The Effect of Exercise on Plasma High Density Lipoproteins

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ABSTRACT

The influence of vigorous activity in man on plasma lipids and lipoproteins is reviewed, with particular emphasis on high density lipoproteins. Both cross sectional and longitudinal (or training) studies have been reported, many of them of less than ideal design. Nonetheless, a consistent pattern emerges in which increased exercise levels lead to lower plasma concentrations of triglycerides and very low density lipoproteins, and of low density lipoproteins. High density lipoprotein levels increase. Sometimes, but not uniformly, plasma total cholesterol level falls as the result of these changes. The increase in plasma high density lipoprotein appears to be the result largely of an increase in the less dense HDL₂ subfraction. Plasma apolipoprotein A-I levels (but not apo-A-II levels) seem to increase concomitantly. The precise biochemical mechanism responsible for these changes has not been elucidated; but the recent finding of increased lipoprotein lipase activity in adipose tissue and muscle of endurance runners suggests that increased lipolytic rate of triglyceride-rich lipoproteins may be an initial step in a sequence of events leading to higher plasma levels of HDL₂.

INTRODUCTION

The topic of exercise in relation to plasma high density lipoprotein (HDL) concentration now lies at the intersection of two areas of increasing scientific study and of considerable public health concern. Interestingly, both exercise and HDL concentration had received Cinderella treatment for many years, while the preponderance of investigative attention was directed towards their more glamorous sisters, diet and low density lipoprotein (LDL), respectively. Remarkable changes of scientific emphasis have occurred recently, particularly in the United States, dating from about 1975. In this year, the classic paper of Miller and Miller (1) appeared, pulling together numerous existing lines of evidence suggesting that low levels of plasma HDL are strongly associated with increased risk of coronary heart disease (CHD) in man. Intense activity in this area has continued in the realms of epidemiology, biochemistry and physiology, with the great majority of subsequent reports supporting and extending the original hypothesis (2). The concept that relatively high plasma HDL levels are associated with less CHD, and that a high HDL level might actually be “protective,” has become familiar to a large section of the general public (3). Almost coincidentally with this upsurge of interest in HDL as a “negative” risk factor for CHD, increased exercise in leisure time has become progressively more popular in the United States (4,5). The present paper attempts to review the current state of knowledge of the influence of the more vigorous, aerobic types of exercise upon plasma lipid and lipoprotein levels, with particular attention to studies of high density lipoproteins in man. Cross sectional studies will be reviewed first, followed by longitudinal (or training) studies and finally by consideration of some biochemical mechanisms that may be involved.

CROSS SECTIONAL STUDIES

Plasma Triglycerides

It is now clear from increasing numbers of cross sectional studies that very active individuals generally exhibit lower plasma concentrations of triglycerides, and thus of very low density lipoproteins (VLDL) than sedentary individuals of the same sex and age range. Bjorntorp et al. (6) reported significantly lower triglyceride concentrations for 15 physically well trained men aged 52-56, compared with 45 sedentary control men. Hurter et al. (7) similarly found lower plasma triglyceride levels in younger male long distance runners compared to sedentary men. Hurter et al. (7) similarly found lower plasma triglyceride levels in younger male long distance runners compared to sedentary men. Using standardized assays (8), Wood et al. (5) examined 41 male and 43 female long distance runners, and relatively sedentary control groups, randomly selected from three northern California towns, while Martin et al. (9) reported on 20 young elite male runners and sedentary controls. As shown in Table I, the more active groups were found to have significantly lower triglyceride levels, for both sexes. Lehtonen and Viikari (10) measured lower triglycerides in 23 men aged 35-68 who were running or skiing 83 km per week in comparison with 15 healthy but inactive men aged 33-58. The same authors (11) also found lower plasma triglyceride levels in 12 Finnish lumberjacks compared with levels in 15 electricians; this study suggests that vigorous physical activity at work, as well as vigorous leisure time activity, results in relatively low plasma triglyceride concentrations.
These and other studies are consistent in their findings of low mean triglyceride levels in physically very active groups. It is noteworthy that the spread of values (as indicated by standard deviations) is also consistently lower in the active groups. Measurements of VLDL cholesterol in male and female long distance runners have confirmed that the triglyceride-rich VLDL is indeed at a very low level in these very active individuals (5).

**Plasma Total Cholesterol**

Numerous cross sectional studies have addressed the question whether or not the vigorously active lifestyle is associated with relatively low levels of plasma total cholesterol. Several reports indicate that significantly lower total cholesterol levels (compared to sedentary controls) are associated with vigorous activity, for instance in cross-country runners and skiers (6); in middle-aged male (12) and female (5) long distance runners; and in young elite (national class) long distance runners (9). On the other hand, many studies have failed to show significant differences between active and sedentary controls, for instance in male marathon runners aged 24-43 (7), in English male civil servants aged 40-64 who reported vigorous leisure time activity (13), in Norwegian male cross-country skiers aged 16-74 (14), in Finnish male runners and skiers aged 35-68 (10), and in Finnish lumberjacks (11). A study by Montoye et al. (15) on 1060 males and 119 females from the Tecumseh Community Health Study reported no relationship between maximal oxygen uptake (a measure of physical fitness) and plasma total cholesterol concentration, when the effects of age, weight and adiposity were removed. Several other apparently contradictory cross sectional studies have been reviewed by Naito (16). In summary, there is at present no clear consensus on the question of physical activity level in relation to plasma total cholesterol concentration.

There seem to be several reasons for this lack of consensus. In a number of studies, the difference in level of physical fitness between the active and the sedentary groups may have been too small for an effect to be apparent; and in some instances, the numbers in the groups were quite small. In addition, less than adequate total cholesterol assays in some studies may have contributed to variance to such an extent that true differences between groups were obliterated. Again, lack of appropriate analytical control on certain concomitants of high levels of physical activity (leaneness, abstinence from cigarette smoking, possible dietary differences) may have led to reporting of significant differences in total cholesterol level that were not due to differences in exercise level per se, or alternatively may have obscured true differences when they did exist.

The traditional interest in total cholesterol level derives, of course, from the positive correlations usually found in westernized populations between plasma total cholesterol concentration and risk of future CHD. This relationship results, in turn, from a strong positive correlation in many populations between plasma total cholesterol and the concentration of the atherogenic low density lipoprotein (LDL) fraction. As the proportion of the total cholesterol carried in LDL becomes less, and the proportion carried in HDL becomes greater, the predictive power of a total cholesterol measurement presumably becomes less. In populations, HDL cholesterol concentration generally correlates poorly or not at all with total cholesterol (17); however, in very active populations HDL cholesterol (which constitutes a larger than usual proportion of the whole) may correlate positively with plasma total cholesterol level (14). In view of these considerations, and of the fact that a total cholesterol measurement contains within it the elements of a positive (LDL) and a negative (HDL) risk factor, the predictive importance of total cholesterol is probably considerably diminished, particularly in physically active populations. The focus of attention, then, has moved on from total cholesterol to the lipoprotein fractions, notably HDL.

**Plasma High Density Lipoprotein**

One of the first observations of the association of the vigorously active lifestyle with plasma HDL concentration was that of Carlson and Mossfeldt in 1964 (18); male Swedish skiers showed higher mean HDL cholesterol levels than have been reported for the general male population (19). The twin observations that male Eskimos in northwest Greenland have high plasma HDL levels, and low CHD mortality rates, have been ascribed a common cause – the high physical activity level in this population (20).

Our group has conducted several cross sectional studies in middle-aged male and female runners (5,12) and in young, elite long distance runners (9), each in comparison with a randomly selected control group of appropriate age and sex. Plasma lipid and lipoprotein concentrations recorded are summarized in Table I. Comparisons are made between groups of dedicated long distance runners and age- and sex-matched control groups, without any