are incubated together (Patsch et al 1978). Schmitz et al (1982), however, found that LCAT and not LPL was responsible for the in vitro conversion of HDL_3 to HDL_2. They suggested that Patsch et al (1978) failed to assess residual LCAT activity.

LCAT, which is synthesized in the liver and acts in the serum, apparently esterifies cholesterol picked up from the arterial wall by HDL (see Fig. 1). LCAT is activated by Apo A-I (Glomset 1968). Schmitz et al (1982) noted that, in vitro, LCAT increased the cholesterol ester content of HDL_2.

A summary of lipoprotein metabolism is presented in Appendix I.

Part of the following sections on exercise will deal with the relationship between physical activity and lipoprotein metabolism.



Postulated mechanism for the transport of cholesterol from membranes of peripheral cells to the liver. Lecithin:cholesterol acyltransferase reacts with circulating lipoproteins to form cholesteryl esters from unesterified cholesterol and lecithin. The lipoproteins subsequently pick up unesterified cholesterol from cell membranes, circulate through the liver, and release esterified cholesterol. C, unesterified cholesterol; CE, cholesteryl ester; PL, phospholipid.

Fig. 1 (Glomset 1968)

Exercise Studies

Acute Exercise and Lipoprotein Profiles in Humans

The existing acute exercise studies (Table III) in which serum lipid and lipoprotein profiles were examined, have, with few exceptions (Enger et al 1980, Thompson et al 1980, Dufaux et al 1982), failed to follow the serum chemistry for a period of time post-exercise. Given that there may be a lag in the increase of LPL activity (Lithell et al 1979a, Enger et al 1980), such post-exercise work should continue to confirm if lipoprotein cholesterol changes occur in that period.

A significant decrease in TSTGL with acute exercise has been observed by Carlson and Mossfeldt (1964) while no change has been noted by Holloszy et al (1964). In the Carlson and Mossfeldt (1964) study, about 75% of the fall in TSTGL was due to the decrease in VLDL-TGL. This study, however, unlike Holloszy et al (1964), may be criticized for improperly controlling the diet in that the subjects were allowed unlimited calories immediately prior to the 1962 ski race. The result of this lack of control may have been a temporary increase in TSTGL (see Appendix II) thus preventing those investigators from seeing the full impact of exercise on the resting levels of this lipid parameter.

Nikkila et al (1978a) observed an inverse relation between VLDL-TGL and skeletal muscle LPL while Nikkila (1978b) noted that HDLc is inversely related to VLDL-TGL in humans in resting studies.

Lithell et al (1979a) found that the post-exercise LPL

TABLE III - ACUTE EXERCISE - HUMAN LIPID AND LIPOPROTEIN, LPL AND LCAT PROFILES

AUTHORS	AVAILABLE DETAILS ON SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Carlson and Mossfeldt 1964	1962 race - 9 men 1963 race - 9 men	- all subjects trained for five months prior to race - 85 kilometers cross country ski race (Vasaloppet) average time 8-9 hours -blood sampled immediately pre-race breakfast and immediately post-race	-all results are pre-/post- within group -1962 TSC and TSTGL down significantly -1963 - TSC, VLDLc and LDLc no significant Δ* -TSTGL and VLDL-TGL down significantly -HDLc no significant Δ* -75% of fall in TSTGL due to fall in VLDL-TGL
Holloszy et al 1964	15 males 35-55 years mean age 41.7 years sedentary 3 or more years prior to study	training program of increasing intensity (unspecified) of running and calisthenics 2-4 miles/week, 3 times/week, 6 months; 4 of 15 men with previous high TSTGL (pre-tr'. program) were asked to remain sedentary 5-6 days after study and then run 3 miles (intensity unspecified) - acute study done on isocaloric diet of 40%/40%/20% fat/cholesterol/protein average caloric intake 2350 calories/day.	acute results - no significant Δ* in TSTGL for the acute experiment
Lithell et al 1979a	7 males	85 km ski race	LPL significantly up in vastus lateralis TGL significantly down in slow oxidative fibres only all results immediately pre- and post-race

* change
' pre-training

TABLE III - ACUTE EXERCISE - HUMAN LIPID AND LIPOPROTEIN, LPL AND LCAT PROFILES (CONTINUED)

AUTHORS	AVAILABLE DETAILS ON SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Enger et al 1980	2 groups of well trained men 1) 21-29 years (n=10) (mean 24.7 years) 2) 51-57 years (n=10) (mean 53.3 years)	70 kilometers ski race blood sampled 1 day prior to race, immediately post race and 1, 2, and 4 days post race	significantly higher HDLc immediately post-exercise, 1, 2, and 4 days post-exercise - TSC significantly lower 1, 2 days post-exercise and TSTGL significantly lower immediately post-exercise and 1 day post-exercise. -all changes relative to pre-exercise levels -no difference in pattern of changes between 2 groups
Taskinen et al 1980	10 male active competitors in cross country running (weekly training program of 80-120 kilometers)	20 kilometers run (85-105 minutes)	-gluteal adipose LPL, -vastus lateralis LPL ↑ significantly -no significant Δ LDLc, Δ HDLc pre-post exercise Δ = change
Dufaux et al 1982	15 healthy male subjects (21-25 years) none had previously taken part in a regular endurance program no control group	ran 3 hours average of 29.6±3.1 kilometers	HDLc ↑ significantly pre-1 day post*, pre-2 day post* TSC ↓ significantly pre-1 day post*, pre-2 day post* * post-exercise
Thompson et al 1980	n=12 males (24-50 years) well trained (run 42-142 kilometers/week)	42 kilometers marathon (mean = 232 minutes) (152-322 minutes)	TSTGL ↓ significantly 18&42 hours post-exercise TSC ↓ significantly 4, 18, 42, 66 hours post-exercise LDLc ↓ significantly 4, 18, 42, 66 hours post exercise HDLc ↑ significantly 18 hours post-exercise highest HDLc:TSC ratio, lowest TSC, highest HDLc } 18 hour post exercise (pre-post significantly Δ)
Lithell et al 1979b	n=7 (mean age 24) range 22-28 years non-obese, healthy (1 female, 6 male) -no control group	1 hour at a load that led to exhaustion	no significant Δ in skeletal (vastus lateralis) LPL pre-to post-exercise

of the vastus lateralis was significantly higher with the greatest increase in that enzyme's activity taking place in the least trained skier. It seems possible that with acute exercise a significant increase in HDLc is possible via the LPL mediated transfer of cholesterol and cholesterol esters from VLDL to HDL (Eisenberg et al 1975).

Lithell et al (1979b) observed no significant change in the skeletal muscle LPL activity immediately after 1 hour of acute exercise. Therefore, any exercise-mediated and hematocrit-corrected increase in the extended post-exercise profile of HDLc might result from enhanced LPL in the post-exercise period. Lithell et al (1979a) suggested that with acute exercise there may be a lag in peak LPL activity after exercise. Indeed, concomitant maximal HDLc and minimal TSTGL levels have been observed in the extended post-exercise profile (Thompson et al 1980 and Enger et al 1980). This suggests a lag in the peak of LPL activity.

Enger et al (1980) and Thompson et al (1980) observed that the peak HDLc and minimum TSC levels occurred simultaneously 1 day after the end of exercise. Even if HDLc and TSC do not change significantly one might see a significant increase in the HDLc:TSC ratio in the extended post-exercise profile. Enger et al (1980), however, failed 1) to account for any changes in hematocrit (Hct.) and 2) to take blood from fasting subjects. These two situations could conceivably have introduced variability into their analyses (Burke 1980). Further, Enger et al (1980) used the heparin-manganese precipitation technique which tends to overestimate HDLc (Lopes-Virella et al 1977).

The literature, therefore, suggests that acute exercise can lead to increases in HDLc. If TSC concomitantly decreases (Enger et al 1980) or remains the same, an increase in HDLc:TSC ratio is also a possibility. Further, such suggestions imply that lipoprotein metabolism may be sensitive to an exercise stressor and that the improved lipoprotein profiles associated with increased physical activity may actually be attributed to the exercise. None of the existing acute studies have accounted, however, for the short term effects of diet, cigarettes, alcohol and medication on lipoprotein metabolism nor have they corrected TSC, TSTGL and lipoprotein cholesterol concentrations for shifts in hematocrit. It is difficult, therefore, to ascertain the impact of acute exercise on the distribution of cholesterol among the lipoprotein fractions.

The effects of chronic exercise, which will constitute the next topic, may be the accumulation of a series of acute effects.

Chronic Exercise Studies

It has been suggested that chronic aerobic exercise tends to augment HDLc levels (Ratliff et al 1978, Wood et al 1976, 1977). HDLc has been shown to be inversely related to CASHD (Miller and Miller 1975, Pearson et al 1979). The effects of chronic exercise are perhaps the result of a series of acute effects - the acute and chronic effects not necessarily being the same. In this regard it has been noted by Bjorntorp (1976) that acute studies may reveal how early these effects occur, the order of these changes, and also which changes are characteristically representative of the sort of adaptations seen in the exercise period - i.e. which of the acute and chronic effects are the same except for magnitude. The thoughts of Bjorntorp (1976) apply to the current study in that a more thorough examination of the nature of the proposed exercise induced changes in serum High Density Lipoprotein cholesterol concentrations is required.

Cross-Sectional Training Studies and Lipoprotein Profiles in Humans

The lipid and lipoprotein profiles of long distance runners and cross-country skiers have generally represented a decreased CASHD risk (higher HDLc, lower LDLc - that is, an improved lipoprotein profile) relative to sedentary subjects (Enger et al 1977, Masarei et al 1982, Hartung et al 1978, 1980a, Wood et al 1976, 1977, Adner and Castelli 1980, Krauss et al 1977 (see Table IV)). Significantly higher HDLc levels were found in the trained subjects in all these studies. Schnabel and Kindermann (1982) found that sports requiring a high aerobic capacity generally produced a significantly higher HDLc as compared to sedentary control subjects.

The higher HDLc might be explained by the observation of Krauss et al (1977) that endurance runners have higher

TABLE IV - LIPID AND LIPOPROTEIN PROFILES IN SUBJECTS ALREADY TRAINED

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXERCISE PROTOCOL	KEY RESULTS
Enger et al 1977	n=220 males (treatment group) (195 non smokers 21 who smoked 1-10 cigarettes/day 4 who smoked 10 cigarettes/day 16-74 years (mean=41 years)	well trained cross country skiers	HDLc HDLc: TSC ratio was significantly up in the skiers over the two control groups on an age and sex-matched basis and in the skiers who smoked
	n=247 male control group 1 40-59 years (mean 50 years) who were apparently free of CASHD as determined by a near maximum exercise test and resting EKG	of average physical activity (average undefined)	
	n=87 (19-59) years - 44 of whom were daily smokers - control group 2		
Hoffman et al 1967	n=229 active senior (40-55 years) United States air force officers vs officers of same age range who were less active	more active determined by those regularly following the RCAF 5BX plan or the equivalent thereof	active group had significantly lower lipid* content associated with the VLDL fraction (reduction found only in those officers whose pre-training total VLDL was significantly below the median VLDL of both the active and control groups) - lipid* content of HDL significantly up in active vs control group * lipid content or portion undefined

TABLE IV - LIPID AND LIPOPROTEIN PROFILES IN SUBJECTS ALREADY TRAINED (CONTINUED)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXERCISE PROTOCOL	KEY RESULTS
Hartung et al 1980a	59 marathoners (40 miles/week average) and completion of at least one marathon in the year prior to the study, 85 joggers (11 miles/week average) and 74 inactive people all male and all between the ages of 35-66 years	see left	HDLc significantly higher in joggers and marathoners
Christie et al 1980	males aged 40-50 years (mean age both groups 45 years) n=12 harriers - no smokers n=13 Rotarians - 4 smoked average of 12 cigarettes/day alcohol and familial history of schemic heart disease same in both groups	see left	HDLc significantly higher in harriers - significantly different HDLc resulted from those 7 harriers who ran ≥ 56 kilometers/week or those 7 (not all same as first 7) who had run for 4 years or more. concluded that running ≥ 56 kilometers/week or ≥ 4 years of running necessary to raise HDLc levels significantly
Masarei et al 1982	43 male executives at senior administrative level in 3 Australian companies mean age=38.2 ± 7.1 years	group divided into high and low fitness sub-groups. high fitness group mean PWC_{170}=18.8±1.8 $(kg.kg^{-1}.min^{-1})$ low fitness group mean PWC_{170}=16.0±1.1 $(kg.kg^{-1}.min^{-1})$	HDLc significantly higher in high fitness group
Schnabel & Kindermann 1982	260 competitive athletes (male) (17-30 years) vs 20 sedentary male controls of approximately same age classification	those sports having high aerobic capacities	generally significantly ↑ HDLc:TSC ratio, significantly ↑ HDLc vs controls

TABLE IV - LIPID AND LIPOPROTEIN PROFILES IN SUBJECTS ALREADY TRAINED (CONTINUED)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXERCISE PROTOCOL	KEY RESULTS
Wood et al 1976	n=41 very active subjects (defined as running 15 miles/week) for year previous to study males mean=47 years range 35-59 years randomly selected from 3 Californian communities. control group 1 n=743 males, 2 n=147 males } all sedentary for year prior to study control group 2 randomly selected subset of control group 1	see details of subjects	HDLc ↑ significantly different relative to control group 2 TSTGL ↓ significantly different relative to control group 1 LDLc ↓ significantly different relative to control group 2
Wood et al 1977	n=41 active male 35-59 years (45 ± 6.5 years) - controls n=145 for HDLc[1] n=743 for TSTGL 1 also VLDLc and LDLc	actives running average of 15 miles/week for year prior to study - questionnaires to determine cholesterol, saturated:unsaturated fat ratio in diet, smoking habits (cigarettes/day and whether ex-smoker) and alcohol consumption	male results - significantly lower VLDLc and LDLc and higher HDLc - all relative to the controls
Adner and Castelli 1980	n=50 (49 male, 1 female) actives	distance runners	significantly higher HDLc, no significant difference in TSC, TSTGL or LDLc
	n=43 (42 male, 1 female) controls	non-distance runners	- all relative to controls
Krauss et al 1977	actives n=7 - males aged 42-58 years	distance runners	HDLc and HDL_2 significantly higher in runners - no significant difference in HDL_3 all relative to controls
	vs appropriately matched sedentary controls		

TABLE IV - LIPID AND LIPOPROTEIN PROFILES IN SUBJECTS ALREADY TRAINED (CONTINUED)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXERCISE PROTOCOL	KEY RESULTS
Hartung et al 1978	marathoners (n=59), joggers (n=85) and sedentary people (n=74)	see left	re: HDLc significantly ↑ marathoners > joggers marathoners > sedentary

serum apo A-I levels. Since apo A-I is an essential activator of LCAT, it would appear that HDLc should thereby rise (Glomset 1968).

Enger et al (1977) demonstrated a significantly higher HDLc:TSC ratio in well-trained skiers. LDLc was significantly lower in a study by Wood et al (1977) but not in Adner and Castelli (1980). The significantly increased HDLc:TSC ratio might be explained by a finding of a significantly lower LDLc. LDLc has a high positive correlation with TSC (Castelli et al 1977b).

All of these cross-sectional results are to be interpreted in light of the following concerns:

1) In papers in which smoking was considered (e.g. Enger et al 1977), it is hard to evaluate the precise effect of nicotine in lowering HDLc. The number smoked can only be considered as a rough guide to the actual dosage of nicotine received by each subject because the dosage varies according to the brand and type (filter or non-filter) of cigarette smoked.

2) The blood was drawn from non-fasting skiers (Enger et al 1977). The use of serum from non-fasting individuals can affect the results of HDLc analysis (Burke 1980).

3) The lack of identification of which lipid components of the lipoproteins changed in the study by Hoffman et al (1967) makes that study more difficult to compare to more recent studies (Wood et al 1976, 1977, Adner

and Castelli 1980, Krauss et al 1977). Further, Hoffman et al (1967) did not use a truly sedentary control group and this makes comparisons to other studies more difficult.

4) Shephard et al (1980) felt that there were difficulties in separating the effects of exercise from "inherited constitutional differences" found in cross-sectional studies (Wood et al 1976 and Enger et al 1977). Young and Barboriak (1980) questioned the conclusion of Hartung et al (1980a) that the distance run is the single most important variable in lipoprotein levels because they felt that the shared healthy dietary pattern of the marathoners made them unlike other men. Therefore, they argued, long distance running may be a symbol of good lifestyle and running may be as important symbolically as it is physiologically - a view supported by Hartung et al in a later paper (1980b).

5) Wood et al (1977) has been criticized by Haskell et al (1980) for not adjusting their results for cigarette smoking, adiposity, or alcohol consumption, all of which affect lipoprotein metabolism (see Appendix II).

Most of the cross-sectional studies lack the control of longitudinal studies and have failed to properly assess the important variables of cigarette smoking, alcohol consumption and diet which affect the distribution of cholesterol among the lipoprotein fractions. The usefulness of existing cross-sectional studies in the assessment of chronic endurance exercise on the distribution of cholesterol among the lipoprotein fractions, therefore, is limited.

Longitudinal Training Studies and Lipoprotein Profiles in Humans

Several studies in which previously sedentary adults were exposed to training programs of varying intensities, frequencies, and durations (13.1 to 45 min./session, over a period of 7-20 weeks) have demonstrated a variety of results. In most papers, an increase in HDLc and a decrease in LDLc and TSTGL was observed (Altekruse and Wilmore 1973, Clark et al 1981, Huttenen et al 1979, Lopez-S et al 1974, Hartung et al 1981, Hartung and Squires 1980, Peltonen et al 1981, Ratliff et al 1978, Murdoch 1980, Roundy et al 1978, Webster et al 1978, Erkelens et al 1979) (Table V).

There is some controversy over the duration of an exercise program required to produce significant changes in lipoprotein cholesterol concentrations in the serum. Significant increases in HDLc were noted after three weeks (Webster et al 1978) and one week (Erkelens et al 1979). Murdoch (1980), however, found no significant change in HDLc after 12 weeks, the explanation for which may have been a decrease in HDL_3c proportional to an increase in HDL_2c as seen by Nye et al (1981) or insufficient intensity in the exercise program. Murdoch (1980) suggested that intensity is a very important factor in the speed with which such a change occurs. The results of Mhyre et al (1981) suggested that lower intensity, longer duration exercise produced greater increases in HDLc. Further, the Erkelens et al (1979) study may have discredited its findings by using the heparin $MnCl_2$ precipitation technique which, as noted earlier, overestimates HDLc

TABLE V - HUMAN CHRONIC AEROBIC EXERCISE STUDIES - LIPID AND LIPOPROTEIN PROFILES BEFORE AND AFTER A TRAINING PROGRAM

AUTHORS	AVAILABLE DETAILS ON SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Altekruse and Wilmore 1973	n=39 male, mean age=33 years age range=17-39 years sedentary prior to training program	10 weeks, 3 times/week, average of 7.5 mph and 13.1 minutes/session	a-lp* ↑ significant B-lp* ↓ significant TSTGL no significant change
Huttenen et al 1979	male 40-45 years sedentary prior to study (n=46 control group) (n=44 treatment group)	questionnaire on previous physical activity, cigarette and alcohol consumption active subjects exposed to exercise[1] of progressing intensity RHR + .4 (MHR-RHR)→ RHR + .66 (MHR-RHR) [1]walk, jog, ski, swim, cycle	the trained subjects had significantly higher and lower HDLc and LDLc in those maintaining constant body weight (lp-c* results are pre/post within group and vs control group. - between stages pre-and post-program a highly significant correlation of -.37 between TSTGL and HDLc and a significant decrease in TSTGL in training group
Lopez-S et al 1974	n=13 medical students	7 weeks, 4 times/week, 30 minutes per session - 10-15 minutes jogging, 5-10 minutes biking, 5-10 minutes calisthenics all at intervals of 7 mets	TSTGL ↓ significantly B and pre-B ↓ 29% a-lp* ↑ significantly; LCAT activity ↑ significantly[1] in four of 13 subjects; [1]Not explained why only 4 of 13 subjects were considered.
Ratliff et al 1978	n=14 previously untrained middle-aged firemen (treatment group); n=14 sedentary controls - firemen	jogging program of increased intensity and duration 3 times /week for 20 weeks	HDLc ↑ significantly LDLc ↓, VLDLc ↓, TSTGL ↓ } significantly relative to post-program controls

* lp = lipoprotein
lp-c = lipoprotein cholesterol

TABLE V - HUMAN CHRONIC AEROBIC EXERCISE STUDIES - LIPID AND LIPOPROTEIN PROFILES BEFORE AND AFTER A TRAINING PROGRAM (CONTINUED)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Peltonen et al 1981.	20 males (training group) 31-49 years 7 males (controls) 26-53 years both groups mainly sedentary prior to study	30-60 minutes/session at least 3 sessions/week intensity - 140-160 beats per minute 15 weeks of training	significant pre- post training group: ↑ HDLc; ↑ HDLc:TSC; ↓ LDLc; post-heparin* plasma LPL ↑
Kiens et al 1980	training group n=24 mean age ± S.D. 40 years ± 3.4 control group n=13 mean age ± S.D. 39 ± 5.0 years	various indoor and outdoor sports (e.g. gymnastics, running, or games) 45 minutes/day 3 times/week for 12 weeks at about 80% $\dot{V}O_2$ max	apoA-I ↑ significantly HDLc ↑ significantly TSC ↓ significantly TSTGL ↓ significantly all changes all pre- to post-training in the treatment group
Mhyre et al 1981	n=6 male treatment subjects (age 26.3 ± 3.7 years (S.D.)) active in cross-country skiing n=5 male control subjects (age 26.6 ± 5.9 years (S.D.)) sedentary	2 training periods 1) low intensity 70-80% VO_2max (July to December) 2) high intensity 80-95% VO_2max (December to March) fewer hours/month of training than low intensity period.	low intensity longer duration exercise produces greater increase in HDLc than does high intensity short duration exercise.
Streja & Mymin 1979	n=32 males aged 35-68 years mean age=53 years all subjects were sedentary prior to study	walking and jogging for 20-30 minutes/session at 70-85% of maximum heart rate (MHR) as determined by Balke treadmill test - training lasted 13 weeks	HDLc ↑ significantly no change in TSTGL

* LPL measured after intravenous injection of heparin
  - heparin releases LPL from the wall of a blood vessel

TABLE V - HUMAN CHRONIC AEROBIC EXERCISE STUDIES - LIPID AND LIPOPROTEIN PROFILES BEFORE AND AFTER A TRAINING PROGRAM (CONTINUED)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Murdoch 1980	12 sedentary males aged 25-59 with a history of high TSC, normotriglyceridemia, normal glucose tolerance, and normal body weight	12 weeks, 3 times/week, jogging (.6 (MHR-RHR) + RHR) and calisthenics	HDLc not Δ* significantly HDLC:TSC ↑ significantly LDLc, TSC ↓ significantly TSTGL not Δ significantly when compared pre- to post-training treatment relative to control
Thoden and Heick 1980	95 volunteer participants in Ontario Fitness Van	self-directed training program for 90 days	HDLc not Δ significantly HDLc:TSC ↑ significantly
Hartung et al 1981	-18 male participants with coronary disease -aged 32-67 years	-3 times weekly for 20 minutes increasing to 40 minutes at 70-85% of maximum heart rate -walking, jogging, ergometer and calisthenics -3 months of training	-HDLc, -HDLc:TSC ↑ significantly
Clark et al 1981	19 recent MI's 23 controls	-19 MI's underwent incremental (undefined) exercise program	training group pre/post: LDL, TSTGL ↓ significantly HDLc, A-I, HDL_2 ↑ significantly no significant change in HDL_3
Nye et al 1981	17 previously sedentary men 30-45 years	exercising 30-45 minutes at least twice/week -10 week period -intensity unspecified	pre-post training: HDL_2c ↑ significantly HDL_3c ↓ significantly HDLc no sig. change LDLc ↓ significantly

* Δ = changed

TABLE V - HUMAN CHRONIC AEROBIC EXERCISE STUDIES - LIPID AND LIPOPROTEIN PROFILES BEFORE AND AFTER A TRAINING PROGRAM (Continued)

AUTHORS	AVAILABLE DETAILS OF SUBJECTS	EXPERIMENTAL PROTOCOL	KEY RESULTS
Roundy et al 1978	51 adults - types II and IV hyperlipo-proteinemics	10 weeks, 3 times/week increasing duration constant intensity (pre-determined HR for each subject)	pre-B*, B* } lipoproteins significantly ↓ a-lp* ↑ significantly
Webster et al 1978	30 males in active group mean age 43.2 years 15 sedentary controls mean age 42.2 years	12 weeks, 3 times/week 45 minutes/session at a target HR of 76.4% (APMHR-RHR)+RHR	TSTGL, VLDLc } ↓ significantly no significant change in HDLc:LDLc ratio LDLc, TSC Significantly ↑ HDLc after 3 weeks of program - all significant changes are relative to the control group
Erkelens et al 1979	treatment group - 83 MI survivors control group I - 103 non-exercising MI survivors control group II - 172 randomly selected population controls	moderate exercise walking, jogging and calisthenics, 3 times/week of progressing intensity for 3 months	after 1 week (HDLc up significantly - mean change 4.9 mg%) - HDLc significantly higher in exercising MI survivors relative to non-exercising MI controls but not to group II
Hartung and Squires 1980	n=147 volunteer males (35-66 years) and 78 sedentary controls in same age range	active group jogged 6 miles/week (2 miles/session, 3 sessions/week)	HDLc significantly ↑ TSTGL significantly ↓ even when cigarette smoking/ body weight accounted for

* a-lp[1] (electrophoretic separation) ≚ HDL (ultracentrifugation) - approximately equal because a-lp may be contaminated with pre-B lipoprotein in electrophoresis - therefore LDL=B lipoprotein and pre-B lipoprotein ≙ VLDL

1 - lp = lipoprotein

sometimes because of incomplete precipitation of VLDL and LDL from the serum (Lopes-Virella et al 1977).

Other criticisms of longitudinal studies include: 1) failing to specify the type of diet since changes in the sources of calories can affect α-lipoprotein levels and have the inverse effect on pre-β and β-lipoprotein (Altekruse and Wilmore 1973) (see Appendix II), 2) the failure to control for weight loss (Ratliff et al 1978 and Hartung et al 1981) and 3) failing to use a control group as exemplified by Hartung et al (1981) which makes it difficult to know whether it was the exercise or seasonal variation in the lipoprotein concentrations (Warnick and Albers 1976) that was responsible for the increase in HDLc.

The TSTGL concentration dropped significantly in some studies (Huttenen et al 1979, Hartung and Squires 1980, Lopez-S et al 1974, Ratliff et al 1978, Webster et al 1978). This may have been due to enhanced peripheral uptake of fatty acids (FA) from TSTGL, which in turn may have been because of increased LPL activity (Froberg 1969). Increased LPL activity may lead to enhanced HDLc (Eisenberg et al 1975). TSTGL did not change significantly, however, in studies by Altekruse and Wilmore (1973) and Erkelens et al (1979). Perhaps the finding of no significant difference found by Altekruse and Wilmore (1973) resulted from either the short duration each session or the fact that increases in α-lipoprotein may not be mediated entirely by LPL.

The majority of longitudinal studies have failed to provide a comprehensive analysis of cigarette and alcohol consumption, dietary patterns and medications. Murdoch (1980) has written the most comprehensive study to date in terms of the factors affecting the distribution of cholesterol among the lipoprotein fractions. Murdoch found no significant change in HDLc but observed a significant rise in the HDLc:TSC ratio in the pre- to post-exercise treatment group as compared to the same period in the control group. Analysis of dietary pattern (including alcohol consumption) and cigarette consumption showed no change in either group and suggested that the significant changes seen were likely due to the exercise (Murdoch 1980). This study suggested that medication had not effected the changes seen in the biochemical variables.

Human LPL and LCAT Studies with Chronic Exercise

The levels of LPL and LCAT may rise with chronic physical activity (Nikkila et al 1978b, Lopez-S et al 1974).

Enhanced LPL activity, perhaps required to replete intramuscular TGL stores after each session of acute exercise, may lead to increased HDLc (Nikkila et al 1978b). LPL activity may rise secondary to an increase in skeletal muscle capillarization, the latter being dependent on chronic physical activity levels (Lithell et al 1981a).

Chronic exercise may lead to increased apo A-I levels which may result in an enhanced LCAT activity (Albers et al 1976). An increased LCAT activity was noted in 4 of 13 subjects (Lopez-S et al 1974). It was not specified why only

4 of the 13 subjects were assayed for LCAT activity and so the significant increase in LCAT activity may not represent the whole subject population. Further, apo A-I was not measured and therefore it is not known whether the increase seen in the four subjects was an apo A-I induced or enzyme concentration induced change or perhaps a combination of those processes. The method used to measure LCAT was that of Portman and Sugano (1964). This technique measures the enzyme concentration. LCAT has been suggested to augment HDLc concentrations (Glomset 1968).

Human studies suggest that an increase in LPL or LCAT activity is possible with chronic physical activity and that these increases may be the way by which exercise perhaps increases serum HDLc concentrations (Nikkila et al 1978b, Lopez-S et al 1974).

Summary of the State of the Knowledge of Human Chronic Exercise Studies, Lipoprotein, LPL, and LCAT Profiles

A lower risk of CASHD had been observed in the face of increased HDLc serum concentrations (Miller and Miller 1975, Rhoads et al 1976a, Tyroler et al 1975, and Castelli et al 1975). TSTGL and HDLc seem, respectively, to fall (Kiens et al 1980, Clark et al 1981) and rise (Webster et al 1978, Erkelens et al 1979) significantly with chronic aerobic exercise. It seems that chronic exercise may be responsible for a more positive lipid and lipoprotein profile relative to CASHD. However, in the studies indicating positive results (increased

HDLc and HDLc:TSC ratio), there are a number of inherent problems. These include the failure to control for weight loss, alcohol usage, changes in the levels of adiposity, the effects of the use of blood from non-fasting subjects and the imprecise data for the effects of smoking. Other problems include the failure to separate the effects of exercise from inherited constitutional differences and the lack of appropriate control groups.

CHAPTER III

METHODOLOGY

Introduction

There were two objectives for the experiment:

primary: to determine if one hour of cycling at a heart rate of 140-160 beats per minute (bpm) affects the immediate, 1 hour, 2 hour and 24 hour post-exercise measurements of serum HDLc, TSC, TSTGL, the HDLc:TSC ratio and the calculated LDLc in 19-51 year old untrained males.

secondary: to examine whether the post-exercise profiles were significantly altered in subjects who have either experienced or not experienced three bouts of exercise in the preceding 6 days.

All subjects conformed to the requirement of at least one year of sedentary lifestyle carried through the study.

Subjects

The thirty-one male volunteers ranged in age from 19 to 51 years. They were normolipidemic*, untrained ($\dot{V}O_2max$ < 50 mL/kg/min) without diabetic tendencies and with

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*TSC: 2.59-6.48 mmol/1
TSTGL: 0.79-2.82 mmol/1

clinically normal blood pressure (B.P.)($<$140/90 mm Hg). They demonstrated no clinical evidence of CHD, MI, EKG abnormalities, respiratory or other uncontrolled chronic disease. The acute treatment group (n=17) had a mean age of 24.6 years $\pm$ 6.1 ($\pm$ S.D.) with a range of 19-45 years, while the acute control group (n=14) had a mean age of 35.6 years $\pm$11.3 with a range of 19-51 years. The chronic treatment group (n=5) (subjects 2, 3, 8, 15, 17) had a mean age of 29.6 years $\pm$9.3 with a range of 21-45 years while the chronic control group (n=4) (subjects 19, 22, 31, 33) had a mean age of 26.0 years $\pm$7.6 with a range of 19-34 years. An insufficient number of volunteers wanted to participate as their own controls in the 2 experiments. This meant that two completely different groups of subjects had to be used in the treatment and control group. The percentage of recommended body weight was determined by the body mass index (kg /m^2) found in Thomas et al (1976). People with a TSTGL concentration of less than 4.52 mmol/l were used to meet that criterion of the Friedwald equation. Anyone taking specific antihyperlipidemic, antibiotic, terpene, nicotinic acid (niacin), corticosteroid, anti-malarial, tranquillizer, D-thyroxine, antiepileptic, or diuretic medications, and/or exposed to chlorinated hydrocarbon insecticides was eliminated from consideration because of the effect that these drugs and chemicals have on lipoprotein and/or lipid concentrations in the serum (Appendix II). All subjects were asked if they were using any of these agents at the time of the experiment. Subjects were asked to keep written records of alcohol and cigarette consumption as well as dietary patterns. Subjects were asked to maintain a normal but relatively isocaloric diet during the course of the study. There was, however, poor cooperation with the alcohol and diet request by some of the subjects but good cooperation by all smokers with regard to cigarettes.

Testing Procedures

A flow chart of the methodology for the acute and chronic phases of the experiment is found in Tables VI and VII. The treatment subjects cycled for only ½ hour on days 4 and 5 of the chronic experiment because the majority of them were unwilling to comply with 3 one hour rides due to constraints on their time and, more importantly, to exert themselves for one hour on each of 3 days.

The $\dot{V}O_2$max for all the treatment subjects was determined on a Monark bicycle ergometer and by open circuit gas analysis. The starting load was 600 kgm/min. for 5 minutes, with intermittent loads increasing by 300 kgm for each bout until the subject was able to complete 3 but not necessarily 5 minutes of a given load or was unable to accept a higher load of exercise. The expired air of the last 30 seconds of the 3rd and 5th minute of each exercise bout was collected and analyzed for carbon dioxide and oxygen. There was a 5 minute rest (or recovery to a heart rate of 110 bpm) between each exercise bout. The subject was considered to have reached his $\dot{V}O_2$max if he demonstrated a

TABLE VI
ACUTE EXPERIMENT
FLOW CHART OF METHODOLOGY (n=17 treatment
=14 control)

Day 1
1) pre-exercise blood* and hematocrit (pre(a))
2) weighing of subject
3) $\dot{V}O_2max$ test

↓ approximately 48 hours

Day 2
1) pre-exercise blood and hematocrit (pre(b))
2) weighing of subject
3) 1 hour of exercise at 140-160 bpm
4) immediately post-exercise blood sample and hematocrit (post)
5) 1 hour post-exercise (1) blood sample and hematocrit
6) 2 hour (2) post-exercise blood sample and hematocrit

↓ 24 hours

Day 3
1) 24 hour post-exercise blood and hematocrit (24(a))
2) weighing of subject

* all blood samples = 3 vacutainer vials x 5 cc blood/vial
control group treated identically to treatment group
except for exercise.

TABLE VII
CHRONIC EXPERIMENT FLOW CHART
OF METHODOLOGY

n=5 treatment subjects
n=4 control subjects

Days 1 to 3 inclusive
Acute experimental protocol for
subjects 2, 3, 8, 15, 17 *
Control subjects 19, 22, 31, 33.*

↓ 24 hours

Day 4
1) Weighing of subject
2) one half hour of exercise at
140-160 bpm

↓ 48 hours

Day 5
1) weighing of subject

2) one-half hour of exercise at
140 to 160 beats per minute

↓ 24 hours

Day 6
1) 24 hour post-Day 5 exercise
(24b)
2) weighing of subject

* immediately post-exercise(p0), 1 hour post(p1) and 2 hours post-exercise(p2) samples were taken but this data could not be used in the repeated measures analysis of covariance due to the small number of subjects.

' p0 - non-exercising control group equivalent of immediately post-exercise
p1 - non-exercising control group equivalent of 1 hour post-exercise
p2 - non-exercising control group equivalent of 2 hours post-exercise

plateauing of his oxygen consumption in the final 2 or 3 bouts. A linear regression analysis was done between $\dot{V}O_2$max (ordinate) and load (abcissa) for each subject to determine the 60% $\dot{V}O_2$max load.

A submaximal predictive $\dot{V}O_2$max test was done, at the request of their physician, on a bicyle ergometer by eight of the older control subjects for whom maximal exercise may have offered some risk. This was performed following their last blood sample on day 3. It was felt that there was no value in having the 6 remaining control subjects do a $\dot{V}O_2$max test.

The heart rate for the exercise treatment group was determined by graphing heart rate (ordinate) against $\dot{V}O_2$ (abcissa) for each of the workloads of the $\dot{V}O_2$max test. The intersection of the 60% $\dot{V}O_2$max point with the plot determined the heart rate for the exercise treatments. So as to present approximately the same exercise stressor to each subject, the intensity was maintained between 140 and 160 beats per minute and was assessed at ten-minute intervals during the ride. Open circuit gas analysis and heart rates were used to ensure the maintenance of the pre-determined intensity for a given subject (deviations of no more than $\pm$150 ml of O_2/ hour (open circuit gas analysis) or $\pm$5 heart beats/min were allowed).

The Cambridge VS4 EKG instrument was used to determine heart rates. Gas analysis was done by a Tissot tank, Godart Oxygen analyzer and Godart capnograph. A Narco four-B physiograph was used to record $\dot{V}O_2$ and the volume of expired

CO_2 per minute ($\dot{V}CO_2$). A potentiometer attached to the Tissot tank was used to determine the ventilations and the total expired gas volume per minute ($\dot{V}e$).

The subjects were asked to cycle at 50 rpm* (as assessed by an rpm counter) until they had cycled for the time dictated by the experimental protocol or until they met the major American College of Sports Medicine (ACSM 1976) guidelines for the cessation of exercise. These are:

1. The presence of successive or multifocal premature ventricular contractions (PVC's), the occurrence of 2 PVC's within a 6 second interval or a PVC falling on a T wave.

2. A rapid continuous fall in the ST_2 segment, below -2 mm. or an ST_2 segment reading of -2.5 mm.

3. A horizontal or downsloping ST_2 slope, with an ST_2 segment depression of -1 mm. or more.

4. A rise in the diastolic B.P. over 100 mm. Hg. or a rise of more than 20 mm. Hg.

5. A sudden or continuous fall in the systolic blood pressure.

6. Symptoms of significant exertional intolerance such as dizziness, angina, unusual fatigue, claudication or pain.

---

*50 rpm was selected as being the most comfortable pace for the subjects for the $\dot{V}O_2$max test and this pace was carried into the experimental protocol.

7. Signs of intolerance, such as staggering, mental confusion, cyanosis, pallor, dyspnea, or nausea.

These criteria were applied to the $\dot{V}O_2$max test as well.

The control group differed only in that they did not do the exercise treatment for a given experiment.

Blood Analysis

The blood sampling protocol was identical for the experimental and control group and is detailed in Tables VI and VII.

Hematocrit (Hct.) was done at each of the blood sampling times. All biochemical parameters were linearly corrected for changes in hematocrit on the basis of:

$$\left.\begin{array}{l} y = x - \%\ \text{increase in hematocrit}\ (x) \\ \\ y = x + \%\ \text{decrease in hematocrit}\ (x) \end{array}\right\} \begin{array}{l}\text{Percentage is for a} \\ \text{given post-exercise point} \\ \text{relative to pre-exercise.}\end{array}$$

x = uncorrected value

y = corrected value

Fasting (12-14 hours) serum was used for all determinations of lipoproteins and lipids. The subjects were asked if they had complied with the request to fast. Two samples were taken within approximately 48 hours of each other to determine mean resting levels of all biochemical parameters. Samples were taken at the same time every day.

HDLc Analysis

Samples taken for HDLc analysis were assayed within one month of being drawn to avoid the increase in HDLc observed with prolonged freezing of serum (Reckless et al 1977).

HDLc was isolated from LDL and VLDL by precipitation of the latter two lipoproteins with polyvalent anions and bivalent cations, a method originally developed by Burstein and Samaille (1960). The basis of the precipitation technique for the determination of HDLc in this study was based on the precipitation of the apo-B containing lipoproteins (VLDL and LDL) by sodium phosphotungstate and $MgCl_2$. It is thought that the sodium phosphotungstate binds to the lipoprotein and then Mg^{2+} binds to the sodium phosphotungstate. This process formed an insoluble lipoprotein-polyanion-divalent cation complex (Burstein et al 1970). The centrifugation step led to the completion of the precipitation of the VLDL and LDL leaving the HDL in the supernatant. The determination of the cholesterol in the supernatant, therefore, reflected the cholesterol content of the HDL fraction.

Sodium phosphotungstate and magnesium were used since the alternate heparin manganese precipitation has been noted to overestimate HDLc levels (Lopes-Virella et al 1977). This overestimation occurs because of incomplete precipitation of VLDL and LDL. The method of precipitation used in this study correlates r = +0.82 with ultracentrifugation, but according to Albers et al (1978) and Calvert et al (1980) may give an underestimation in some cases. As the sodium phosphotungstate is stable for six months (Lopes-Virella et al 1977) which is not the case with heparin, it may be used for a greater number of samples. Therefore, the variability in HDLc analysis is less using sodium phosphotungstate than it is with heparin (Murdoch 1980).

The supernatants were prepared for HDLc analysis according to the method of Lopes-Virella et al (1977) except that all volumes were reduced by one-half. The cholesterol of the supernatant was analyzed according to the Worthington cholesterol reagent method which is based largely on the technique of Allain et al (1974).

The reproducibility of this method was determined using 10 aliquots of pooled serum which were analyzed for HDLc at the same time. Intra-analysis variability was determined by separating the serum into 3, 1.5 ml. aliquots all of which were analyzed on different days for HDLc. The quality control work appears in Appendices III and IV.

TSC and TSTGL Analysis

TSC and TSTGL were analyzed enzymatically, the former by the Worthington cholesterol reagent method and the latter by the Boehringer Mannheim triglyceride kit (based on Eggstein and Kreutz 1966).

The first step of the TSC determination was the hydrolysis of cholesterol esters by cholesterol esterase to cholesterol and free fatty acids. The cholesterol was then oxidized by cholesterol oxidase to cholesten-3-one and hydrogen peroxide. The hydrogen peroxide was coupled by peroxidase with the chromogen, 4-aminoantipyrine, in the presence of phenol to produce a quinoneimine dye. The change in absorption at 500 nm., the absorption maximum for the dye, directly reflected the TSC (Lopes-Virella et al 1977).

The first step of the TSTGL determination was the saponification of the triglyceride with alcoholic potassium hydroxide to form glycerol and free fatty acids. Glycerol kinase converted the glycerol and ATP to glycerol-3-phosphate and ADP. Pyruvate kinase converted the ADP and phosphoenolpyruvate to ATP and pyruvate. The pyruvate in the presence of NADH and protons was changed to lactate. NAD^+ was also produced in this last reaction. The amount of NADH, a photoabsorptive molecule, oxidized is equal to the glycerol and hence the TSTGL in the sample. That is, the decrease in the absorption is a direct measure of the TSTGL.

Two different runs on different days using cholesterol and triglyceride standards were done to determine a coefficient of variance respectively for TSC and TSTGL. Reliability was assessed by analyzing a pooled serum sample on two different days for TSTGL and TSC. The cholesterol standard (2.93 mmol/l) was diluted to 1.465 mmol/l and also analyzed on two different days as an additional measure of the reliability of the HDLc determinations. Appendices III and IV contain quality control work for these assays.

LDLc Analysis

LDLc was determined by calculation (LDLc = TSC-(TSTGL /5)-HDLc) (Friedwald et al 1972) and for this reason only those subjects with TSTGL levels of less than 4.52 mmol/l were accepted for study.

Statistical Analysis

A two-way repeated measures analysis of covariance (ANCOVA) was used for the hematocrit, weight and biochemical variables of the acute and chronic experiments.

In ANCOVA, the post-exercise means are adjusted to account for the variance in the pre-exercise means. That is, the post-exercise means were adjusted on the basis of the variance in the pre-exercise means. The statistical analysis pertained only to the adjusted post-exercise means. In the treatment group, significant change ($p < .05$) was determined, for both designs, by comparing the difference between all possible combinations of any two post-exercise points to the comparable period in the control group.

Treatment subject 9 was dropped from all repeated measures ANCOVA due to missing data. Treatment subject 5 was dropped from all statistical analyses with TSTGL due to 2 missing pre-values. Control subjects 27 and 28 were initially considered and then were removed due to their use of propranolol. This explains the two control groups consisting of 14 and then 12 subjects.

There were 2 pre-exercise values taken for each of the biochemical parameters. Full correlations were done between all of the biochemical variables using the averaged pre-exercise values in the total subject pool. Partial correlations for the total subject pool were run among the averaged pre-exercise values of all the biochemical variables; in this case, the effects of age, weight and body mass index (BMI) were factored out[1]. Partial correlations for the treatment group were also run between each of the averaged pre-exercise values of the 5 biochemical variables. In this case, $\dot{V}O_2max$, age, weight and BMI were factored out[1]. Correlations between HDLc and TSTGL, HDLc and TSC, the HDLc:TSC ratio and TSTGL, and TSC and LDLc were done for the immediately post-exercise to 1 hour post-exercise interval[1]. Immediately post- to 1 hour post-exercise was important because of the significant increase in the HDLc:TSC ratio and the significant decrease in LDLc in that interval of the acute experiment.

In the total subject pool (n=9) of chronic experiment, full and partial correlations were run between each of the mean pre-exercise levels of each of the 5 biochemical variables. When the partial correlations were done, the effect of age, weight and BMI on the averaged pre-exercise values of the biochemical variables were factored out. In order to give more meaning to the correlations, their 95% confidence intervals are found in each table of correlations.

[1] Correlations were not done between age, weight, BMI, $\dot{V}O_2max$ and the biochemical variables or changes in the biochemical variables since there was no significant difference between the full and partial correlations. Correlations were not done for any biochemical variable and changes in that variable since an ANCOVA would compensate for any effect that any group differences in the pre-values could have on the post-values. Correlations are only a measure of association and not necessarily of cause and effect. Significance ($p < .05$) means that there is less than a 5% chance of rejecting a null hypothesis.

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter the acute data is presented and discussed. This is followed by the presentation and discussion of acute data where the treatment group has been matched with the control group on the basis of age, weight and BMI. The final section deals with the chronic experiment's data. An outline of the chapter is presented in Table VIII.

The statistically significant changes are defined in the context of going from one post-exercise point to another post-exercise point in the treatment group and comparing it to the same period in the control group.

Acute Experiment - Biochemical Data

There was a statistically significant ($p < .05$) increase and decrease respectively in the HDLc:TSC ratio and the LDLc concentration in going from immediately post- to 1 hour post-exercise . The statistical analysis used was a repeated measures ANCOVA.

The levels of LDLc were significantly lower (Table IX) and the HDLc:TSC ratio significantly higher (Table X) at 1 hour post-exercise than at any other post-exercise point. There were no other statistically significant results in the biochemical variables.

In the treatment group (n=16), HDLc and the HDLc:TSC ratio consistently rose to 1 hour post-exercise. By two hours

TABLE VIII
FLOW CHART FOR THE PRESENTATION AND DISCUSSION OF RESULTS OF THE CURRENT EXPERIMENT

Presentation and discussion of un-matched* acute experiment data

↓

concern expressed over treatment vs control group differences in age, weight and body mass index (BMI)

↓

presentation and discussion of matched* acute data

↓

presentation and discussion of chronic exercise data
(includes statement of whether chronic effects are the accumulation of acute effects)

[1]changes in hematocrit
[1]changes in weight
[1]changes in adiposity

[1]alcohol
[1]medications
[1]diet
[1]cigarettes

* un-matched - use of data where the treatment group was not post-hoc matched with the control group on the basis of age, weight and BMI

* matched - use of data where the treatment group was post-hoc matched with the control group on the basis of age, weight and BMI

1 factors affecting concentration of cholesterol in lipoprotein fractions.
The current study controlled for changes in weight, hematocrit, adiposity and cigarette consumption. This is a refinement of the state of the art for acute exercise studies.

TABLE IX
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN LOW DENSITY LIPOPROTEIN CHOLESTEROL
LDLc (mmol/1)

TREATMENT Subject No.[1]	pre[a]	post[a]	A.D.[b]	% Diff[b]	1[a]	A.D.[b]	% Diff[b]	2[a]	A.D.[b]	% Diff[b]	24a[a]	A.D.[b]	% Diff.[b]
01	1.83	1.50	-0.33	-18.0	1.71	-0.12	- 6.7	2.11	0.28	15.4	1.97	0.14	7.9
02	2.40	2.70	0.30	12.3	2.75	0.35	14.3	2.45	0.05	1.7	2.80	0.40	16.5
03	2.02	2.32	0.30	14.9	2.32	0.30	14.9	2.14	0.12	6.0	1.85	-0.17	- 8.5
04	1.91	1.91	0.00	0.0	1.62	-0.29	-15.1	1.49	-0.42	-21.8	1.64	-0.27	-14.1
05	3.25	3.05	-0.20	- 6.3	2.54	-0.71	-21.8	3.57	0.32	9.8	4.78	1.53	47.2
06	2.09	2.18	0.09	4.2	2.08	-0.01	- 0.5	2.39	0.30	14.5	2.70	0.61	29.3
07	2.95	2.61	-0.34	11.8	2.13	-0.82	-27.9	2.80	-0.15	- 5.1	2.70	-0.25	- 8.6
08	3.60	4.08	0.48	13.4	3.99	0.39	10.9	4.27	0.67	18.7	3.82	0.22	6.3
09	3.24	3.37	0.13	4.1	3.07	-0.17	- 5.4	3.39	0.15	4.4	#	#	#
10	2.64	2.67	0.03	1.2	2.37	- 0.27	-10.2	2.83	0.19	7.4	2.22	-0.42	-15.9
11	2.55	2.83	0.28	11.0	2.71	0.16	6.1	2.57	0.02	0.6	2.23	-0.28	-12.7
12	2.02	1.84	-0.18	- 9.0	1.92	-0.10	- 4.6	1.30	-0.72	-35.6	2.08	0.06	2.4
13	3.53	3.59	0.06	1.6	3.46	-0.07	- 2.1	3.53	0.00	0.0	2.70	-0.83	-23.4
14	1.87	1.69	-0.18	- 9.1	1.39	-0.48	-25.9	1.18	-0.69	-37.3	1.56	-0.31	-16.6
15	1.78	1.35	-0.43	-24.4	1.80	0.02	0.7	1.72	-0.06	- 3.5	1.58	-0.20	-11.5
16	1.57	1.56	-0.01	-0.08	0.78	-0.79	-50.1	1.49	-0.08	- 4.6	1.66	0.09	5.8
17	1.57	1.47	-0.10	- 6.4	1.69	0.12	8.1	2.12	0.55	35.5	2.15	0.58	37.4
Mean ± S.D.	2.39* ± 0.67	2.33* ± .80	-0.02	- 0.7	2.20* ± 0.78	-0.15	- 6.1	2.37* ± 0.86	0.02	0.7	2.40* ± 0.87	0.05	0.2

[a]pre = pre-exercise (average of pre-a and pre-b)
[a]post = immediately post-exercise
[a]1 = 1 hour post-exercise
[a]2 = 2 hours post-exercise
[a]24a = 24 hours post-exercise
# = subject failed to present for sample
* means ± S.D. (excluding subject 9) (mmol/1)
[b] A.D. = absolute difference
[b] % Diff. = percentage difference
b = differences are pre- to a given post-exercise point

TABLE IX
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN LOW DENSITY LIPOPROTEIN CHOLESTEROL
LDLc (mmol/l) (Continued)

CONTROL Subject No.	pe[a]	p0[a]	A.D.[b]	% Diff.[b]	p1[a]	A.D.[b]	% Diff.[b]	p2[a]	A.D.[b]	% Diff.[b]	p24a[a]	A.D.[b]	% Diff.[b]
19	2.95	2.80	-0.15	- 4.8	3.66	0.71	24.4	3.81	0.86	29.1	2.59	-0.36	-12.0
20	2.53	2.63	0.10	4.2	2.41	-0.12	- 4.6	2.09	-0.44	-17.4	2.10	-0.43	-17.1
22	3.36	3.25	-0.09	- 3.3	3.43	0.07	2.1	3.48	0.12	3.5	3.20	-0.16	- 4.8
23	2.05	1.42	-0.63	-30.7	2.05	0.00	0.0	1.95	-0.10	- 5.2	1.89	-0.16	- 8.0
24	2.82	2.42	-0.40	-14.0	2.96	0.14	4.9	2.72	-0.10	- 3.8	3.11	0.29	10.3
25	3.79	4.05	0.26	7.0	3.78	-0.01	- 0.2	4.20	0.41	10.9	3.20	-0.59	-15.5
26	3.77	3.63	-0.14	- 3.8	3.81	0.04	0.9	3.33	-0.44	-11.7	3.43	-0.34	- 9.2
27	2.88	3.30	0.42	14.9	3.13	0.25	8.9	2.70	-0.18	- 6.8	2.48	-0.40	-13.9
28	1.13	1.74	0.61	53.7	1.92	0.79	69.7	1.76	0.63	55.7	1.24	0.11	9.7
29	3.72	4.33	0.61	16.7	4.00	0.28	7.0	4.45	0.73	19.8	4.20	0.48	13.0
30	3.96	2.80	-1.16	-29.6	2.90	-1.06	-26.9	3.33	-0.63	-16.0	3.03	-0.93	-23.8
31	3.28	3.19	-0.09	- 2.6	3.26	-0.02	- 0.6	3.05	-0.23	- 7.0	3.09	-0.19	- 5.8
32	3.29	3.96	0.67	20.6	3.87	0.58	17.7	3.64	0.35	10.9	3.77	0.48	14.7
33	1.75	1.06	-0.69	-39.2	1.95	0.20	11.2	2.02	0.27	15.1	1.55	-0.20	-11.2
Mean ± S.D.	2.95 ± 0.84	2.90 ± 0.99	-0.05	- 1.6	3.08 ± 0.74	0.13	4.5	3.04 ± 0.86	0.09	3.0	2.78 ± 0.84	-0.17	- 5.8

[a]pe = non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p0 = non-exercising control group equivalent of post-exercise in treatment group
p1 = non-exercising control group equivalent of 1 in treatment group
p2 = non-exercising control group equivalent of 2 in treatment group
p24a = non-exercising control group equivalent of 24a in treatment group
A.D. = absolute difference
% Diff. = percentage difference
[b] - differences are pe- to any other blood sampling time

TABLE X
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN THE HIGH DENSITY LIPOPROTEIN
CHOLESTEROL:TOTAL SERUM CHOLESTEROL RATIO
HDLc:TSC RATIO

TREATMENT Subject No.	pre[a]	post[a]	A.D.[b]	% Diff.[b]	1[a]	A.D.[b]	% Diff.[b]	2[a]	A.D.[b]	% Diff.[b]	24a[a]	A.D.[b]	% Diff.[b]
01	.360	.403	.043	11.9	.396	.036	10.0	.363	.003	0.8	.349	-.011	- 3.1
02	.251	.235	-.016	- 6.4	.239	-.012	- 4.8	.253	.002	0.8	.228	-.023	- 9.2
03	.313	.335	.022	7.0	.321	.008	2.6	.342	.029	9.3	.317	.004	12.8
04	.344	.323	.021	- 6.1	.394	.050	14.5	.369	.025	7.3	.342	-.002	- 0.7
05	.236	.253	.017	7.2	.334	.098	41.5	.215	-.021	-8.9	.207	-.029	-12.3
06	.242	.322	.080	33.1	.339	.097	40.1	.301	.059	24.4	.390	.148	61.2
07	.261	.284	.023	8.8	.324	.063	24.1	.271	.010	3.8	.297	.036	13.8
08	.244	.223	-.021	- 8.6	.223	-.021	- 8.6	.208	-.036	-14.8	.253	.009	3.7
09	.230	.223	-.007	- 3.0	.243	.013	5.7	.222	.008	3.5	#	#	#
10	.281	.284	.003	1.1	.291	.010	3.6	.259	-.022	-7.8	.313	-.032	-11.4
11	.265	.240	-.025	- 9.4	.256	-.009	- 3.4	.261	-.004	-1.5	.315	.050	18.9
12	.306	.299	-.007	- 2.3	.331	.025	8.2	.370	.064	20.9	.289	.017	5.6
13	.206	.190	-.016	- 7.8	.190	-.016	- 7.8	.186	-.020	-9.7	.211	-.005	2.4
14	.315	.345	.030	9.5	.417	.102	32.3	.456	.141	44.8	.407	.092	29.2
15	.358	.461	.103	28.8	.392	.034	9.5	.381	.023	6.4	.409	.051	14.2
16	.406	.399	-.007	-17.2	.548	.142	35.0	.425	.019	4.7	.398	-.008	- 2.0
17	.433	.480	.037	8.5	.412	-.021	- 4.8	.378	-.055	-12.7	.369	-.064	-14.8
Mean	.301*	.317*	.016	3.3	.338*	.037	12.3	.315*	.014	4.7	.318*	.017	5.6
S.D.	±.065	±.084			±.089			±.081			±.068		

[a]pre = pre-exercise (average of pre-a and pre-b)
[a]post = immediately post-exercise
[a]1 = 1 hour post-exercise
[a]2 = 2 hours post-exercise
[a]24a = 24 hours post-exercise
# = subject failed to present for sample
* means ± S.D. (excluding subject 9) (mmol/l)
A.D. = absolute difference
% Diff. = percentage difference
b = differences are pre- to a given post-exercise point

TABLE X
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN THE HIGH DENSITY LIPOPROTEIN
CHOLESTEROL:TOTAL SERUM CHOLESTEROL RATIO
HDLc:TSC RATIO (Continued)

CONTROL Subject No.	pe[1,a]	po[a]	A.D.[b]	% Diff.[b]	p1[a]	A.D.[b]	% Diff.[b]	p2[a]	A.D.[b]	% Diff.[b]	p24a[a]	A.D.[b]	% Diff.[b]
19	.239	.271	.032	13.3	.224	-.015	- 6.3	.237	-.002	- 0.8	.313	.074	30.9
20	.340	.323	-.017	- 5.0	.338	-.002	- 0.7	.350	.010	2.9	.363	.023	6.8
22	.235	.254	.019	8.1	.264	.029	12.3	.246	.011	4.7	.279	.044	18.7
23	.385	.507	.122	37.7	.390	.005	1.3	.398	.013	3.4	.396	.011	2.9
24	.305	.337	.032	10.5	.293	-.012	- 3.9	.344	.039	12.8	.302	-.003	- 0.9
25	.207	.215	.008	3.9	.224	.017	8.2	.211	.004	19.3	.252	.045	21.7
26	.181	.189	.009	5.0	.178	-.003	- 1.7	.220	.039	21.5	.183	.002	1.1
27	.230	.211	-.019	- 8.3	.227	-.003	- 1.3	.244	.014	6.1	.243	.013	5.6
28	.333	.291	-.042	-12.6	.258	-.075	-22.5	.264	-.069	-20.7	.383	.050	15.0
29	.198	.178	-.020	-10.1	.185	-.013	- 6.6	.173	-.025	-12.7	.180	-.018	- 9.1
30	.198	.274	.076	38.3	.274	.076	38.3	.261	.063	31.8	.256	.058	29.3
31	.212	.228	.016	7.5	.221	.009	4.2	.214	.002	0.8	.234	.022	10.4
32	.166	.156	-.010	- 6.0	.160	-.006	- 3.6	.163	-.003	- 1.8	.161	-.005	- 3.0
33	.374	.441	.067	17.9	.379	.005	1.3	.367	-.007	- 1.9	.437	.063	16.8
Mean S.D.	.257 ±.074	.277 ±.099	.020	7.8	.258 ±.071	.001	0.9	.264 ±.073	.007	2.7	.284 ±.086	.027	10.5

1 - average of pe-a and pe-b values
a pe = non-exercising control group equivalent of pre-exercise in treatment group
po = non-exercising control group equivalent of post-exercise in treatment group
p1 = non-exercising control group equivalent of 1 in treatment group
p2 = non-exercising control group equivalent of 2 in treatment group
p24a = non-exercising control group equivalent of 24a in treatment group
A.D. = absolute difference
% Diff. = percentage difference } b - differences are pe- to any other blood sampling time

post-exercise they had decreased,but approaching 24 hours post-exercise (24a) showed a slight rise (Tables X and XI). In the control group (n=14), HDLc and the HDLc:TSC ratio increased to p0* but decreased to pe* levels at p1* and then rose gradually through p2* to p24a* (Tables X and XI).

TSC remained fairly constant in the treatment group except for a 4.0% drop at 1 hour post-exercise relative to the pre-exercise level (Table XII). This pattern was repeated by LDLc (Table IX). In the control group, both LDLc and TSC maintained a reasonably flat profile with a mild drop between p2 hours and p24a (Tables IX and XII). LDLc, however, was somewhat elevated at p1 and p2 hours in the control group.

The treatment group revealed a fairly stable profile in TSTGL except for a pronounced 10.1% drop at 1 hour post-exercise relative to the pre-exercise level (Table XIII). The TSTGL levels of the control group were constant until a sharp drop at p1. This depressed mean value was maintained through p2 hours. The p24a levels were near those of pe (Table XIII).

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*pe = equivalent in the non-exercising control subjects of pre-exercise in the treatment subjects.
*p0 = equivalent in the non-exercising control subjects of immediately post-exercise (post-) in the treatment subjects.
*p1 = equivalent in the non-exercising control subjects of 1 hour post-exercise (1) in the treatment subjects
*p2 = equivalent in the non-exercising control subjects of 2 hours post-exercise (2) in the treatment subjects
*p24a = equivalent in the non-exercising control subjects of 24 hours post-exercise (24a) in the treatment subjects.

TABLE XI
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN HIGH DENSITY LIPOPROTEIN CHOLESTEROL
HDLc (mmol/l)

TREATMENT Subject No.	pre[a]	post[a]	A.D.[b]	% Diff.[b]	1[a]	A.D.	% Diff.	2[a]	A.D.	% Diff.	24a[a]	A.D.	% Diff.
01	1.22	1.26	0.04	3.6	1.34	0.12	10.0	1.29	0.07	6.4	1.23	0.01	0.9
02	0.98	1.03	0.05	4.8	1.03	0.05	4.8	1.04	0.06	5.8	1.02	0.04	4.5
03	1.20	1.32	0.12	10.0	1.25	0.05	4.1	1.25	0.05	4.1	1.20	0.00	0.00
04	1.14	1.00	-0.14	-11.4	1.18	0.04	3.4	1.07	-0.07	- 6.4	1.04	-0.10	- 8.4
05	1.14	1.20	0.06	5.2	1.32	0.18	15.7	1.27	0.13	12.1	1.31	0.17	15.3
06	1.12	1.19	0.07	6.5	1.23	0.11	10.4	1.09	-0.03	- 2.1	1.25	0.13	11.6
07	1.20	1.20	0.00	0.0	1.24	0.04	2.8	1.24	0.04	2.8	1.20	0.00	0.0
08	1.25	1.27	0.02	1.6	1.24	-0.01	- 0.8	1.20	-0.05	- 4.1	1.37	0.12	9.3
09	1.18	1.13	-0.05	- 3.7	1.22	0.04	3.3	1.17	-0.01	- 0.4	#	#	#
10	1.17	1.24	0.07	6.4	1.21	0.03	3.6	1.10	-0.07	- 6.4	1.22	0.05	4.9
11	1.02	0.99	-0.03	- 3.5	-0.99	-0.03	- 3.5	-0.99	-0.03	- 3.5	1.11	0.09	8.9
12	1.05	1.09	0.04	3.7	1.12	0.07	6.7	1.22	0.17	15.5	1.05	0.00	0.0
13	1.04	1.01	-0.03	- 2.8	1.00	-0.04	- 3.0	0.96	-0.08	- 7.0	1.05	0.01	1.5
14	1.02	1.09	0.07	6.6	1.16	0.14	12.9	1.30	0.28	26.8	1.26	0.24	23.2
15	1.16	1.37	0.21	18.0	1.28	0.12	10.2	1.26	0.10	8.5	1.32	0.16	13.4
16	1.28	1.25	-0.03	- 2.8	1.26	-0.02	- 2.0	1.27	-0.01	- 0.6	1.28	0.00	0.0
17	1.58	1.73	0.15	9.7	1.56	-0.02	- 0.5	1.55	-0.03	- 1.8	1.40	-0.18	-11.0
Mean $\pm$ S.D.	$1.16 \pm .14$*	$1.20 \pm .18$*	0.04	3.5	1.21 ± 0.05*	0.05	4.1	$1.19 \pm .14$*	0.03	2.7	$1.21 \pm .12$*	0.05	4.1

[a] pre = pre-exercise (average of pre-a and pre-b)
[a] post = immediately post-exercise
[a] 1 = 1 hour post-exercise
[a] 2 = 2 hours post-exercise
[a] 24a = 24 hours post-exercise
= subject failed to present for sample
* means $\pm$ S.D. (excluding subject 9) (mmol/l)
A.D. = absolute difference
% Diff. = percentage difference
b = differences are pre- to a given post-exercise point

TABLE XI
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN HIGH DENSITY LIPOPROTEIN CHOLESTEROL
HDLc (mmol/1) (Continued)

CONTROL Subject No.	pe[1][a]	p0[a]	A.D.[b]	% Diff.[b]	p1[a]	A.D.[b]	% Diff[b]	p2[a]	A.D.[b]	% Diff[b]	p24a[a]	A.D.[b]	% Diff.[b]
19	1.24	1.47	0.23	18.7	1.27	0.03	2.9	1.27	0.03	2.9	1.51	0.27	22.2
20	1.35	1.43	0.08	6.2	1.38	0.03	2.3	1.34	-0.01	- 0.7	1.41	0.06	5.0
22	1.27	1.25	-0.02	- 1.4	1.31	0.04	3.7	1.31	0.04	3.7	1.28	0.01	0.8
23	1.51	1.67	0.16	10.2	1.44	-0.07	- 4.8	1.52	0.01	0.6	1.48	-0.03	- 2.1
24	1.47	1.55	0.08	5.6	1.46	-0.01	- 0.6	1.63	0.16	11.2	1.52	0.05	3.5
25	1.27	1.34	0.07	5.1	1.30	0.03	2.0	1.23	-0.04	- 3.5	1.41	0.14	10.4
26	0.99	1.04	0.05	4.4	0.98	-0.01	- 1.3	1.13	0.14	14.0	0.97	-0.02	- 2.9
27	0.99	0.99	0.00	0.0	1.06	0.07	7.0	1.08	0.09	9.7	1.04	0.05	5.7
28	1.16	1.06	-0.10	- 8.3	0.92	-0.24	-20.7	0.92	-0.24	-20.7	1.24	0.08	6.5
29	1.14	1.08	-0.06	- 5.9	1.05	-0.09	- 8.4	1.07	-0.07	- 6.1	1.09	-0.05	- 4.4
30	1.08	1.25	0.17	16.0	1.23	0.15	13.9	1.32	0.24	22.6	1.16	0.08	7.5
31	0.97	1.04	0.07	8.0	1.02	0.05	5.6	0.93	-0.04	- 4.1	1.02	0.05	5.6
32	0.92	0.95	0.03	3.1	0.95	0.03	3.1	0.91	-0.01	- 1.4	0.96	0.04	4.5
33	1.25	1.39	0.14	11.0	1.39	0.14	11.0	1.36	0.11	9.1	1.38	0.13	10.4
Mean ± S.D.	1.19±0.18	1.25±.23	0.06	5.5	1.20±.19	0.01	0.9	1.22±.22	0.03	2.6	1.25±.21	0.06	5.5

[1] - average of pe-a and pe-b values
[a] pe = non-exercising control group equivalent of pre-exercise in treatment group
p0 = non-exercising control group equivalent of post-exercise in treatment group
p1 = non-exercising control group equivalent of 1 in treatment group
p2 = non-exercising control group equivalent of 2 in treatment group
p24a = non-exercising control group equivalent of 24a in treatment group
A.D. = absolute difference
% Diff. = percentage difference $\}$ b - differences are pe- to any other blood sampling time

TABLE XII
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM CHOLESTEROL
TSC (mmol/1)

TREATMENT Subject No.	pre[a]	post[a]	A.D.[b]	% Diff[b]	1[a]	A.D.[b]	% Diff[b]	2[a]	A.D.[b]	% Diff[b]	24a[a]	A.D.[b]	% Diff[b]
01	3.38	3.12	-0.26	- 7.5	3.38	0.00	0.0	3.56	0.18	5.4	3.51	0.13	4.0
02	3.89	4.37	0.48	12.3	4.30	0.41	10.3	4.10	0.21	5.3	4.50	0.61	15.5
03	3.82	3.91	0.09	2.7	3.88	0.06	1.5	3.65	-0.17	- 4.5	3.79	-0.03	- 0.9
04	3.31	3.12	-0.19	- 5.7	2.98	-0.33	- 9.8	2.88	-0.43	-12.8	3.04	-0.27	- 7.9
05	4.81	4.80	-0.01	- 0.3	3.95	-0.86	-18.0	5.94	1.13	23.4	6.32	1.51	31.4
06	3.85	3.69	-0.16	- 4.3	3.63	-0.22	- 5.7	3.63	-0.22	- 5.7	3.20	-0.65	-17.1
07	4.59	4.23	-0.36	- 8.3	3.82	-0.77	-17.2	4.55	-0.04	- 0.8	4.05	-0.54	-12.1
08	5.12	5.71	0.59	11.5	5.56	0.44	8.5	5.76	0.64	12.5	5.41	0.29	5.7
09	5.11	5.08	-0.03	- 0.7	4.99	-0.12	- 2.2	5.26	0.15	3.0	∅	∅	∅
10	4.15	4.36	0.21	5.1	4.15	0.00	0.0	4.23	0.08	1.8	3.91	-0.24	- 5.8
11	3.85	4.12	0.27	6.9	3.86	0.01	- 0.3	3.79	-0.06	- 1.7	3.54	-0.31	- 8.1
12	3.45	3.65	0.20	5.6	3.39	-0.06	- 1.8	3.28	-0.17	- 4.9	3.62	0.17	4.9
13	5.10	5.30	0.20	3.8	5.14	0.04	0.8	5.18	0.08	1.5	4.99	-0.11	- 2.1
14	3.25	3.16	-0.09	- 2.9	2.77	-0.48	-14.7	2.84	-0.41	-12.5	3.10	-0.85	- 4.5
15	3.25	2.99	-0.26	- 8.1	3.27	0.02	0.5	3.31	0.06	1.9	3.23	-0.02	- 0.7
16	3.16	3.12	-0.04	- 1.1	2.29	-0.87	-27.4	2.97	-0.19	- 5.8	3.23	0.07	2.3
17	3.64	3.60	-0.04	- 0.9	3.79	0.15	4.1	4.10	0.46	12.6	3.76	0.12	3.3
Mean * ± S.D.	3.92±0.67	3.95±0.82	0.03	0.8	3.76±0.81	-0.16	- 4.0	3.99±0.96	0.07	1.8	3.95±0.92	0.03	0.9

[a]pre = pre-exercise (average of pre-a and pre-b)
[a]post = immediately post-exercise
[a]1 = 1 hour post-exercise
[a]2 = 2 hours post-exercise
[a]24a = 24 hours post-exercise
∅ = subject failed to present for sample
* means ± S.D. (excluding subject 9) (mmol/1)
A.D. = absolute difference
% Diff. = percentage difference
b = differences are pre- to a given post-exercise point

TABLE XII
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM CHOLESTEROL
TSC (mmol/l) (Continued)

CONTROL Subject No.	pe[a]	p0[a]	A.D.[b]	% Diff.[b]	p1[a]	A.D.[b]	% Diff.[b]	p2[a]	A.D.[b]	% Diff.[b]	p24a[a]	A.D.[b]	% Diff.[b]
19	5.18	5.40	0.22	4.3	5.69	0.51	9.8	5.85	0.67	13.0	4.84	-0.34	- 6.6
20	3.91	4.43	0.52	13.2	4.01	0.10	2.5	3.82	0.09	- 2.3	3.86	- 0.05	- 1.3
22	5.40	4.92	-0.38	- 8.8	4.98	-0.42	- 7.7	5.33	- 0.07	- 1.3	5.27	- 0.13	- 2.4
23	3.93	3.34	-0.59	-15.0	3.75	-0.18	- 4.6	3.78	-0.15	- 3.8	3.72	-0.21	- 5.6
24	4.83	4.61	-0.22	- 4.5	5.01	0.18	3.8	4.75	-0.08	- 1.6	5.05	0.22	4.5
25	6.13	6.21	0.08	1.2	5.80	-0.33	- 5.4	5.84	-0.29	- 4.8	5.58	-0.55	- 9.0
26	5.49	5.47	-0.02	- 0.3	5.51	0.02	0.3	5.12	- 0.37	- 6.7	5.23	-0.26	- 4.1
27	4.30	4.69	0.39	9.3	4.66	0.36	8.5	4.43	0.13	3.2	4.29	-0.01	- 0.2
28	3.49	3.67	0.18	4.8	3.56	0.07	2.1	3.49	0.00	0.0	3.23	-0.26	- 7.3
29	5.77	6.05	0.28	4.9	5.65	-0.12	- 2.2	6.18	0.41	7.3	6.05	0.28	4.9
30	5.45	4.58	-0.87	-16.1	4.48	-0.97	-17.9	5.07	-0.38	- 7.0	4.51	0.94	-17.1
31	4.55	4.57	0.02	0.3	4.62	0.07	1.5	4.36	-0.19	- 4.3	4.36	-0.19	- 4.3
32	5.55	6.10	0.55	9.9	5.95	0.40	7.3	5.58	0.03	0.6	6.01	0.46	8.3
33	3.34	3.16	-0.18	- 5.3	3.67	0.33	9.9	3.71	0.37	11.0	3.16	-0.18	- 5.3
Mean ± S.D.	4.81±0.89	4.80±.98	-0.01	- 0.2	4.81±0.84	0.00	0.0	4.81±0.89	0.00	0.0	4.67±.95	-0.14	- 3.2

[a]pe = non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b)
p0 = non-exercising control group equivalent of post-exercise in treatment group
p1 = non-exercising control group equivalent of 1 in treatment group
p2 = non-exercising control group equivalent of 2 in treatment group
p24a = non-exercising control group equivalent of 24a in treatment group
A.D. = absolute difference
% Diff. = percentage difference

b - differences are pe- to any other blood sampling time

TABLE XIII
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM TRIGLYCERIDE
TSTGL (mmol/l)

TREATMENT D Subject No.	pre[a]	post[a]	A.D.[b]	% Diff.[b]	1[a]	A.D.[b]	% Diff.[b]	2[a]	A.D.[b]	% Diff.[b]	24a[a]	A.D.[b]	% Diff.[b]
01	0.73	0.80	0.07	9.6	0.72	-0.01	- 0.6	0.34	-0.39	-53.4	0.69	-0.04	- 4.8
02	1.11	1.40	0.29	26.4	1.14	0.03	2.2	1.34	0.23	20.8	1.48	0.37	32.2
03	1.32	0.63	-0.69	-52.3	0.69	-0.63	-47.8	0.57	-0.75	-57.0	1.61	0.29	22.1
04	0.57	0.43	-0.14	-24.9	0.41	-0.16	-28.9	0.72	0.15	24.9	0.80	0.23	39.3
05	$	1.20	-	-	0.19	-	-	2.39	-	-	0.49	-	-
06	1.42	0.71	-0.71	-50.0	0.70	-0.72	-50.8	0.33	-1.09	-77.1	0.33	-1.09	-77.1
07	0.99	0.91	-0.09	- 8.0	0.99	0.00	0.0	1.18	0.19	19.5	0.33	0.66	-67.0
08	0.60	0.79	0.19	30.3	0.73	0.13	20.7	0.65	0.05	7.5	0.49	-0.11	-19.6
09	1.50	1.26	-0.26	-17.0	1.55	0.05	3.3	1.53	0.03	2.4	#	#	#
10	0.74	0.99	0.25	33.2	1.25	0.51	68.2	0.65	-0.09	-12.8	1.02	0.28	38.1
11	0.61	0.65	0.04	7.9	0.36	-0.25	-40.4	0.51	-0.10	-15.7	0.43	-0.18	-28.2
12	0.84	1.57	0.73	87.9	0.75	0.09	-10.4	1.68	0.84	100.0	1.11	0.25	32.1
13	1.16	1.52	0.36	30.5	1.53	0.37	31.7	1.50	0.34	29.8	2.69	1.53	130.6
14	0.74	0.80	0.06	7.4	0.50	-0.24	-33.3	0.80	0.06	7.6	0.61	-0.13	-18.1
15	0.66	0.58	0.08	-13.3	0.42	-0.16	-36.9	0.63	-0.03	- 5.3	0.72	0.06	8.7
16	0.67	0.68	0.01	1.5	0.58	-0.09	-14.2	0.49	-0.18	-27.0	0.37	-0.30	-44.6
17	1.08	0.88	-0.20	-18.1	1.16	0.08	7.1	0.93	-0.15	-14.3	0.46	-0.62	-58.8
Mean ± S.D.	0.88±.28*	0.89±.35*	0.01	1.1	0.78±.35*	-0.10	-10.1	0.82±.42*	-0.06	- 7.2	0.87±.64*	-0.01	- 1.1

[a]pre = pre-exercise (average of pre-a and pre-b)
[a]post = immediately post-exercise
[a]1 = 1 hour post-exercise
[a]2 = 2 hours post-exercise
[a]24a = 24 hours post-exercise
# = subject failed to present for sample
* means ± S.D. (excluding subjects 5 and 9)(mmol/l)
[b]A.D. = absolute difference
[b]% Diff. = percentage difference
b = differences are pre- to a given post-exercise point
$ = lost samples

TABLE XIII
ACUTE EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM TRIGLYCERIDE
TSTGL (mmol/l) (Continued)

CONTROL Subject No.[a]	pe[a]	p0[a]	A.D.[b]	% Diff.[b]	p1[a]	A.D.[b]	% Diff.[b]	p2[a]	A.D.[b]	% Diff.[b]	p24a[a]	A.D.[b]	% Diff.[b]
19	2.18	2.47	0.19	13.1	1.64	-0.54	-24.8	1.69	-0.49	-22.6	1.59	-0.59	-27.1
20	0.75	0.79	0.04	5.7	0.53	-0.24	-28.7	-0.87	0.12	16.3	0.79	0.04	5.7
22	1.68	0.93	-0.75	-44.7	1.32	-0.32	-21.5	1.17	-0.51	-30.6	1.73	0.05	2.8
23	0.80	0.48	-0.32	-39.2	0.52	-0.28	-0.35	0.73	-0.07	- 8.8	0.77	-0.03	- 3.7
24	1.17	1.38	0.21	17.8	1.25	0.08	7.1	0.88	-0.29	-24.9	0.90	-0.27	-23.1
25	2.34	1.79	0.55	23.6	1.58	-0.76	-32.3	0.88	-1.46	-62.2	2.13	-0.21	- 8.7
26	1.57	1.74	0.17	11.1	1.56	-0.01	- 0.7	1.44	-0.07	- 4.4	1.90	0.33	21.1
27	0.94	0.87	-0.07	- 7.7	1.03	0.09	9.2	1.46	0.52	55.6	1.69	0.75	79.1
28	2.61	1.86	-0.75	-28.5	1.57	-1.04	-39.8	1.77	-0.84	-39.8	1.64	-0.97	-37.2
29	1.98	1.39	-0.59	-29.8	1.38	-0.60	-30.6	1.45	-0.53	-27.0	1.66	-0.32	-16.1
30	0.88	1.15	0.27	30.1	0.75	-0.13	-14.7	0.90	0.02	1.3	0.73	-0.15	-17.4
31	0.67	0.74	0.07	10.2	0.75	0.08	11.6	0.82	0.15	22.6	0.54	-0.13	-19.4
32	2.92	2.59	-0.33	-11.3	2.41	-0.51	-17.5	2.25	-0.67	-23.1	2.78	-0.14	- 4.8
33	0.74	1.53	0.79	106.4	0.72	-0.02	- 2.6	0.72	-0.02	- 2.6	0.49	-0.25	-33.4
Mean ± S.D.	1.52 ± 0.76	1.41 ± 0.64	-0.11	- 7.2	1.22 ± 0.53	-0.30	-19.8	1.22 ± 0.47	-0.30	-19.8	1.38 ± 0.68	-0.14	- 8.9

[a]pe = non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p0 = non-exercising control group equivalent of post-exercise in treatment group
p1 = non-exercising control group equivalent of 1 in treatment group
p2 = non-exercising control group equivalent of 2 in treatment group
p24a = non-exercising control group equivalent of 24a in treatment group
A.D. = absolute difference
% Diff. = percentage difference

[b] - differences are pe- to any other blood sampling time

Any concerns about the size of the standard deviations were alleviated by the recognition of their similarity to standard deviations in the published data of the acute exercise field.

Acute Experiment - Weight and Hematocrit Data

A two-way repeated measures analysis of covariance revealed a statistically significant ($p < .05$) decrease in the treatment group's (n=16) hematocrit (47.5% $\pm$ 2.1 to 45.8% $\pm$ 2.4) in the immediately post-exercise to 1 hour post-exercise interval. The mean hematocrit level was, relative to all other post-exercise points, significantly at its highest level immediately post-exercise. Hematocrit levels in the treatment group approached pre-exercise levels at 1 hour post-exercise where they remained until 24a. A summary of blood related parameters is found in Table XIV. Weights increased significantly from day 2 to day 3 (73.0 $\pm$ 11.7 kg. to 73.3 $\pm$ 11.7 kg.) (treatment n=16). The weights and hematocrit changed significantly when compared to the n=14 but not to the n=12 control group.

Dietary Adherence and Cigarette Consumption

Because some of the subjects did not keep adequate written records of diet, including alcohol consumption, it was not possible to assess the extent of dietary adherence. Cigarette consumption did not change in either experiment.

TABLE XIV
ACUTE EXPERIMENT
SUMMARY OF BLOOD PARAMETERS

		pre-[a]	post-[a]	1[a]	2[a]	24[a]
HDLc *$	T(16)	1.16 ± 0.14	1.20 ± 0.18	1.21 ± 0.05	1.19 ± 0.14	1.21 ± 0.12
	C(14)	1.19 ± 0.18	1.25 ± 0.23	1.20 ± 0.19	1.22 ± 0.22	1.25 ± 0.21
	C(12)	1.20 ± 0.19	1.29 ± 0.22	1.23 ± 0.18	1.25 ± 0.22	1.26 ± 0.22
LDLc *$	T(16)	2.35 ± 0.67	2.33 ± 0.80	2.20 ± 0.78+	2.37 ± 0.86	2.40 ± 0.87
	C(14)	2.95 ± 0.84	2.90 ± 0.99	3.08 ± 0.74	3.04 ± 0.86	2.78 ± 0.84
	C(12)	3.11 ± 0.71	2.96 ± 1.0	3.17 ± .072	3.17 ± .084	2.93 ± 0.77
HDLc: TSC ratio $	T(16)	.301 ± .065	.317 ± .064	.338 ± .089+	.315 ± .081	.318 ± .068
	C(14)	.257 ± .074	.277 ± .099	.258 ± .071	.264 ± .073	.284 ± .086
	C(12)	.253 ± .078	.281 ± .106	.261 ± .077	.265 ± .079	.280 ± .087
TSC *$	T(16)	3.92 ± 0.67	3.95 ± 0.82	3.76 ± 0.81	3.99 ± 0.96	3.95 ± 0.92
	C(14)	4.81 ± 0.89	4.80 ± 0.98	4.81 ± 0.84	4.81 ± 0.89	4.67 ± 0.95
	C(12)	4.96 ± 0.86	4.90 ± 1.0	4.93 ± 0.82	4.95 ± 0.87	4.51 ± 0.39
TSTGL *$	T(15)	0.88 ± 0.28	0.89 ± 0.35	0.78 ± 0.35	0.82 ± 0.42	0.87 ± 0.64
	C(14)	1.52 ± 0.76	1.41 ± 0.64	1.22 ± 0.53	1.22 ± 0.47	1.38 ± 0.68
	C(12)	1.47 ± 0.75	1.42 ± 0.66	1.20 ± 0.57	1.15 ± 0.47	1.34 ± 0.73
HCT *$ percent	T(16)	[illegible] ± 1.9	47.5 ± 2.1+	45.8 ± 2.4	46.1 ± 2.7	45.6 ± 2.7
	C(14)	46.5 ± 1.6	46.4 ± 2.1	46.1 ± 2.1	46.1 ± 2.0	46.1 ± 1.8
	C(12)	46.5 ± 1.7	46.3 ± 2.2	46.1 ± 2.3	46.1 ± 2.2	46.2 ± 1.9

+ $p < .05$ relative to all other post exercise points

* (T = 16 vs C = 14 only)

' T = treatment (e.g. 16)--)number of subjects
C = control (e.g. 14)----)T=16, subject 9 missing
T = 15, subjects 5 and 9 missing
C = 12, subjects 27 and 28 missing

$ HCT = Hematocrit
HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglyceride

[a] pre- = pre-exercise
post- = immediately post-exercise
1 = 1 hour post-exercise

[a] 2 = 2 hours post-exercise
24 = 24 hours post-exercise
* mean ± S.D. (mmol/1)

Acute Experiment-Discussion

The most important finding of this study was a statistically significant increase in the HDLc:TSC ratio in going from immediately post- to 1 hour post-exercise (Table X) when 30 subjects were considered.

However, when two of the control subjects (#27 and 28) were dropped from consideration due to their use of propranolol (Inderal), the HDLc:TSC ratio no longer increased significantly. The data (Table XIV) suggests that it was the increase in variance in the n=12 control group that may have led to the discrepancy.

There were no statistically significant differences, as determined by a t-test, between any of the 2 sets pre-exercise values of the 5 biochemical variables. Further, there were reasonably high correlations between the 2 sets of pre-exercise levels (Appendix V). These two facts suggest that there was good reproducibility in the biochemical analysis. This is justification for allowing the pre-b values of subject 6 for the TSTGL and the TSC parameters to stand as the averaged respective pre-exercise levels. The same applies to the pre-b value for TSC for subject 5.

Maximal exertion $\dot{V}O_2max$ determinations were done only in the treatment group. In the treatment group, there were no significant differences between the full and partial correlations between the averaged pre-exercise values of the 5 biochemical variables when the effects of $\dot{V}O_2max$, age, weight and BMI were removed (Table XV). This suggests that $\dot{V}O_2max$ did not affect the interrelationships between the 5 biochemical variables in the time course pattern of the

TABLE XV

FULL AND PARTIAL* CORRELATIONS AND THEIR 95% CONFIDENCE INTERVALS BETWEEN THE PRE-VALUES[a] OF THE BIOCHEMICAL VARIABLES FOR THE ACUTE EXPERIMENT (TREATMENT GROUP ONLY)

	FULL CORRELATION	95% CONFIDENCE INTERVAL		PARTIAL CORRELATION	95% CONFIDENCE INTERVAL
HDLc vs TSC (n=17)	-.04 N.S.[2]	-.53 to +47	b	-.04 N.S.	-.53 to +47
vs TSTGL (n=16)[3]	-.03 N.S.	-.48 to +52	b	.25 N.S.	-.37 to +72
vs LDLc (n=17)	-.26 N.S.	-.68 to +.27	b	-.34 N.S.	-.76 to +.29
vs HDLc:TSC ratio (n=17)	.64 $p < .05$	.21 to .86	b	.69 $p < .05$	.20 to +.91
TSC vs TSTGL (n=16)	.41 N.S.	-.11 to +.76	b	.39 N.S.	-.24 to .79
vs LDLc (n=17)	.96 $p < .05$	.89 to .99	b	.93 $p < .05$	.77 to .98
vs HDLc:TSC ratio (n=17)	-.76 $p < .05$	-.91 to -.42	b	-.69 $p < .05$	-.91 to -.20
TSTGL vs LDLc (n=16)	.21 N.S.	-.33 to .64	b	.12 N.S.	-.49 to .65
vs HDLc:TSC ratio (n=16)	-.39 N.S.	-.74 to .14	b	-.21 N.S.	-.69 to .42
LDLc vs HDLc:TSC ratio (n=17)	-.84 $p < .05$	-.94 to -.57	b	-.83 $p < .05$	-.95 to -.50

HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglycerides
[2] N.S. = not significantly different from zero
* effects of $\dot{V}O_2$ max, age, weight and BMI removed
a - values used are the average of pre-a and pre-b for a given subject
b - no significant difference ($p < .05$) between full and partial correlations
[3] N=16 (subject 5 missing)

treatment group. The $\dot{V}O_2$max values determined by a submaximal predictive test for 5 of the 8 older control subjects are found in Appendix VI. A summary of pre-exercise means for age, weight, BMI and $\dot{V}O_2$max is also found in Appendix VI. Of the 8 older* subjects (#24, 25, 26, 27, 19, 29, 30, 32), subjects 27, 28 and 32 were taking bradycardia inducing medication. Thus, any $\dot{V}O_2$max value obtained from a submaximal predictive test would be inaccurate.

There were significant group differences in the acute experiment between averaged pre-exercise (pe) values for LDLc, TSC, TSTGL, age, weight, and BMI (Tables IX, XII, XIII and Appendix VI). However, there were no significant differences in the full and partial correlations between the averaged pre-exercise values of the 5 biochemical variables (Table XVI). The age, weight and BMI factors were partialled out. This suggests that they did not affect the relationships among the pre-values and therefore were unlikely to affect the same relationships in the post-exercise period. Post-hoc dumping of data was not the best approach according to the purists in the statistics field. There were no significant differences in the pre-exercise treatment and control group means for the HDLc:TSC ratio and HDLc. These are the two most important variables in this experiment due to their proposed antiatherogenic nature. Therefore, significant group differences in the other biochemical

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* $\geq$ 34 years of age

TABLE XVI

FULL AND PARTIAL* CORRELATIONS AND THEIR 95% CONFIDENCE INTERVALS BETWEEN THE PRE-VALUES[a] OF THE BIOCHEMICAL VARIABLES FOR THE ACUTE EXPERIMENT (TOTAL SUBJECT POOL)

	FULL CORRELATION	95% CONFIDENCE INTERVAL		PARTIAL CORRELATION	95% CONFIDENCE INTERVAL
HDLc' vs TSC' (n=31)[b]	-.12 N.S.[2]	-.45 to +.25	c	-.02 N.S.	-.39 to +.35
vs TSTGL' (n=30)[b]	-.11 N.S.	-.45 to +.25	c	.15 N.S.	-.49 to +.24
vs LDLc' (n=31)	-.28 N.S.	-.58 to +.08	c	-.31 N.S.	-.61 to +.07
vs HDLc:TSC ratio (n=31)	.63 p < .05	.35 to .80	c	.70 p < .05	.45 to .85
TSC vs TSTGL (n=30)[b]	.55 p < .05	.25 to .76	c	.23 N.S.	-.16 to +.54
vs LDLc (n=31)	.93 p < .05	.86 to .97	c	.90 p < .05	.79 to .94
vs HDLc:TSC ratio (n=31)	-.82 p < .05	-.66 to -.91	c	-.68 p < .05	-.41 to -.84
TSTGL vs LDLc (n=30)[b]	.27 N.S.	-.09 to +.57	c	-.14 N.S.	-.49 to +.25
vs HDLc:TSC ratio (n=30)[b]	-.46 p < .05	-.70 to -.13	c	-.07 N.S.	-.43 to .31
LDLc vs HDLc:TSC ratio (n=31)	-.86 p < .05	-.93 to -.73	c	-.81 p < .05	-.91 to +.63

' HDLc = High Density Lipoprotein Cholesterol
' LDLc = Low Density Lipoprotein Cholesterol
' TSC = Total Serum Cholesterol
' TSTGL = Total Serum Triglycerides
2 N.S. = not significant ($p < .05$) from zero
* = effects of age, weight, and Body Mass Index factored out
a = values used are the average of the pre-a and pre-b for a given subject
b = subject 5 missing
c = N.S. difference between full and partial correlations

variables were not as relevant. It should be recognized that the 31 subjects in the acute experiment pool were closer to the population at large toward which the results are meant to be extrapolated.

Finally, this was the first acute study to adjust for shifts in hematocrit and account for cigarette smoking. This assists in establishing whether lipoprotein metabolism is sensitive to an exercise stressor.

High Density Lipoprotein cholesterol

The finding of no significant change in HDLc was similar to the results of Carlson and Mossfeldt (1964) and Taskinen et al (1980) but was contrary to those of Enger et al (1980), Dufaux et al (1982) and Thompson et al (1982). Certain subjects (#1, 5, 6, 12, 14, 15) however, showed appreciable increases in HDLc at 1 hour post-exercise relative to the pre-values (Table XI). While the absolute changes were small the percentage changes were more substantial. These subjects had the common features of being young (less than 34 years of age), non-obese, and all but one had calculated average or below average HDLc levels. Thus, one possibility may be that such characteristics predisposed the subjects to substantially increased HDLc levels. Greater numbers of subjects and/or exercise volume may also lead to significant changes in HDLc.

That HDLc did not change may have been the result of no change in TSTGL and LPL. There is an inverse relationship between changes in HDLc and TSTGL which can be explained by the Kinnunen (1979) equation. This equation is mediated by LPL which hydrolyzes VLDL-TGL, the major proportion of TSTGL. Lithell et al (1981b) noted that it took more than one hour of exercise to produce significant increases in LPL activity immediately post-exercise. Indeed, there were only 2 subjects (#6, 14) with concomitant increases in HDLc and decreases in TSTGL at 1 hour post-exercise (Tables XI and XIII). Further, it may be difficult to reconcile a lag in LPL since LDLc decreased at 1 hour post-exercise. The observation of no significant change in TSTGL may also be explained by the suggestion of Thompson et al (1980) that in part, free fatty acid concentrations determine hepatic free fatty acid uptake (McElroy et al 1960 and Spitzer and McElroy 1960) and hence hepatic triglyceride output. That is to say that it was possible that the rates of serum triglyceride catabolism and synthesis were similar at the times when blood was sampled. This is supported, perhaps, by the absence of significant change of the treatment group correlations (-0.26 to -0.11) (both $p > .05$) between TSTGL and HDLc going from immediately post-exercise to 1 hour post-exercise (Table XVII). The same is true of the non-significant correlations (-.49 to -.42) between the HDLc:TSC ratio and TSTGL in going from immediately post- to 1 hour post-exercise (Table XVII). The absence of significant change in TSTGL was unlike the studies of Carlson and Mossfeldt (1964), Enger et al (1980) and Thompson et al (1980).

TABLE XVII
ACUTE EXPERIMENT

IMPORTANT CORRELATIONS AND THEIR 95% CONFIDENCE INTERVALS FOR THE IMMEDIATELY POST-EXERCISE TO ONE HOUR POST EXERCISE TIME FRAME IN THE TREATMENT GROUP

	Immediately post	1 hour post-exercise
HDLc vs TSTGL (N=15)[b]	-.26 (N.S.)[a] *	-.11 (N.S.)
95% confidence interval	-.67 to +.26	-.57 to +.41
HDLc vs TSC (N=16)[c]	-.17 (N.S.) *	-.22 (N.S.)
95% confidence interval	-.60 to +.35	-.64 to +.31
HDLc:TSC ratio vs TSTGL (N=15)	-.49 (N.S.) *	-.42 (N.S.)
95% confidence interval	-.79 to 0.00	-.75 to +.09
TSC vs LDLc N=16	.97 ($p < .05$) *	.97 ($p < .05$)
95% confidence interval	.91 to .99	.91 to .99

HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglycerides

* no significant difference between the correlations in going from immediately post to 1-hour post-exercise
a N.S. non-significant
b N=15, subjects 5, 9 missing
c N=16, subject 9 missing

If LCAT did not increase then the observation of no significant change in HDLc might be explained. LCAT is thought to be responsible for increasing the cholesterol content of HDL (Glomset 1968). Unfortunately, there appears to be no literature on the effect of acute exercise on LCAT.

Low Density Lipoprotein cholesterol and Total Serum Cholesterol

LDLc was significantly lower at 1 hour post-exercise than at any other post-exercise point when 16 treatment subjects were compared to 14 control subjects (Table XIV). When two of the control subjects (#27 and 28) who were taking propranolol were dropped, this significant difference disappeared (Table XIV). Subjects 27 and 28 had pe levels of LDLc that were below the average pe level for the 14 control subjects. Propranolol increases LDLc (Tanaka et al 1976). One may, therefore, be justified in keeping subjects 27 and 28 as part of the repeated measures ANCOVA. One must be careful in the interpretation that the significant decrease in LDLc resulted from acute exercise, since the Friedwald equation which inaccurately estimates VLDLc to be equal to TSTGL/5, was used to calculate LDLc. Therefore, LDLc comparisons are difficult.

The nature of the decrease in LDLc is unknown and it could be that decreased LDLc concentration does not necessarily suggest a decrease in the number of LDL particles. It may mean a decreased cholesterol content of each particle due to a decreased total or apo B protein content of that micelle or a reduced ability of that particle to bind cholesterol.

The significant decrease in LDLc may have been caused by a transient increase in the hepatic lipoprotein lipase (HL). Kussi et al (1979) and Jansen et al (1980) have suggested that when HL perhaps hydrolyses the phospholipids in LDL at the liver's endothelial cells, part of the cholesterol of LDL is taken up by the liver.

LDLc correlated .97 ($p < .05$) with TSC in the treatment group at immediately post- and 1 hour post-exercise (Table XVII). The tendency toward a decrease in TSC at 1 hour post-exercise reflected a significant decrease in LDLc at the same point. The observation of no significant change in TSC did not conform to the results of Enger et al (1980) and Thompson et al (1980) and may reflect an inadequate stimulus to lower VLDLc.

The significant change in LDLc is unlike the results of Taskinen et al (1980) but is similar to those of Thompson et al (1980).

HDLc:TSC Ratio

The significant increase in the HDLc:TSC ratio was due first to a tendency toward an increased cholesterol concentration in the HDL fraction and second to a tendency toward a decrease in TSC, both occurring at 1 hour post-exercise (Tables X, XI and XII). These tendencies may have resulted from the increased hemoconcentration at immediately post-exercise. This enhanced hemoconcentration may have led to an increased concentration of reactants, apo-protein enzyme activators and enzymes responsible for the appreciable increases in HDLc in subjects 1, 5, 6, 12, 14, 15 (Table XI) and the decreases in TSC in subjects 4, 5, 7, 14 and 16 at 1 hour post-exercise (Table XII). All changes are relative to pre-exercise levels. That HDLc was not a reflection of TSC levels is shown in the absence of a significant correlation change of -0.17 to -0.22 (both $p > .05$) between HDLc and TSC in going from immediately post-exercise to 1 hour post-exercise in the treatment group (Table XVII).

Interestingly, the results of Thompson et al (1980) and Enger et al (1980) are similar to those of the present study in that the lowest TSC and greatest HDLc were observed simultaneously at a point well after the exercise had ended.

The nature of the significant increase in the HDLc:TSC ratio is partially unknown since an increased HDLc:TSC ratio does not necessarily suggest an increase in the number of HDL particles. It may mean a tendency toward increased cholesterol content of each particle due to an increased total or apo A-I protein content of that micelle or an enhanced ability of that particle to bind cholesterol.

Since the cigarette consumption did not change significantly, the change in the HDLc:TSC ratio could not have been caused by that factor. The significant increase in weight going from Day 2 to Day 3 does not complicate the analysis since it results in increased LDLc and decreased HDLc (Garrison et al 1978, Ho and Chan 1975), the combination of which would result most likely in a decreased HDLc:TSC ratio.

The increased HDLc:TSC ratio is significant for two reasons. Firstly, it suggests that the ratio may be sensitive to an exercise stressor. This is suggested since the biochemical parameters were examined over a relatively short period of time, thus possibly preventing any substantial intervention by the other exogenous factors (e.g. diet) that affect lipoprotein metabolism. Secondly, Gordon et al (1977) suggested that the HDLc:TSC ratio might be a more powerful negative risk factor than HDLc. The increased percentage of TSC carried by HDL may imply increased cholesterol transport from the periphery to the liver (Burke 1980) or a reduced amount of cholesterol available to LDL.

Acute Experiment - Post Hoc Matching of Subjects

Because of concerns about group differences in age, weight and BMI, 7 treatment (#1, 3, 6, 7, 8, 13, 17) subjects were post-hoc matched with 7 control (#19, 20, 23, 24, 27, 31, 33) subjects on the combined basis of those 3 factors (Table XVIII). When the groups were matched there were no significant differences in age, weight, BMI and the 5 biochemical variables. This matching was done since the partialling out of age, weight, and BMI is only a statistical approach and does not remove all doubt ~~that~~ differences in those 3 factors might affect the outcome of the

TABLE XVIII
ACUTE EXPERIMENT
POST HOC MATCHING OF SUBJECTS ON THE BASIS OF AGE, WEIGHT & BODY MASS INDEX (BMI)
SUMMARY OF BLOOD RELATED PARAMETERS

		pre-[a]	post-[a]	1[a]	2[a]	24a[a]
HDLc*	[b]T(7)	1.23 ± 0.17	1.28 ± 0.22	1.26 ± 0.17	1.23 ± 0.18	1.24 ± 0.12
	C(7)	1.23 ± 0.21	1.37 ± 0.25	1.29 ± 0.15	1.31 ± 0.24	1.34 ± 0.22
LDLc*	T(7)	2.51 ± 0.84	2.53 ± 0.99	2.48 ± 0.89	2.76 ± 0.84	2.56 ± 0.67
	C(7)	2.61 ± 0.54	2.41 ± 0.86	2.77 ± 0.65	2.61 ± 0.67	2.40 ± 0.59
HDLc: TSC ratio	T(7)	.294 ± .080	.320 ± .100	.315 ± .082	.299 ± .075	.312 ± .064
	C(7)	.298 ± .071	.331 ± .109	.296 ± .074	.308 ± .074	.327 ± .076
TSC*	T(7)	4.22 ± 0.72	4.23 ± 0.94	4.17 ± 0.83	4.35 ± 0.86	4.10 ± 0.81
	C(7)	4.29 ± 0.62	4.32 ± 0.79	4.49 ± 0.71	4.39 ± 0.77	4.18 ± 0.66
TSTGL*	T(7)	1.04 ± 0.30	0.89 ± 0.29	0.93 ± 0.32	0.78 ± 1.01	0.94 ± 0.89
	C(7)	1.04 ± 0.53	1.18 ± 0.68	0.92 ± 0.41	1.02 ± 0.39	0.97 ± 0.48
HCT[c] percent	T(7)	45.3 ± 2.1	47.1 ± 1.3	45.4 ± 1.9	45.6 ± 2.4	46.1 ± 1.9
	C(7)	46.7 ± 1.7	46.4 ± 1.9	46.1 ± 2.1	46.1 ± 2.1	45.7 ± 1.6

[a]pre- = pre-exercise
post- = immediately post-exercise
1 = 1 hour post-exercise
2 = 2 hours post-exercise
24a - 24 hours post-exercise
*mean ± S.D. (mmol/l)

[b]T = treatment (7)-- } Number of subjects
C = control (7)---- }
T subjects 1, 3, 6, 7, 8, 13, 17
C subjects 19, 20, 23, 24, 27, 31, 33

HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglycerides
[c]HCT. = hematocrit

experiment. Matching the treatment with the control subjects would have been best from the outset but with volunteers one cannot easily do this procedure.

There were no statistically significant results in the matched acute experiment (Table XVIII). This may have been due to the small sample size. Certain subjects (#1, 6) showed appreciable increases in HDLc at 1 hour post-exercise (Table XI). These subjects were young (less than 34 years of age), non-obese and had below average HDLc levels. These factors may predispose one to more pronounced increases in HDLc. The characteristics of youth (less than 34 years of age) and non-obesity may have resulted in subjects 1, 6 and 7 having substantial increases in the HDLc:TSC ratio at 1 hour post-exercise (Table X).

Chronic Experiment

A two-way repeated measures analysis of covariance revealed no statistically significant ($p < .05$) changes in the weights, hematocrit or in the biochemical parameters of the chronic experiment.

In the treatment and control groups, HDLc showed an increase going from pre-exercise (pe) to 24a (p24a). The treatment group demonstrated an increase in the HDLc levels in the 24a to 24b interval but the reverse was true in the control group between p24a and p24b (equivalent in non-exercising control subjects of 24 hours post the final acute exercise session for the experimental subjects) (Table XIX).

TABLE XIX
CHRONIC EXPERIMENT
POST-EXERCISE CHANGES HIGH DENSITY LIPOPROTEIN CHOLESTEROL (HDLc (mmol/l))

Subject No.	Treatment group pre[a]	24a[a]	A.D.[b]	% Diff.[b]	24b[a]	A.D.[b]	% Diff.[b]
02	0.98	1.02	0.04	4.5	0.97	-0.01	-1.0
03	1.20	1.20	0.00	0.0	1.14	-0.06	-5.0
08	1.25	1.37	0.12	9.3	1.26	0.01	0.8
15	1.16	1.32	0.16	13.4	1.61	0.45	38.7
17	1.58	1.40	-0.18	-11.0	1.96	0.38	24.1
Mean ±S.D.	1.23±0.23	1.26±0.15	0.03	2.3	1.31±0.28	0.08	6.3

Subject No.	Control group pe$	p24a$	A.D.[b]	% Diff[b]	p24b$	A.D.[b]	% Diff[b]
19	1.24	1.51	0.27	22.2	1.48	0.24	19.3
22	1.27	1.28	0.01	0.8	1.10	-0.17	-13.3
31	0.97	1.02	0.05	4.5	1.03	0.06	6.2
33	1.25	1.38	0.13	10.4	1.47	0.12	9.6
Mean ±S.D.	1.18±0.14	1.30±0.21	0.12	10.1	1.27 ± 0.24	0.09	8.1

[a]pre - pre-exercise (average of pre-a and pre-b)
24a - 24 hours post - 1st acute exercise session
24b - 24 hours post - 3rd acute exercise session
$pe - non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p24a - non-exercising control group equivalent of 24a in treatment group
p24b - non-exercising control group equivalent of 24b in treatment group

[b]A.D. = absolute difference
[b]%Diff. = percentage difference
[b]all differences are pre- to a given point post exercise

In the treatment group, there was a slight decrease in the HDLc:TSC ratio between pre- and 24a and a further decrease from 24a to 24b. In the control group, the HDLc:TSC ratio peaked at p24a and then declined to pe levels at p24b (Table XX).

TSC rose from pre-exercise to 24a and further increased toward 24b in the treatment group (Appendix VII). The control group showed a decrease from pe to p24a, but a rise from p24a to p24b (Appendix VII).

LDLc rose to 24a with a further increase to 24b in the treatment group (Appendix VIII). In the control group, there was a decrease in LDLc between pe and p24a, but a rise from p24a to p24b (Appendix VIII).

The TSTGL of the treatment group was near pre-exercise levels at 24a and 24b (Appendix IX). In the control group, there was a decrease in TSTGL from pe to p24a but an increase between p24a and p24b (Appendix IX).

The pattern in the hematocrit in the treatment and the control group was similar to their respective counterparts in the acute experiment. A summary of the blood related parameters is found in Table XXI. The flat profile of the weights was identical over time in the two groups.

TABLE XX

CHRONIC EXPERIMENT. POST-EXERCISE CHANGES IN THE HIGH DENSITY LIPOPROTEIN CHOLESTEROL: TOTAL SERUM CHOLESTEROL RATIO (HDLc:TSC RATIO)

TREATMENT Subject No.	pre[a]	24a[a]	A.D.[b]	% Diff.[b]	24b[a]	A.D.[b]	% Diff.[b]
02	.251	.228	-.023	-9.2	.220	-.031	-12.4
03	.313	.317	.004	12.8	.260	-.053	-16.9
08	.244	.253	.009	3.7	.224	-.020	- 8.2
15	.358	.409	.051	14.2	.397	.039	10.9
17	.433	.369	-.064	-14.8	.459	.026	6.0
Mean	.319	.315	-.004	-1.3	.312	-.007	-2.2
S.D.	±.079	±.076			±.109		

CONTROL Subject No.	pe$	p24a$	A.D.[b]	% Diff.[b]	p24b$	A.D.[b]	% Diff.[b]
19	.239	.313	.074	30.9	.218	-.021	- 8.8
22	.235	.279	.044	18.7	.196	-.039	-16.6
31	.212	.234	.022	10.4	.261	.049	23.1
33	.374	.437	.063	16.8	.390	.016	4.3
Mean	.265	.316	.051	19.2	.266	.001	0.9
S.D.	±.074	±.087			±.086		

[a]pre - pre-exercise (average of pre-a and pre-b)
24a - 24 hours post - 1st acute exercise session
24b - 24 hours post - 3rd acute exercise session
$pe - non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p24a - non-exercising control group equivalent of 24a in treatment group.
p24b - non-exercising control group equivalent of 24b in treatment group.

[b]A.D. = absolute difference
[b]% Diff. = percentage difference
[b]all differences are pre- to a given point post-exercise

TABLE XXI - CHRONIC EXPERIMENT
SUMMARY OF BLOOD PARAMETERS

		pre-[b]	24a[b]	24b[b]
[a]HDLc*	[1]T(5)	1.23 ± 0.23	1.26 ± 0.15	1.31 ± 0.28
	[1]C(4)	1.18 ± 0.14	1.30 ± 0.21	1.27 ± 0.24
[a]LDLc*	T(5)	2.27 ± 0.80	2.44 ± 0.90	2.76 ± 0.80
	C(4)	2.83 ± 0.74	2.61 ± 0.75	3.02 ± 0.75
HDLc: TSC ratio	T(5)	.319 ± .079	.315 ± .076	.312 ± .109
	C(4)	.265 ± .074	.316 ± .087	.266 ± .086
[a]TSC*	T(5)	3.95 ± 0.70	4.14 ± 0.84	4.38 ± 0.79
	C(4)	4.62 ± 0.92	4.41 ± 0.91	5.02 ± 1.42
[a]TSTGL*	T(5)	0.96 ± 0.31	0.95 ± 0.56	0.95 ± 0.41
	C(4)	1.32 ± 0.74	1.09 ± 0.66	1.70 ± 1.23
HCT[2]* percent	T(5)	46.5 ± 1.9	46.3 ± 2.5	45.0 ± 3.6
	C(4)	46.1 ± 2.0	45.0 ± 1.3	45.9 ± 2.9

[1] T = treatment (5)-- } number of subjects
[1] C - control (4)---- }
[2] HCT = Hematocrit
[a] HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglycerides
[b] pre- = pre-1st acute session
24a = 24 hours post 1st acute session
24b = 24 hours post 3rd acute session
*mean ± S.D. (mmol/1)

That HDLc did not change significantly is possibly because it is unlikely that much muscle TGL depletion occurred. Untrained individuals use less of their intramuscular lipid stores (Lithell et al 1979a, Paul 1975). Froberg et al (1978) found a correlation of r= -0.62 between the k2 (fractional removal rate from plasma of intravenously (IV) injected Intralipid) and the TGL concentration of the muscle in resting subjects. LPL activity correlated .91 with k2 in normolipeamic adults (Kekki 1980). LPL may increase HDLc (Kinnunen 1979). Therefore, it is possible that there were no adaptive increases in LPL activity.

There is some controversy over the duration of an exercise program required to produce significant increases in HDLc concentrations (Webster et al 1978, Erkelens et al 1979, Murdoch 1980). The intensity and/or duration of the current study may have been insufficient to produce significant changes. Further, greater numbers of subjects in Erkelens et al's experiment over the current one may have contributed to their observation of significant change.

It seems that youth (less than 34 years of age) and non-obesity may have contributed to the appreciable increases in HDLc and in the HDLc:TSC ratio in subjects 15 and 17 in the pre-exercise to 24b interval (Tables XIX AND XX).

A possible absence of significantly increased LCAT activity may have led to the lack of a summation effect in HDLc and the HDLc:TSC ratio. An increased LCAT activity with training was noted by Lopez-S et al (1974). Animal studies (Simko and Kelley 1979a,b) support the concept of increased LCAT as the result of chronic exercise. Even if LCAT led to significantly increased HDL_2c (Schmitz et al 1982) there was no increase in HDLc. Nye et al (1981) reported a significant increase and decrease in HDL_2c and HDL_3c respectively with no significant increase in HDLc with chronic exercise. Further, HL may have failed to sufficiently lower LDLc and hence TSC. Concomitant increases in HDLc and decreases in TSC can lead to increases in the HDLc:TSC ratio.

Due to a low number of subjects, the treatment group could not be post-hoc matched with the control group on an age, weight and BMI basis. However, any concerns about group differences in BMI and weights may be allayed by the knowledge of no significant difference in the full and partial correlations between each of the 5 biochemical variables using the averaged pre-exercise variables. Age, weight and BMI were factored out for the partial correlations (Table XXII). There were no other group differences.

There was no accumulation of acute effects in HDLc, the HDLc:TSC ratio, TSTGL, TSC and LDLc. The reasons for this are uncertain.

TABLE XXII

FULL AND PARTIAL* CORRELATIONS AND THEIR 95% CONFIDENCE INTERVALS BETWEEN THE PRE-VALUES[a] OF THE BIOCHEMICAL VARIABLES FOR THE CHRONIC EXPERIMENT (TOTAL SUBJECT POOL)

	FULL CORRELATION	95% CONFIDENCE INTERVAL		PARTIAL CORRELATION	95% CONFIDENCE INTERVAL
HDLc[1] vs TSC[1] (n=9)	-.06 N.S.[2]	-.70 to +.63	b	-.33 N.S.	-.90 to +.66
vs TSTGL[1] (n=9)	.18 N.S.	-.55 to +.75	b	.35 N.S.	-.65 to +.90
vs LDLc[1] (n=9)	-.35 N.S.	-.90 to +.65	b	.74 N.S.	-.18 to +.97
vs HDLc:TSC ratio (n=9)	.67 $p < .05$	.01 to .92	b	.86 $p < .05$	.16 to .98
TSC vs TSTGL (n=9)	.50 N.S.	-.25 to .87	b	.23 N.S.	-.72 to .88
vs LDLc (n=9)	.92 $p < .05$	.62 to .98	b	.69 N.S.	-.27 to +.96
vs HDLc:TSC ratio (n=9)	-.78 $p < .05$	-.95 to -.25	b	-.76 N.S.	-.97 to +.13
TSTGL vs LDLc (n=9)	.18 N.S.	-.55 to +.75	b	-.49 N.S.	-.93 to .53
vs HDLc:TSC ratio (n=9)	-.27 N.S.	-.79 to +.48	b	.10 N.S.	-.77 to +.84
LDLc vs HDLc:TSC ratio (n=9)	-.90 $p < .05$	-.98 to -.59	b	-.87 $p < .05$	-.99 to -.20

[1] HDLc = High Density Lipoprotein Cholesterol
LDLc = Low Density Lipoprotein Cholesterol
TSC = Total Serum Cholesterol
TSTGL = Total Serum Triglyceride
[2] N.S. = not significantly different ($p < .05$) from zero
* = effects of age, weight and BMI removed
a = values are the average of pre-a and pre-b for a given subject
b = no significant difference ($p < .05$) between full and partial correlations

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The primary objective of this study was to determine if acute exposure to continuous bicycle ergometer exercise performed for one hour has an effect on the immediate and extended post-exercise profile of lipoprotein cholesterol fractions in untrained adult males. Specifically, does one hour of cycling at a heart rate of 140-160 beats per minute (bpm) affect the immediate, 1 hour, 2 hour and 24 hour post-exercise measurements of serum HDLc, TSC, TSTGL, the HDLc:TSC ratio and the calculated LDLc in 19-51 year old untrained males?

A secondary objective of this study was to examine the post-exercise profiles in subjects who have either experienced or not experienced three bouts of exercise in the preceding 6 days. All subjects conformed to the requirement of at least one year of sedentary lifestyle carried through the study.

The effect of acute and chronic exercise on HDLc and the HDLc:TSC ratio was of importance for two reasons. Firstly, HDLc and the HDLc:TSC ratio have been inversely related to CASHD. Secondly, it is of importance to explore the effects of acute and chronic aerobic exercise on the metabolism of HDLc and the HDLc:TSC ratio. That is, are the effects of chronic exercise an accumulation of the effects of acute exercise?

Thirty-one males, 19-51 years, participated in the study. All were normolipidemic within the definitions given above. The subjects were divided into a treatment group (n=17) and a control group (n=14) for the acute phase of this study. In the acute experiment, subject 9 was dropped from all 2 way repeated measures ANCOVA due to missing data. Subject 5 was dropped from all statistical analysis involving TSTGL due to 2 missing pre-exercise levels. For the acute experiment, 2 pre-exercise values, an immediately post, one hour post (1), 2 hour post and 24 hour post (24a) exercise samples were taken. To ease concerns about group differences in age, weight, and BMI, 7 treatment subjects were post-hoc matched with 7 control subjects on the combined basis of these 3 factors. For the chronic experiment, 5 of the 17 acute treatment and 4 of the 14 acute control subjects were used in similar roles. The chronic experiment included 2 pre (first acute) - exercise samples, a sample at 24 hours (24a) post - the first acute session and a 24 hour (24b) sample after the final exercise session. Significance, in both designs, was determined by measuring the change in every combination of any 2 post-exercise points in the treatment group and comparing it to the comparable time period in the control group.

Conclusions

Within the scope and limitations of this study, the following conclusions about the effects of acute and chronic exercise may be drawn:

1) HDLc was not significantly affected by the acute exercise. However, some subjects demonstrated appreciable increases at one hour post-exercise in the acute study.

2) When the data from all the subjects is considered, the HDLc:TSC ratio was significantly increased in the sample taken one hour following the acute exercise session. However, when the two control subjects (#27,28) who were taking propranolol were removed, this significant difference was lost. Similarly, there was no significant difference in the HDLc:TSC ratio when experimental and control subjects were matched on the basis of age, weight and BMI. Thus, while the trends toward an increased HDLc:TSC ratio at one hour post-exercise remained the same regardless of the method of grouping and matching subjects, it is concluded that a single bout of acute exercise does not significantly affect the HDLc:TSC ratio.

3) Similarly, the significant decrease in LDLc at one hour post-exercise in the acute experiment is lost when the "propranolol" subjects are removed and when the groups are matched on the basis of age, weight and BMI.

4) The TSTGL and TSC did not change significantly as the result of the acute exercise.

5) The HDLc, TSC, the HDLc:TSC ratio, LDLc and TSTGL did not change significantly in the three exercise session experiment. Thus, three sessions were not sufficiently "chronic" to achieve significant positive changes in any of the measured lipoprotein fractions.

Additional Observations

1) The exact roles of LPL, HL and LCAT in HDL metabolism as well as their metabolic regulation have not been fully elucidated. Given *in vitro* studies, it seems that LPL, HL and LCAT may have cooperated in the production of a significantly increased HDLc:TSC ratio at 1 hour post-exercise in the treatment group of the acute session.

2) More exercise volume and/or subject numbers may be required to produce significant changes in HDLc, TSC and TSTGL with acute exercise and all of the biochemical parameters of this study with chronic exercise.

Recommendations

Within the experimental protocol of this study the following are recommended:

1) Clarification of the biochemical mechanisms by which exercise affects total HDL, HDLc, HDL_2, HDL_3, VLDL, VLDLc, LDL, LDLc, TSTGL and TSC metabolism including the roles of LCAT, HL and LPL.

2) Further to recommendation #1, the lipid and apoprotein components of HDL_2, HDL_3, LDL and VLDL should be radioactively labelled so that their fate in the body as the result of exercise can be determined.

3) Further, to recommendation #2, the concentration of apo A-I and apo C-II must be determined.

4) The first three recommendations should be carried out under different exercise volumes and/or subject numbers to determine the respective threshold points for significant change.

5) Studies are required on the short term effects of those agents, such as, caffeine, diet, cigarettes, etc. that affect lipoprotein metabolism.

6) The exact role of HDL in CASHD needs clarification. There is presently considerable debate in the literature whether HDL transports cholesterol from the periphery to the liver for catabolism and excretion (Murdoch 1980).

7) Further to recommendation #6, the role of HDL_2 and HDL_3 in CASHD requires elucidation since data on the lipid: protein and the quantitative analysis of the number of micelles between CASHD and normal subjects is lacking (Murdoch 1980).

8) Determination of the factor that is most strongly linked in a cause-effect relationship with CASHD, since several factors have been proposed: those being, HDL, HDLc, the HDLc:TSC ratio, the HDLc:LDLc ratio, LDLc, HDL_2, the HDL_2:HDL_3 ratio and the apo A-I concentration.

9) The precipitation techniques are subject to error and hence require improvement. The required improvement is particularly important in this study since the changes in the biochemical parameters were relatively small. While ultracentrifugation is the method of choice in determining

lipoprotein concentrations, the lack of availability of this instrument forced the use of a precipitation technique and hence the calculation of LDLc by the Friedwald equation.

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APPENDIX I

LIPOPROTEIN METABOLISM

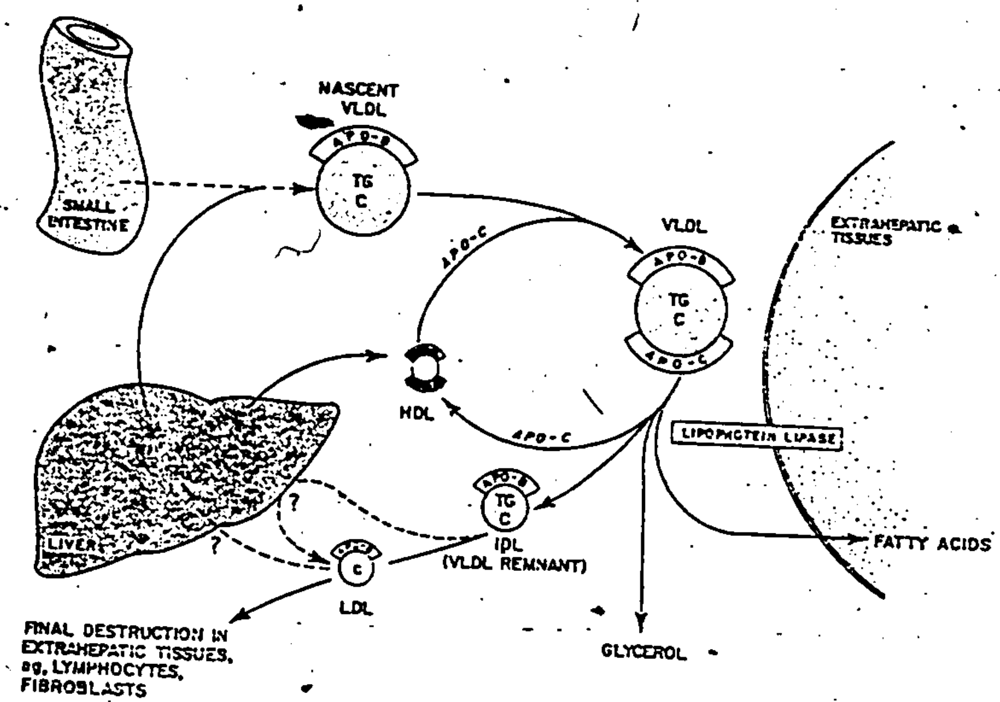
A SUMMARY

VLDL Formation

Much of the serum VLDL is formed in the liver and is the major transport vehicle for endogenous serum TGL. Apo-B is synthesized in the ribosomes (rough endoplasmic reticulum) of liver cells and is incorporated into lipoproteins in the smooth endoplasmic reticulum which is the major synthesis site for TGL, phospholipids and cholesterol. It is thought that carbohydrate residues are added to this lipoprotein in the Golgi apparatus. The VLDL is released from intestinal or hepatic cells by "fusion of the secretory vacuole with the cell membrane (reverse pinocytosis)" Harper et al (1977). Apo-B is essential for the synthesis of VLDL. Newly secreted VLDL (nascent VLDL) contains little or no apo-C and it is felt that the Apo-C complement comes from HDL after VLDL has entered the serum) (Fig. 2).

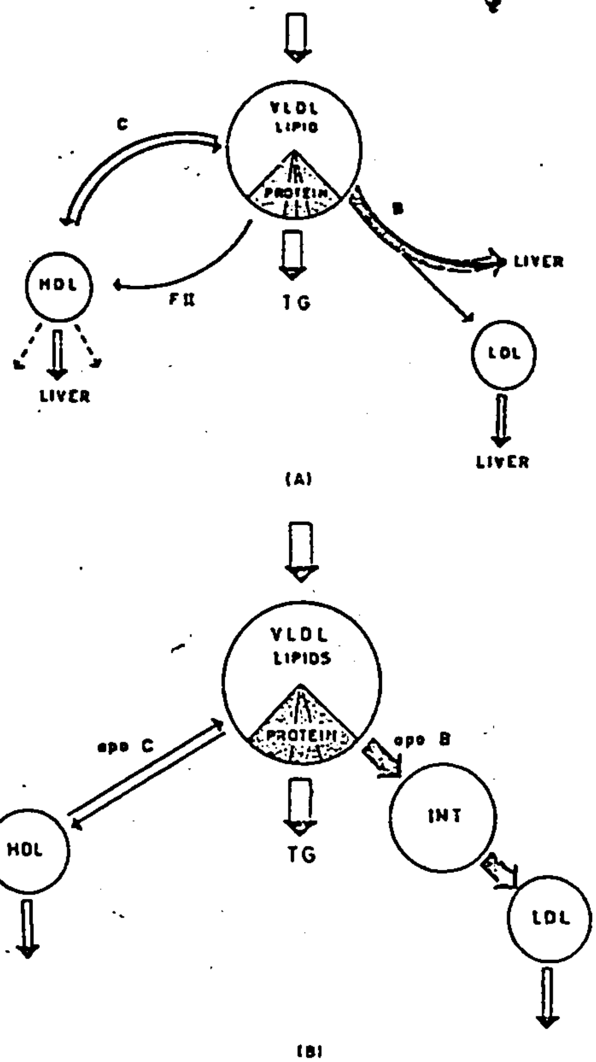
VLDL Catabolism

The role of LPL has been outlined in Fig 2. Both apo C-II and phospholipids are necessary co-factors for LPL (Harper et al 1977). The transfer of apoproteins has been outlined by Eisenberg and Levy (1975) (Fig. 3).



Metabolic fate of very low density lipoproteins (VLDL). (APO-B, apolipoprotein B; APO-C, apolipoprotein C; HDL, high density lipoprotein; TG, triacylglycerol; IDL, intermediate density lipoprotein; LDL, low density lipoprotein; C, cholesterol and cholesteryl ester.)

Fig. 2 (Harper et al 1977)



Schematic representation of probable pathways for VLDL apoprotein metabolism in rats (A) as compared to that in humans (B). In humans as in the rat, the liver is the probable site of HDL and LDL clearance from the blood stream.

Fig 3 (Eisenberg and Levy 1975)

LDL Metabolism

It appears that LDL is not secreted from the liver or the intestine per se. It seems that the catabolism of VLDL results in the formation of LDL as outlined above (Harper et al 1977) (see Fig. 2).

HDL Metabolism

This lipoprotein is synthesized and secreted from hepatic and intestinal cells. Nascent HDL from the intestine contains only apo-A but not apo-C. Thus, it would appear that apo-C is synthesized in the liver only and is passed to HDL of intestinal origin when the latter reaches the plasma. Nascent HDL from the liver is made up of discoid phospholipid bilayers which consist of apoprotein and free cholesterol (these lipoprotein particles are similar to those found in the serum of individuals with LCAT deficiency). It has been suggested that LCAT and possibly that enzyme's activator protein (apo A-I) attach to the disc. LCAT converts the surface phospholipid and free cholesterol into cholesterol esters and lysolecithin. The non-polar cholesteryl esters are transferred to the hydrophobic interior of the bilayer with lysolecithin going to the plasma albumin. This reaction forms a non-polar core which in turn pushes the bilayer apart and continues until a spherical pseudo-micellar HDL is developed. The latter particle has a surface of polar lipids and apoproteins. Thus the majority of serum HDL formed in the serum.

is from nascent HDL. The liver and perhaps the intestine appear to be degradative sites of HDL (Harper et al 1977). A summary of human lipoprotein metabolism occurs in Table XXIII (Smith et al 1978).

LIPOPROTEIN SYNTHESIS AND METABOLISM

Lipoprotein	Location	Process	Major components
Chylomicron	Intestine	assembly, secretion	apoA, apoB, phospholipid cholesterol, cholesteryl ester, triglyceride
	Lymph	transfer	apoC, apoE[a]
	Plasma	transfer	apoC, cholesterol
	Endothelial cell	hydrolysis[b]	triglyceride, phospholipid
		transfer	fatty acid, cholesterol, phospholipid, apoC, apoA, apoE[a]
VLDL	Liver	assembly, secretion	apoB, apoC, cholesterol, phospholipid, triglyceride, cholesteryl ester
	Plasma	transfer	apoC[a], apoE[a], cholesteryl ester
	Endothelial cell	hydrolysis[a]	triglyceride, phospholipid
		transfer	fatty acid, cholesterol, phospholipid, apoC, apoE[a]
LDL	Plasma	formation	from VLDL and chylomicrons
		exchange	cholesterol, phospholipid
	Peripheral tissues, liver[a]	uptake, degradation, regulation	cholesterol, cholesteryl ester
HDL	Liver	assembly, secretion	apoA, apoE, phospholipid, cholesterol
	Plasma	formation[a]	from chylomicrons[a]
		acyltransfer[c]	phosphatidylcholine, cholesterol
		transfer	cholesteryl ester, apoC, apoE[a]
		exchange	apoC, cholesterol, phospholipid
	Liver, peripheral tissues[a]	uptake, degradation	cholesterol, cholesteryl ester

a Inferred but not determined.
b Lipoprotein lipase (triacylglycerol hydrolyase, apoC-II activated).
c Lecithin cholesterol acyltransferase.

TABLE XXIII
(Smith et al, 1978)

APPENDIX II

A SUMMARY OF FACTORS AFFECTING LIPOPROTEIN AND LIPID LEVELS IN HUMAN SERA

	HDLc	total HDL	LDLc	TSC	TSTGL
Dietary Factors					
calories	27 ↓	(↓)1		↑ ?15	↑ ?15, 17
protein		↑1 low prot.			
fat sat.	10, 25 ↓	(↓)1		↑ 17,19	
unsat.	10, 25 ↑	(↑)1		↓ 17	
cholesterol	11 ↓	(↑)1,18		↑ 17	
carbohydrate		↓1		↑ 19	↑ 19,21
alcohol	12, 22 ↑	↑1,8			↑ 13
coffee	9 ↓		31 ↓ 9		↑ 9
(caffeine products)	9 ↓		31 ↓ 9		
Cigarette smoking	22 ↓	↓8			
Adiposity					
weight reduction	14 ↑		↓ 20;24		
obesity	8, 22 ↓			↑ 19	↑ 19
Drugs and Chemicals					
nicotinic acid	23 ↑	↑1			
sitosteral			↓ 3		
clofibrate	23 ↑	(↑)1	↓ 4	↓ 2	↓ 2
cholestyramine				↓ 4	
chlorthalidone			↑26,29		
chloroquine phosphate		↓5			
corticosteroids				↑ 16	
probucol				↓ 2	
propranolol	7, 30 ↓		↑ 7		
D-thyroxine			↓tot LDL 1		
Niacin(ate) (Xanthinol)				↓ 2	↓ 1,2
Chlorinated hydro-carbon insect.		↑6			
rowachol	28 ↑				
Neomycin				↓ 33	
phenytoin	34 ↑		↑ 34		↑ 34
benzodiazepines	35 ↓				

Key to Appendix II

( ) contradictory evidence available
? may lead to an increase

1 Schlierf et al 1977
2 Compendium of Pharmaceuticals and Specialties 1980
3 Oster, P. in H. Greten (ed.) 1975 - type II hyperlipoproteinemia
4 Miller and Miller 1975
5 Maurois et al 1979 - used only one subject
6 Nikkila et al 1978b
7 Tanaka et al 1976 - propranolol inhibits LPL
8 Garrison et al 1978
9 Heyden et al 1979 - combined with cigarettes
10 Hjermann et al 1979
11 Francis 1980
12 Danielsson et al 1978
13 Ginsberg et al 1975
14 Wilson and Lees 1972
15 Burke 1980
16 Paoletti 1964, p.79
17 Connor 1977
18 Mahley et al in Dietschy et al 1978
19 Ho and Chan 1975
20 Mann et al 1955a - B - lipoprotein
21 Nestel 1973
22 Williams et al 1979
23 Nikkila 1978a - total LDL
24 Walker 1953
25 Shepherd 1978
26 Gluck et al 1980
27 Flanagran et al 1980
28 Bell et al 1980 - mix of 6 terpenes
29 Rosenthal et al 1980
30 England et al 1980
31 Rhoads et al 1976b
32 Johansson and Medhus 1974
33 Medical Letter 1980
34 Kaukola et al 1981
35 Wallace et al 1980

Brockerhoff and Jensen (1974) have noted that protamine sulfate and NaCl inhibit extrahepatic LPL and while they did not note it, the lipoprotein metabolism is likely affected by the former two molecules.

APPENDIX III

COEFFICIENTS OF VARIANCE (CV) IN THE THREE ASSAYS

DETERMINATIONS BY WORTHINGTON AND BOEHRINGER MANNHEIM

AUTHORS	METHOD	CV	PRECISION TSC (mmol/1)±	S.D.
Worthington Co. (largely based on the method of Allain et al. 1974)	TSC	± 1.3%	2.51 ± 0.03	CV within 1 day
		± 1.0%	5.52 ± 0.06	
		± 1.0%	9.95 ± 0.09	
		± 2.2%	1.83 ± 0.04	CV Day to Day
		± 1.4%	4.80 ± 0.06	
		± 1.3%	12.45 ± 0.02	
Boehringer Mannheim Triglyceride test combinations based on Eggstein and Kuhlmann (1974) and Eggstein and Kreutz (1966)	TSTGL	3.4%	TSTGL (mmol/1) range 0.84-1.94 CV day to day	
		3.5%	abnormally high levels	

APPENDIX IV

COEFFICIENTS OF VARIANCE IN THE THREE ASSAYS DETERMINATIONS FOR THE CURRENT STUDY

HDLc - pooled sera - within day - 1.44 $\pm$ 0.03 mmol/l C.V. 2.2%

- between days - 1.30 $\pm$ 0.03[1] C.V. 2.6%

- 1.46[1] cholesterol standard - between days - 1.32[1] $\pm$ 0.00 C.V. 0.0%

TSC - pooled sera - between days - 4.50 $\pm$ 0.08[1] C.V. 1.7%

- standard of 2.93[1] - between days - 2.70 $\pm$ 0.03[1] C.V. 0.9%

TSTGL - pooled sera - between days - 1.67 $\pm$ 0.13[1] C.V. 7.96%

- standard of 1.47[1] - between days - 1.42 $\pm$ 0.05[1] C.V. 3.3%

1 - all concentration units are mmol/l

APPENDIX V

SUMMARY OF PRE-A and PRE-B VALUES[a] FOR N=31 SUBJECTS INCLUDING CORRELATIONS BETWEEN PRE-A & -B and THEIR 95% CONFIDENCE INTERVALS

Subject No.	HDLc (N=31)[b]		TSC (N=29)[b]		HDLc:TSC (N=29)[b]		LDLc (N=29)[b]		TSTGL (N=29)[b]	
	pre-a	pre-b	pre-a	pre-b	pre-a	pre-b	pre-a	pre-b	pre-a	pre-b
1	1.23	1.19	3.34	3.41	.359	.350	1.83	1.83	0.61	0.84
2	0.95	1.01	3.38	4.41	.281	.229	0.88	2.78	0.88	1.34
3	1.23	1.16	3.71	3.93	.332	.295	1.67	2.37	1.76	0.88
4	1.16	1.12	3.49	3.12	.332	.358	2.06	1.76	0.60	0.54
5	1.16	1.12	c	4.81	c	.232	c	c	c	c
6	1.12	1.12	c	3.85	c	.290	c	2.09	c	1.42
7	1.34	1.06	5.36	3.85	.249	.276	3.48	2.42	1.19	0.79
8	1.27	1.23	4.85	5.39	.261	.229	3.38	3.83	0.45	0.76
9	1.23	1.16	5.47	4.74	.218	.244	3.62	2.86	1.43	1.57
10	1.06	1.27	4.15	4.15	.257	.305	2.75	2.53	0.72	0.76
11	1.04	1.01	4.08	3.63	.254	.277	2.79	2.32	0.54	0.67
12	1.06	1.04	3.63	3.27	.293	.317	2.42	1.61	0.32	1.36
13	1.04	1.03	4.88	5.32	.212	.194	3.40	3.67	0.97	1.36
14	0.98	1.06	3.38	3.12	.290	.341	2.11	1.67	0.63	0.85
15	1.09	1.23	3.31	3.27	.338	.377	1.79	1.78	0.76	0.56
16	1.27	1.30	3.09	3.31	.411	.402	1.40	1.72	0.89	0.46
17	1.61	1.54	3.34	3.93	.482	.392	2.12	2.32	1.28	0.88
19	1.23	1.30	5.14	5.23	.228	.245	3.19	2.69	1.69	2.68
20	1.34	1.35	3.85	3.97	.347	.342	2.12	2.32	0.86	0.63
22	1.23	1.30	5.51	5.29	.224	.245	3.30	3.42	2.12	1.25
23	1.37	1.65	3.56	4.30	.385	.385	1.77	2.55	0.92	0.66
24	1.44	1.50	4.85	4.81	.297	.312	2.87	2.78	1.19	1.15
25	1.31	1.23	5.75	6.50	.227	.190	3.39	4.19	2.32	2.35
26	0.98	1.01	5.47	5.51	.179	.183	3.77	3.78	1.56	1.58
27	0.97	1.01	4.63	3.96	.209	.254	3.16	2.60	1.10	0.78
28	1.16	1.16	3.52	3.45	.329	.337	1.03	2.39	2.91	2.31
29	1.16	1.13	5.29	6.24	.219	.180	3.03	4.40	2.39	1.57
30	0.92	1.24	4.81	6.09	.191	.203	3.44	4.49	0.98	0.79
31	0.95	0.98	4.59	4.52	.207	.217	3.39	3.17	0.54	0.79
32	0.92	0.92	5.18	5.91	.178	.156	3.01	3.56	2.73	3.12
33	1.09	1.40	3.01	3.67	.363	.382	1.58	1.92	0.73	0.75
mean±S.D.	1.16±0.16	1.18±0.17	4.30±0.88	4.41±0.97	.281±0.76	.282±0.71	2.58±0.84	2.72±0.83	1.21±0.7	1.18±0.6
correlations	.77(p<.05)		.81(p <.05)		.90(p <.05)		.70(p <.05)		.77(p <.05)	
95% confidence intervals	.57 to .88		.57 to .88		.80 to .95		.45 to .85		.57 to .89	

a - mmol/l   b - no. of pairs used in correlations   c - lost samples

APPENDIX VI
SUBJECT CHARACTERISTICS PRIOR TO EXERCISE

SUBJECT NO.	GROUP NO.	$\dot{V}O_2$ MAX+ (ml/kg/min)	AGE (years)	BMI (kg/m^2)*	WEIGHT (kg)
1	1.	38.2	24	23.0	70.8
2	1	30.4	21	25.5	68.3
3	1	24.9	26	21.0	65.1
4	1	28.1	22	30.0	105.2
5	1	43.9	22	23.0	74.4
6	1	32.3	22	27.0	83.0
7	1	35.4	21	24.0	76.8
8	1	38.8	45	21.0	68.0
9	1	30.5	20	32.8	106.4
10	1	35.3	23	21.3	54.0
11	1	44.6	24	22.0	72.8
12	1	47.8	27	23.5	76.6
13	1	17.9	27	25.0	83.4
14	1	41.5	19	18.5	63.5
15	1	36.9	31	22.5	58.5
16	1	45.8	20	23.0	75.5
17	1	40.2	25	22.0	71.2
19	2	a	34	27.0	84.4
20	2	a	22	22.0	65.3
[illegible]	2	a	31	26.5	89.0
[illegible]	2	a	24	22.3	67.6
24	2	47.9	50	24.8	73.5
[illegible]	2	33.5	51	27.0	82.5
[illegible]	2	25.9	46	24.8	82.0
[illegible]	2	b	37	27.0	81.5
28	2	b	32	31.5	132.5
[illegible]	2	40.9	43	29.3	82.1
30	2	31.4	44	27.0	89.6
31	2	a	20	29.0	86.4
32	2	b	46	38.3	133.0
33	2	a	19	23.3	79.8

* Body Mass Index
\+ Maximal exertion $\dot{V}O_2$ max for treatment subjects
. Submaximal predictive $\dot{V}O_2$ max for control subjects
$\dot{V}O_2$ max = maximal oxygen uptake
1 treatment group
2 control group
a no attempt made to obtain
b could not be obtained due to bradycardia inducing medication

APPENDIX VI (Continued)

SUBJECT CHARACTERISTICS PRIOR TO EXERCISE IN THE ACUTE AND CHRONIC EXPERIMENTS

	ACUTE EXPERIMENT All data considered			ACUTE EXPERIMENT Post-hoc matching of subjects on the basis of age, weight and BMI			CHRONIC EXPERIMENT		
AGE* (years)	T(17) C(14)	24.6 ± 6.1 35.6 ± 11.3	$p < .05$	T(7) C(7)	27.1 ± 8.2 29.4 ± 11.4	N.S.[3]	T(5) C(4)	29.6 ± 9.3 26.0 ± 7.6	N.S.[3]
WEIGHT* (kg)	T(17) C(14)	74.9 ± 13.9 87.8 ± 20.3	$p < .05$	T(7) C(7)	74.0 ± 7.2 76.9 ± 8.3	N.S.[3]	T(5) C(4)	62.2 ± 4.8 84.9 ± 3.9	$p < .05$
BMI* (kg/m^2)	T(17) C(14)	23.8 ± 3.5 27.1 ± 4.2	$p < .05$	T(7) C(7)	23.3 ± 2.2 25.1 ± 2.7	N.S.[3]	T(5) C(4)	22.4 ± 1.9 26.4 ± 2.4	$p < .05$
VO_2 MAX* (mlO_2/kg/min)	T(17) C(5)	36.0 ± 7.9 (1) 35.9 ± 8.6 (2)	N.S.[3]	T(7) C(1)	32.5 ± 8.3 [1] 47.9 ± 0.0 [2]		T(5) C(4)	34.4 ± 6.4 a	

T=treatment (no. of subjects)
C=control (no. of subjects)
BMI=body mass index
* means $\pm$ S.D.
a not determined
1 determined by maximal exertion VO_2 max test
2 determined by submaximal predictive VO_2 max test
3 N.S. = not significant

APPENDIX VII
CHRONIC EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM CHOLESTEROL
(TSC (mmol/l))

Subject No.	Treatment group pre[a]	24a[a]	A.D.[b]	% Diff.[b]	24b[a]	A.D.[b]	% Diff.[b]
02	3.89	4.50	0.61	15.5	4.40	0.51	12.9
03	3.82	3.79	-0.03	-0.9	4.38	0.56	14.8
08	5.12	5.41	0.29	5.7	5.61	0.49	9.6
15	3.25	3.23	-0.02	-0.7	4.06	0.81	24.9
17	3.64	3.76	0.12	3.3	3.45	-0.19	-5.3
Mean ± S.D.	3.95±0.70	4.14±0.84	0.17	4.9	4.38±0.79	0.43	11.0

Subject No.	Control group pe$	p24a $	A.D.[b]	% Diff.[b]	p24b $	A.D.[b]	% Diff.[b]
19	5.18	4.84	-0.34	-6.6	6.78	1.60	31.0
22	5.40	5.27	-0.13	-2.4	5.57	0.17	3.1
31	4.55	4.36	-0.19	-4.3	3.95	-0.60	-13.3
33	3.34	3.16	-0.18	-5.3	3.78	0.44	13.2
Mean ± S.D.	4.62±0.92	4.41±0.91	-0.21	-4.6	5.02±1.42	0.40	8.7

[a]pre - pre-exercise (average of pre-a and pre-b)
24a - 24 hours post-1st acute exercise session
24b - 24 hours post-3rd acute exercise session
$ pe - non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p24a - non-exercising control group equivalent of 24a in treatment group
p24b - non-exercising control group equivalent of 24b in treatment group

[b] A.D. = absolute difference
% Diff. = percentage difference
[b]all differences are pre- to a given point post exercise

APPENDIX VIII
CHRONIC EXPERIMENT
POST-EXERCISE CHANGES IN LOW DENSITY LIPOPROTEIN CHOLESTEROL
(LDLc (mmol/l))

Subject No.	Treatment group pre[a]	24a[a]	A.D.[b]	% Diff.[b]	24b[a]	A.D.[b]	% Diff.[b]
02	2.40	2.80	0.40	16.5	2.70	0.30	12.3
03	2.02	1.85	-0.17	-8.5	2.80	0.78	38.9
08	3.60	3.82	0.22	6.1	4.06	0.46	12.8
15	1.78	1.58	-0.20	-11.5	2.21	0.43	23.8
17	1.57	2.15	0.58	37.4	2.02	0.59	28.6
Mean ± S.D.	2.27±0.80	2.44±0.90	0.17	7.4	2.76±0.80	0.49	21.5

Subject No.	Control group pe$	p24a$	A.D.[b]	% Diff.[b]	p24b$	A.D.[b]	% Diff.[b]
19	2.95	2.59	-0.36	-12.0	3.82	0.87	29.8
22	3.36	3.20	-0.16	- 4.8	3.47	0.11	3.3
31	3.28	3.09	-0.19	- 5.8	2.57	-0.71	-21.6
33	1.75	1.55	-0.20	-11.2	2.22	0.47	27.2
Mean ± S.D.	2.83±0.74	2.61±0.75	-0.22	- 8.0	3.02±0.75	0.19	6.7

[a] pre - pre-exercise (average of pre-a and pre-b)
24a - 24 hours post-1st acute exercise session
24b - 24 hours post-3rd acute exercise session
$ pe - non-exercising control group equivalent of pre-exercise in treatment group (average of pe-a and pe-b values)
p24a - non-exercising control group equivalent of 24a in treatment group
p24b - non-exercising control group equivalent of 24b in treatment group

[b] A.D. = absolute difference
[b] % Diff. = percentage difference
[b] all differences are pre- to a given point post exercise

APPENDIX IX
CHRONIC EXPERIMENT
POST-EXERCISE CHANGES IN TOTAL SERUM TRIGLYCERIDES
(TSTGL (mmol/l))

Subject No.	Treatment group pre[a]	24a[a]	A.D.[b]	% Diff.[b]	24b[a]	A.D.[b]	% Diff.[b]
02	1.11	1.48	0.37	32.2	1.59	0.48	43.2
03	1.32	1.61	0.29	22.1	0.97	-0.35	-26.6
08	0.60	0.49	-0.11	-19.6	0.65	0.05	7.5
15	0.66	0.72	0.06	8.7	0.53	-0.16	-19.9
17	1.08	0.46	-0.62	-58.8	1.01	-0.07	- 6.4
Mean ± S.D.	0.96±0.31	0.95 ± 0.56	-0.01	- 1.0	0.95 ± 0.41	-0.01	- 1.0
Subject No.	**Control group pe$**	**p24a $**	**A.D.[b]**	**% Diff.[b]**	**p24b $**	**A.D.[b]**	**% Diff.[b]**
19	2.18	1.59	-0.59	-27.1	3.21	1.03	46.9
22	1.68	1.73	0.05	2.8	2.18	0.50	29.6
31	0.67	0.54	-0.13	-19.4	0.75	0.08	12.5
33	0.74	0.49	-0.25	-33.4	0.64	0.10	-13.5
Mean ± S.D.	1.32±0.74	1.09±0.66	-0.23	-17.5	1.70 ± 1.23	0.38	28.7

[a] pre - pre-exercise (average of pre-a and pre-b)
24a - 24 hours post-1st acute exercise session
24b - 24 hours post-3rd acute exercise session
$ pe - ~~non-exercising~~ control group equivalent of pre-exercise in treatment group (average of po-a and pe-b values)
p24a - non-exercising control group equivalent of 24a in treatment group
p24b - non-exercising ~~control group~~ equivalent of 24b in treatment group

[b] A.D. = absolute difference
% Diff. = percentage difference
All differences are pre- to a given point post exercise