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Effect of Maximal Oxygen Uptake and Different Forms of Physical Training on Serum Lipoproteins*

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Summary. 260 well trained male sportsmen between 17 and 30 years of age participating in a variety of events were examined for total serum cholesterol and lipoprotein cholesterol and compared with 37 moderately active leisure-time sportsmen and 20 sedentary controls of similar ages and sex. Lipoprotein cholesterol distribution was determined by quantitative electrophoresis.

Mean HDL-cholesterol increased progressively from the mean of the sedentary controls to the mean of the long-distance runners, indicating a graded effect of physical activity on HDL-cholesterol. In all sporting groups mean LDL-cholesterol tended to be lower than in the controls, no association between LDL-cholesterol and form of training being apparent. Except for the long-distance runners, all sporting groups tended to be lower in total cholesterol than the controls. The HDL-/total cholesterol and LDL/HDL ratios yielded a better discrimination between the physically active and inactive than the HDL-cholesterol alone.

Significant positive correlations with maximal oxygen uptake and roentgenologically determined heart volume were found for HDL-cholesterol and HDL-/total cholesterol, and negative ones for LDL/HDL. Differences in the regressions among subsets made up of sporting groups under different physical demands suggest a positive relationship between lipoprotein distribution and the magnitude of the trained muscle mass.

Key words: Lipoprotein cholesterol – Total serum cholesterol – Maximal oxygen uptake – Heart volume – Physical training

Introduction

The discovery of the negative correlation between high density lipoprotein (HDL) and coronary heart disease (Carlson and Ericsson 1975b; Castelli et al.

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1975; Rhoads et al. 1976; Gordon et al. 1977; Miller et al. 1977; Steinberg 1978; Zimmer et al. 1980) has strongly stimulated interest in the determinants of the lipoprotein pattern. A number of conditions has been found to be associated with low HDL levels including obesity (Carlson and Ericsson 1975a; Rhoads et al. 1976; Williams et al. 1979), diabetes mellitus (Kennedy et al. 1978; Nikkilä and Hormila 1978), male sex (Carlson and Ericsson 1975a; Avogaro et al. 1978), carbohydrate rich diet (Levy et al. 1966; Wilson and Lees 1972; Blum et al. 1977), and physical inactivity (Hoffman et al. 1967; Williams et al. 1979). By contrast, decreased body fat content (Avogaro et al. 1978; Williams et al. 1979), female sex (Carlson and Ericsson 1975a; Avogaro et al. 1978), alcohol consumption (Castelli et al. 1977; Hennekens et al. 1979), and increased physical activity (Hoffman et al. 1967; Lopes-S. et al. 1974, Huttunen et al. 1979; Miller et al. 1979; Williams et al. 1979) have been shown to accompany high HDL levels.

Apparently the association between high physical activity and elevated HDL can most readily be demonstrated in sportsmen being engaged in events depending on a high aerobic capacity, such as running and cross-country skiing. Thus a number of studies are available on lipoproteins in these sports (Wood et al. 1976, 1977; Enger et al. 1977; Martin et al. 1977; Lehtonen and Viikari 1978; Dufaux et al. 1979; Lehtonen et al. 1979; Adner and Castelli 1980; Hartung et al. 1980), whereas little attention in this regard has been attributed so far to other sports, including those not primarily dependent on a high aerobic capacity (Berg et al. 1980; Lehtonen and Viikari 1980; Vodak et al. 1980).

The present study has been designed to examine the associations between lipoprotein pattern and different kinds of sports and to further elucidate the relationships between aerobic capacity and lipoprotein pattern.

Materials and Methods

A total of 260 male elite sportsmen between the ages of 17 and 30 years was examined. Except for groups of intermediate grade soccer and handball players, all were in the highest national class and by proficiency were eligible to receive the regular medical check-ups offered to top sportsmen in Germany. They had been in regular competitive training for several years and trained more than 5 times per week. The intermediate grade soccer and handball players trained 3–5 times per week.

For comparison groups of 37 leisure-time sportsmen and 20 sedentary controls of similar ages and sex were examined. The leisure-time sportsmen were non-competitive enthusiasts who participated in a variety of sports at a low to moderate intensity and a mean rate of 2–3 times per week. The control subjects were healthy non-sporting males, who neither in occupational life nor in leisure-time were subject to any major physical activity. Their individual relative weight did not exceed 1.15, and like all the sportsmen they were non-smokers. Additional descriptive data are given in Table 1.

All the sportsmen underwent physical examination, resting and exercise ECG, and biochemical screening, the majority also having a chest roentgenogram. No disorder significant to lipid metabolism was detected. None was on any medication known to affect lipids or lipoproteins. In the days before examination they had performed their normal training.

Blood samples were drawn in the fasting state from a cubital vein. After complete coagulation, serum was separated by low-speed centrifugation. Lipoprotein distribution was determined by means of agarose electrophoresis, subsequent precipitation (sodium phosphotungstate 1 g/100 ml,

Table 1. Physical characteristics of subjects

	Number of subjects	Age (years)	Height (cm)	Weight (kg)	Relative weight	Maximal oxygen uptake (ml/min · kg)	Heart volume (ml/kg)
Long-distance running	11	25.0 ± 3.5	179.5 ± 4.0	67.0 ± 5.5	0.84 ± 0.06	72.9 ± 5.7	15.7 ± 1.5
Middle-distance running	19	20.5 ± 3.5	182.0 ± 6.0	71.0 ± 6.0	0.86 ± 0.05	67.2 ± 4.6	13.2 ± 1.3
400 m-running	20	21.0 ± 3.0	184.0 ± 6.0	74.5 ± 6.0	0.89 ± 0.06	58.9 ± 3.4	12.1 ± 0.9
Rowing	34	20.5 ± 3.0	189.0 ± 6.5	87.0 ± 9.5	0.97 ± 0.07	57.5 ± 4.8	12.8 ± 1.1
Speed-skating, long-distance	12	24.5 ± 5.0	180.5 ± 6.0	75.0 ± 6.5	0.93 ± 0.06	60.2 ± 3.8	
Speed-skating, sprint	11	21.5 ± 3.0	178.5 ± 2.5	75.0 ± 3.0	0.95 ± 0.05	57.6 ± 4.2	
Handball high grade (Bundesliga)	14	25.0 ± 3.5	186.5 ± 6.0	89.0 ± 7.5	1.03 ± 0.06	55.6 ± 4.5	12.3 ± 0.7
Handball intermediate grade	34	25.5 ± 5.5	179.0 ± 6.0	80.0 ± 8.0	1.01 ± 0.08	53.9 ± 4.3	11.2 ± 0.8
Soccer high grade (Bundesliga)	17	25.5 ± 4.0	176.0 ± 3.5	71.5 ± 5.5	0.94 ± 0.06	61.4 ± 4.3	13.0 ± 1.4
Soccer intermediate grade	23	17.2 ± 0.6	176.5 ± 5.5	69.0 ± 5.0	0.89 ± 0.11	57.1 ± 3.0	12.3 ± 0.9
Volleyball, basketball	9	24.0 ± 7.0	187.0 ± 9.0	82.5 ± 13.0	0.95 ± 0.10	50.2 ± 3.8	11.1 ± 1.0
Wrestling, boxing	17	20.0 ± 4.0	170.5 ± 6.0	66.5 ± 9.0	0.94 ± 0.07	56.0 ± 5.5	11.7 ± 1.1
Swimming	26	17.0 ± 2.5	182.0 ± 7.5	73.0 ± 9.0	0.89 ± 0.07	55.2 ± 5.2	13.6 ± 3.4
Compository sports (gymnastics, figure-skating)	13	19.5 ± 3.0	173.5 ± 8.0	70.0 ± 9.0	0.95 ± 0.08	51.7 ± 7.1	11.8 ± 1.0
Leisure-time sports	37	22.5 ± 4.0	177.0 ± 6.5	71.5 ± 7.0	0.93 ± 0.08	50.3 ± 7.1	11.6 ± 1.3
Untrained controls	20	23.0 ± 4.0	177.0 ± 6.0	76.0 ± 11.0	0.98 ± 0.10		

magnesium chloride 0.18 mol/l, saline 0.7 mol/l), and densitometric quantitation (Seidel et al. 1973; Neubeck et al. 1977) using a commercially available kit (Lipidophor All In 12, Immuno, Heidelberg, FRG). Densitometry at 500 nm and automatic integration of the densitogram were performed with an Elphograph 3 (Bender & Hobein, Munich, FRG). Total cholesterol was determined enzymatically (kit No. 172626, Boehringer, Mannheim, FRG).

In this laboratory the coefficient of variation, as determined by repeated measurements of identical samples, was about 2.2% for HDL-cholesterol, 3.7% for LDL-cholesterol, and 10.4% for VLDL-cholesterol. Because of the comparatively high coefficient of variation in determination of the latter fraction, VLDL values have to be regarded with reservation and will not be considered in detail.

Maximal oxygen uptake was assessed by means of a standardized progressive exercise test. Runners, wrestlers, boxers, soccer, handball, volleyball, and basketball players were tested on a motor-driven treadmill at a slope of 5%. The initial speed was 6 km/h, in long- and middle-distance runners 8 km/h, and was increased by 2 km/h every 3 min until volitional exhaustion. Speed-skaters, rowers, swimmers, gymnasts, and leisure-time sportsmen were tested on an electrically braked bicycle ergometer, the initial load of 100 W being increased by 50 W every 3 min. Oxygen uptake was determined with an open system. Heart volume was assessed roentgenologically (Musshoff and Reindell 1956).

Relative body weight was calculated as body weight divided by height in cm minus 100. Body fat content was determined by means of skinfold measurements at four sites – biceps, triceps, subscapular, supra iliac – employing a Lange caliper and the regression equations of Womersley and Durnin (1977).

All data are expressed as means ± standard deviation. Differences of means were tested for statistical significance by the two-tailed *t*-test, regression analysis was performed following the recommendations given in Diem and Lentner (1975).

Results

Figure 1 shows the distribution of serum cholesterol in the three main lipoprotein fractions of fasting serum. In each column mean HDL-, LDL-, and VLDL-cholesterol add up to total cholesterol, the columns are arranged with respect to HDL-cholesterol.

The highest HDL-cholesterol was found in the long-distance runners, heading a continuous line of steadily declining HDL-cholesterol values which ended with the controls and the intermediate grade soccer players. Long-distance runners, middle-distance runners, high grade handball players, wrestlers and boxers, and long-distance speed-skaters differed significantly in HDL-cholesterol from the sedentary controls (Table 2).

It is noteworthy that events demanding a high aerobic capacity concentrate in the left half of the diagram. Furthermore in runners and speed-skaters training over longer distances goes along with the tendency towards higher HDL-cholesterol. In the soccer and handball players higher competitiveness is paralleled by the tendency towards higher HDL-cholesterol. Consequently, there is some indication of a positive relation between HDL-cholesterol and endurance exercise capacity.

Regarding Fig. 1 no association appears to exist between LDL-cholesterol and form of physical activity in the sporting groups. In the majority of events LDL-cholesterol tended to be lower than in the controls, differences being significant in middle-distance runners, rowers, swimmers, and intermediate grade handball players (Table 2).

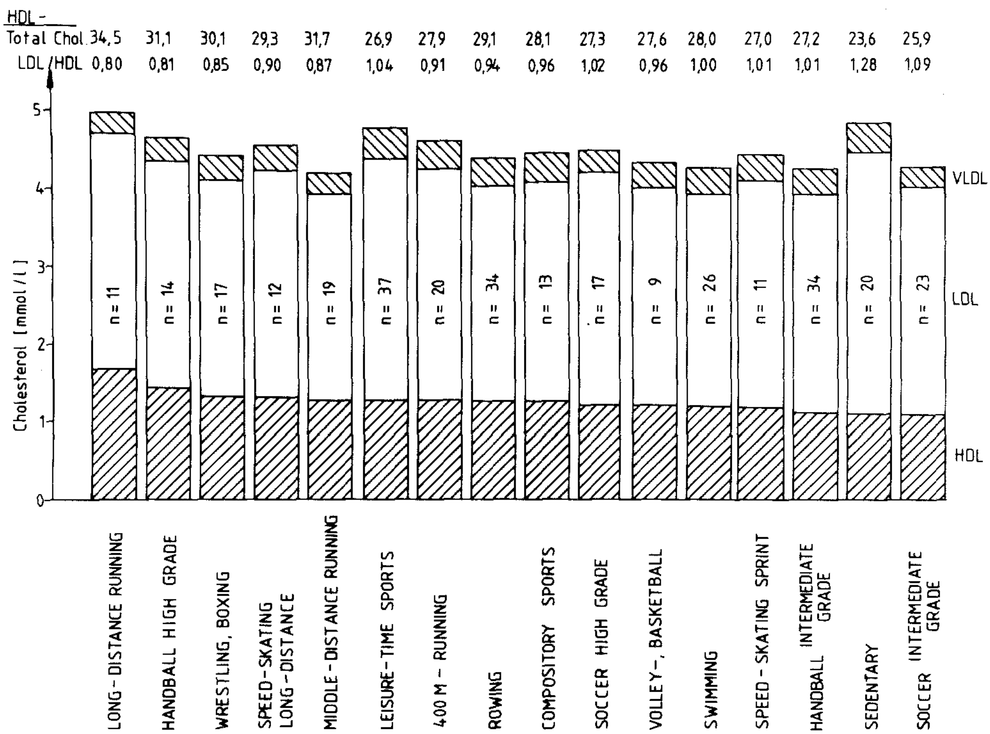

Fig. 1. Distribution of total serum cholesterol between HDL-, LDL-, and VLDL-cholesterol. Events are arranged with respect to HDL-cholesterol

Differences in total cholesterol between groups were relatively small. Except in the long-distance runners total cholesterol tended to be lower in all sporting groups than in the controls, but the difference was only significant in the swimmers and intermediate grade handball players.

Figure 2 shows the HDL-/total cholesterol and LDL/HDL ratios, the groups being arranged with respect to HDL-/total cholesterol. Statistically significant differences from control values are indicated in Table 2. The two ratios correlated closely, though correlation was not perfect. Correlation analysis within groups yielded correlation coefficients between $r = -0.800$ and $r = -0.987$.

Significant linear correlations were found between HDL- and LDL-cholesterol respectively and total cholesterol in all sporting groups, in the sedentary controls no significant correlation was obtained between HDL-cholesterol and total cholesterol (Table 3).

Skinfold measurements for the assessment of body fat content were carried out on 17 wrestlers, 28 soccer players, 26 swimmers, 14 handball players, and 41 rowers. Neither HDL- nor LDL- or total cholesterol correlated with body fat content as expressed in percent body weight in any of these groups or in the pooled data.

Table 2. Lipoprotein cholesterol distribution in study groups (means, standard deviations, significance of differences from controls)

	Number of subjects	HDL cholesterol (mmol/l)	LDL cholesterol (mmol/l)	Total cholesterol (mmol/l)	HDL-/total cholesterol (%)	LDL/HDL
Long-distance running	11	1.68 ± 0.31***	3.02 ± 0.87	4.99 ± 0.83	34.5 ± 7.5***	0.80 ± 0.34**
Middle-distance running	19	1.28 ± 0.24*	2.64 ± 0.62*	4.21 ± 0.72	31.7 ± 6.5***	0.87 ± 0.34**
400 m-running	20	1.27 ± 0.24	2.98 ± 0.66	4.62 ± 0.74	27.9 ± 5.5*	0.91 ± 0.20**
Rowing	34	1.27 ± 0.29	2.77 ± 0.58*	4.39 ± 0.78	29.1 ± 6.5**	0.94 ± 0.37**
Speed-skating, long-distance	12	1.31 ± 0.26*	2.92 ± 0.82	4.55 ± 1.03	29.3 ± 5.1*	0.90 ± 0.23*
Speed-skating, sprint	11	1.18 ± 0.28	2.90 ± 0.67	4.42 ± 0.88	27.0 ± 5.2	1.01 ± 0.26
Handball high grade	14	1.44 ± 0.25**	2.91 ± 0.52	4.65 ± 0.75	31.1 ± 3.5**	0.81 ± 0.12**
Handball intermediate grade	34	1.12 ± 0.24	2.78 ± 0.76*	4.24 ± 0.90*	27.2 ± 5.6*	1.01 ± 0.27*
Soccer high grade	17	1.22 ± 0.26	2.99 ± 0.60	4.50 ± 0.70	27.3 ± 5.4	1.02 ± 0.29
Soccer intermediate grade	23	1.09 ± 0.24	2.91 ± 0.74	4.26 ± 0.90	25.9 ± 4.6	1.09 ± 0.24
Volleyball, basketball	9	1.21 ± 0.24	2.77 ± 0.43	4.32 ± 0.49	27.6 ± 4.9	0.96 ± 0.30
Wrestling, boxing	17	1.33 ± 0.30*	2.77 ± 0.57	4.43 ± 0.83	30.1 ± 3.8**	0.85 ± 0.19**
Swimming	26	1.19 ± 0.39	2.72 ± 0.47*	4.25 ± 0.67*	28.0 ± 7.5*	1.00 ± 0.35*
Compository sports	13	1.26 ± 0.37	2.83 ± 0.67	4.46 ± 0.93	28.1 ± 6.3	0.96 ± 0.27*
Leisure-time sports	37	1.29 ± 0.38	3.10 ± 0.68	4.78 ± 0.89	26.9 ± 6.0	1.04 ± 0.35
Untrained controls	20	1.10 ± 0.29	3.35 ± 1.06	4.83 ± 1.21	23.6 ± 6.7	1.28 ± 0.49

Level of significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

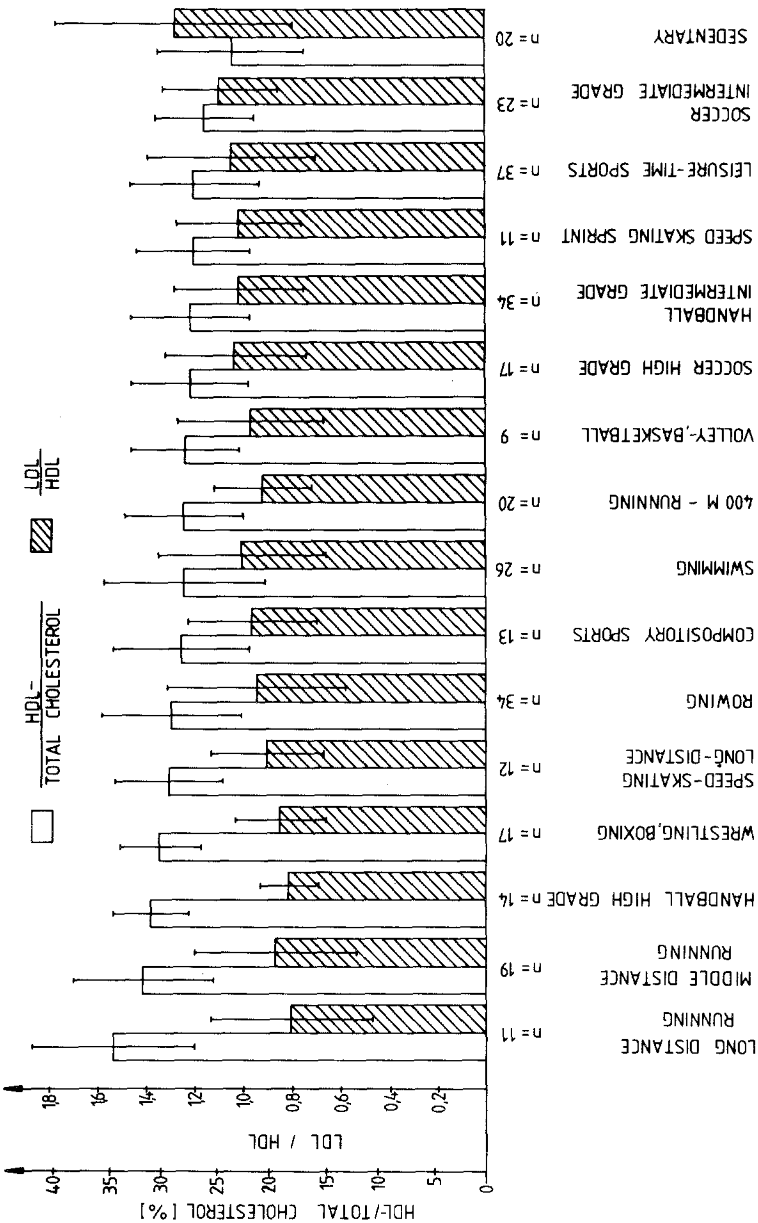

Fig. 2. HDL-/total cholesterol and LDL/HDL ratios (means and standard deviations). Events are arranged with respect to HDL-/total cholesterol

To further clarify the relationships between physical activity and lipoprotein cholesterol the values of the sporting groups were correlated with maximal oxygen uptake and heart volume. Figures 3 and 4 show the dependence of HDL-/total cholesterol, HDL-, LDL-, and total cholesterol on maximal oxygen uptake as assessed by treadmill exercise in the pooled data of 183 sportsmen irrespective of form of training. Positive correlations were obtained between

Table 3. Correlation coefficients for HDL- and LDL-cholesterol versus total cholesterol in different events

	Number of subjects	HDL-cholesterol	LDL-cholesterol
Long-distance and middle-distance running	30	0.660***	0.902***
400 m-running	20	0.419	0.965***
Soccer	40	0.607***	0.966***
Handball	48	0.605***	0.956***
Speed-skating	23	0.627**	0.974***
Rowing	34	0.508**	0.891***
Leisure-time sports	37	0.633***	0.893***
Inactive controls	20	0.214	0.962***

Level of significance: ** $p < 0.01$; *** $p < 0.001$

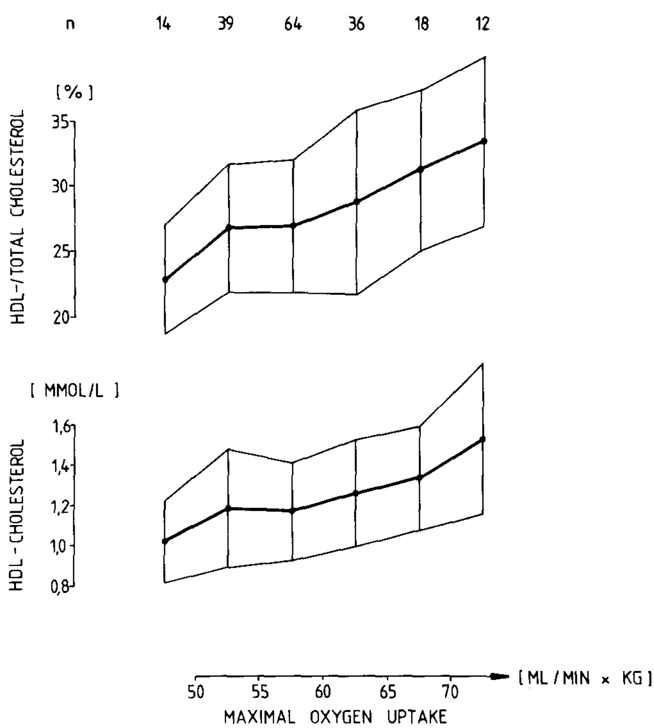

Fig. 3. Relationships of HDL-/total cholesterol and HDL-cholesterol (means and standard deviations) to maximal oxygen uptake in 183 sportsmen

HDL-cholesterol ($r = 0.320$, $p < 0.001$) and HDL-/total cholesterol ($r = 0.389$, $p < 0.001$) respectively and maximal oxygen uptake. LDL- and total cholesterol exhibited no dependence on maximal oxygen uptake. Similar relations were found in 93 sportsmen tested for maximal oxygen uptake by bicycle exercise (not depicted).

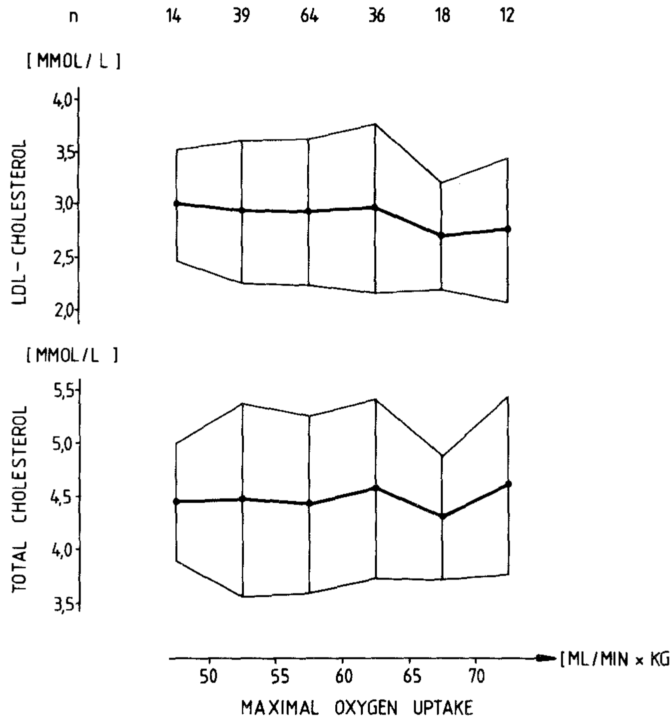

Fig. 4. Relationships of LDL- and total cholesterol (means and standard deviations) to maximal oxygen uptake in 183 sportsmen

Furthermore, positive correlations between HDL-cholesterol ($r = 0.329$, $p < 0.001$) and HDL-/total cholesterol ($r = 0.193$, $p < 0.01$) respectively and heart volume were obtained in the pooled data of 248 sportsmen (not depicted). Correlating LDL- and total cholesterol with heart volume failed to reveal any systematic association.

In addition, these parameters were correlated within subsets of sporting groups with similar regressions. Thereby significant linear correlations were found between HDL-cholesterol, HDL-/total cholesterol, and LDL/HDL on the one hand, and maximal oxygen uptake and heart volume on the other, in the pooled data of runners and soccer players (Table 4). There was no correlation between either LDL- or total cholesterol with maximal oxygen uptake or heart volume.

A second subset with significant correlations was made up of handball, volleyball, and basketball players, and wrestlers. Significant correlations were obtained in the pooled data of these groups between HDL-/total cholesterol and LDL/HDL respectively and maximal oxygen uptake, and between HDL-cholesterol and heart volume (Table 4).

Where significant correlations appeared between lipoprotein parameters and maximal oxygen uptake or heart volume in both subsets, the respective regression lines were similar in slope, as indicated by the absence of significant

Table 4. Regression analysis for the relationships between lipoprotein parameters and maximal oxygen uptake or heart volume

Correlated parameters: y-variable	Correlated parameters: x-variable	Running, soccer	Handball, volleyball, basketball, wrestling
HDL-cholesterol	$VO_{2\,max}$	y = −0.108 + 0.022 x $r =$ 0.488 (n = 93) $p < 0.001$	$r =$ 0.162 (n = 73) NS
HDL-/total cholesterol	$VO_{2\,max}$	y = 2.271 + 0.429 x $r =$ 0.443 (n = 93) $p < 0.001$	y = 10.594 + 0.333 x $r =$ 0.313 (n = 73) $p < 0.01$
		$p < 0.01$	
LDL/HDL	$VO_{2\,max}$	y = 2.047 − 0.018 x $r =$ −0.446 (n = 93) $p < 0.001$	y = 1.999 − 0.020 x $r =$ −0.375 (n = 73) $p < 0.01$
		$p < 0.001$	
HDL-cholesterol	Heart volume	y = 0.208 + 0.081 x $r =$ 0.418 (n = 85) $p < 0.001$	y = 0.107 + 0.100 x $r =$ 0.349 (n = 70) $p < 0.01$
		$p < 0.05$	
HDL-/total cholesterol	Heart volume	y = 12.572 + 1.286 x $r =$ 0.333 (n = 85) $p < 0.01$	$r =$ 0.209 (n = 70) NS
LDL/HDL	Heart volume	y = 1.557 − 0.050 x $r =$ −0.330 (n = 85) $p < 0.01$	$r =$ −0.218 (n = 70) NS

differences between the regression coefficients, but differed significantly in the intercept on the y-axis. The handball, volleyball, basketball, and wrestlers subset had, in proportion to maximal oxygen uptake or heart volume, significantly higher HDL-cholesterol and HDL-/total cholesterol and lower LDL/HDL than the runners and soccer players. Where no significant correlations were obtained in the former subset, their means for HDL-cholesterol and HDL-/total cholesterol were higher, and for LDL/HDL lower, than in the latter when related to maximal oxygen uptake or heart volume.

Discussion

As evidenced by Fig. 1, HDL-cholesterol values in the different events form a continuum from the mean of the sedentary controls to the mean of the long-distance runners. Though the differences from the control values reached statistical significance in selected groups only, a tendency towards elevated HDL-cholesterol was common to all sporting groups, including the leisure-time sportsmen with a moderate amount of training. This implies that all kinds of dynamic exercise involving large muscle groups are able to elevate HDL-cholesterol. It furthermore implies a graded effect of physical activity on HDL-cholesterol, as has already been suggested by other studies (Enger et al. 1977; Martin et al. 1977; Lehtonen and Viikari 1978; Berg et al. 1980; Hartung et al. 1980).

LDL-cholesterol varied independently from HDL-cholesterol, all sporting groups exhibiting at least a tendency towards depressed LDL-cholesterol. In a number of reports increased physical activity has been shown to be associated with decreased LDL-cholesterol (Hoffmann et al. 1967; Wood et al. 1976, 1977; Martin et al. 1977; Adner and Castelli 1980; Berg et al. 1980; Hartung et al. 1980). Longitudinal studies have demonstrated that already moderate physical activity is able to reduce LDL-cholesterol (Altekruse and Wilmore 1973; Lopez-S. et al. 1974; Weltman et al. 1979). These findings in combination with the decreased LDL-cholesterol in the sporting groups in this material, the lack of major differences in LDL-cholesterol between the sporting groups, and the lack of correlation between maximal oxygen uptake or heart volume and LDL-cholesterol, are compatible with the concept that for reduction of LDL-cholesterol a relatively low threshold activity is necessary , above which no further depression can be achieved.

Changes in total serum cholesterol depend on the magnitude of changes in the fractional cholesterol values. If the reduction in LDL-cholesterol together with the well established reduction in VLDL-cholesterol (Lopez-S. et al. 1974; Wood et al. 1976, 1977; Martin et al. 1977; Huttunen et al. 1979) exceeds the elevation in HDL-cholesterol, as is the case in the majoritiy of events in this material, total cholesterol decreases. In the case of grossly elevated HDL-cholesterol, as in the long-distance runners, total cholesterol can equal that of the physically untrained (Fig. 1). The conflicting evidence from cross-sectional studies, some indicating significantly lower total cholesterol in physically active (Hoffmann et al. 1967; Martin et al. 1977; Wood et al. 1977), and some no significant difference between active and sedentary groups (Wood et al. 1976; Enger et al. 1977; Lehtonen and Viikari 1978; Adner and Castelli 1980; Vodak et al. 1980) or even higher total cholesterol in the active (Lehtonen and Viikari 1980), may at least in part result from these additive effects.

Due to the differences in LDL-cholesterol, the differences in lipoprotein cholesterol distribution between sedentary controls and sporting groups increased in magnitude when the HDL-/total cholesterol or LDL/HDL ratios were considered instead of the HDL-cholesterol alone. Particularly in those events where HDL-cholesterol was only moderately elevated, the reduction in LDL-cholesterol contributed markedly to the discrimination between physically active and inactive. As in epidemiological and clinical studies lipid profiles including more than one lipoprotein parameter, e.g. the HDL-/total cholesterol or LDL/HDL ratios, correlated better with the risk of coronary heart disease than did single parameters (Gordon et al. 1977; Miller et al. 1977; Zimmer et al. 1980), these ratios deserve special attention.

Reportedly there is little if any correlation between HDL-cholesterol and total cholesterol in physically untrained populations (Rhoads et al. 1976; Enger et al. 1977; Gordon et al. 1977). The evidence available suggests that, with higher level of fitness, the correlation becomes closer (Enger et al. 1977). The absence of significant correlation between HDL-cholesterol and total cholesterol in the sedentary control group in this study is in agreement with these reports. In contrast, the sporting groups exhibited markedly stronger correlations between these parameters. Thus increased physical activity appears to reduce the variability in the quantitative relations between the lipoproteins.

The way by which this is accomplished can only be a matter of speculation. As lipoprotein distribution is influenced by a multiplicity of factors, some of which have been mentioned above, the absence of correlation in untrained populations may be the result of the interference of multiple interacting factors. Possibly, increased physical activity leads to elimination or mitigation of some of these.

One factor of potential impact on lipoprotein distribution is body composition. A negative correlation between body fat content or relative body weight and HDL-cholesterol in untrained populations has been confirmed by a number of studies (Rhoads et al. 1976; Wood et al. 1976; Gordon et al. 1977; Avogaro et al. 1978; Williams et al. 1979). In this material no association existed between body fat content or relative body weight and HDL-cholesterol in the sporting groups, confirming former evidence (Wood et al. 1976). Consequently, in physically highly active populations body composition appears to have no significant effect on HDL-cholesterol, which conceivably leads to a reduction in the variability in the quantitative relations between the lipoproteins.

Another factor of potential impact is dietary behaviour. Endurance athletes tend to prefer a carbohydrate rich diet (Strauzenberg et al. 1979). In acute and more extended studies with untrained subjects, high carbohydrate content of the diet has been shown to depress HDL-cholesterol (Levy et al. 1966; Wilson and Lees 1972; Blum et al. 1977). Whether these findings can be extrapolated to the situation of habitual high carbohydrate intake is unclear, as long-term studies are not available. Moreover, it is conceivable that in physically trained subjects the response of the lipoproteins to increased carbohydrate consumption is blunted. Reports that endurance trained sportsmen, who were on a carbohydrate rich diet before a prolonged race, did not differ in lipoprotein distribution from their non-carbohydrate loading counterparts (Enger et al. 1977; Adner and Castelli 1980) may provide a hint of this possibility.

These considerations favour the assumption that in physically trained individuals the effects of body composition and dietary behavior on lipoprotein distribution are subordinate in degree to other factors. One factor common to all sports included in this study is dynamic exercise with varying demands on aerobic capacity. The positive relationship between maximal oxygen uptake or heart volume and HDL-cholesterol in the whole material, and the magnitude of the correlation coefficients in the subsets made up of sportsmen under similar physical demands, strongly suggest that aerobic capacity acts as an independent factor on lipoprotein distribution.

The differences in regression among the subsets indicate that the effect of aerobic capacity on HDL-cholesterol, though similar in power in both subsets, as indicated by similar regression coefficients, is superimposed with some other factor. One factor discriminating handball, volleyball, and basketball players and wrestlers from runners and soccer players is the magnitude of the trained muscle mass. Whereas in the latter training concentrates on the musculature of the lower extremities, the training of the former includes the musculature of the upper extremities and the trunc as well. Thus there seems to be a positive relationship between HDL-cholesterol and the magnitude of the trained muscle mass.

In conclusion, the differences in lipoprotein pattern between sportsmen participating in the events examined in this study and untrained individuals appear to be attributable mainly to differences in aerobic capacity. The large interindividual variability in lipoprotein pattern in both the trained and the untrained underlines that physical activity is only one determinant among others. Furthermore, it hampers the attempt to establish statistically significant differences in lipoprotein pattern in bilateral comparisons between groups of different physical activity. However, the uniform trend in lipoprotein distribution in the events examined here shows that every kind of regular dynamic exercise involving large muscle groups, even of moderate intensity, is able favourably to change the lipoprotein pattern. If the negative correlations of HDL-cholesterol or HDL-/total cholesterol and the positive one of LDL/HDL with coronary heart disease hold for sportsmen with exercise-induced changes as well as for untrained populations, regular activity in any of these sports my help to reduce coronary risk.

References

Adner MM, Castelli WP (1980) Elevated high-density lipoprotein levels in marathon runners. JAMA 243: 534–536

Altekruse EB, Wilmore JH (1973) Changes in blood chemistries following a controlled exercise program. J Occup Med 15: 110–113

Avogaro P, Cazzolato G, Bittolo Bon G, Quinci GB, Chinello M (1978) HDL-cholesterol, Apolipoproteins A_1 and B. Age and index body weight. Atherosclerosis 31: 85–91

Berg A, Keul J, Ringwald G, Deus B, Wybitul K (1980) Physical performance and serum cholesterol fractions in healthy young men. Clin Chim Acta 106: 325–330

Blum CB, Levy RI, Eisenberg S, Hall M, Goebel RH, Berman M (1977) High density lipoprotein metabolism in man. J Clin Invest 60: 795–807

Carlson LA, Ericsson M (1975a) Quantitative and qualitative serum lipoprotein analysis. Part. 1: Studies in healthy men and women. Atherosclerosis. 21: 417–433

Carlson LA, Ericsson M (1975b) Quantitative and qualitative serum lipoprotein analysis. Part. 2: Studies in male survivors of myocardial infarction. Atherosclerosis 21: 435–450

Castelli WP, Doyle JT, Gorden T, Hames C, Hulley SB, Kagan A, McGee D, Vicic WJ, Zukel WJ (1975) HDL cholesterol levels in coronary heart disease: A cooperative lipoprotein phenotyping study. Circulation [Suppl 2] 52: 97

Castelli WP, Gordon T, Hjortland MC, Kagan A, Doyle JT, Hames CG, Hulley SB, Zukel WJ (1977) Alcohol and blood lipids. The cooperative lipoprotein phenotyping study. Lancet 1: 153–155

Diem K, Lentner C (1975) Wissenschaftliche Tabellen. Documenta Geigy. Thieme, Stuttgart, S 175–181

Dufaux B, Liesen H, Rost R, Heck H, Hollmann W (1979) Über den Einfluß eines Ausdauertrainings auf die Serum-Lipoproteine unter besonderer Berücksichtigung der Alpha-Lipoproteine (HDL) bei jungen und älteren Personen. Dtsch Z Sportmed 30: 123–128

Enger SCh, Herbjörnsen K, Erikssen J, Fretland A (1977) High density lipoproteins (HDL) and physical activity: The influence of physical exercise, age, and smoking on HDL-cholesterol and the HDL-/total cholesterol ratio. Scand J Clin Lab Invest 37: 251–255

Gordon T, Castelli WP, Hjortland MC, Kannel WB, Dawber TR (1977) High density lipoprotein as a protective factor against coronary heart disease. Am J Med 62: 707–714

Hartung HH, Foreyt JP, Mitchell RE, Vlasek I, Gotto AM (1980) Relation of diet to high-density-lipoprotein cholesterol in middle-aged marathon runners, joggers, and inactive men. N Engl J Med 302: 357–361

Hennekens CH, Willett W, Rosner B, Cole DS, Mayrent SL (1979) Effects of beer, wine, and liquor in coronary deaths. JAMA 242: 1973–1974

Hoffmann AA, Nelson WR, Goss FA (1967) Effects of an exercise program on plasma lipids of senior air force officers. Am J Cardiol 20: 516–524

Huttunen JK, Länsimies E, Voutilainen E, Ehnholm Ch, Hietanen E, Penttilä I, Siitonen O, Rauramaa R (1979) Effect of moderate physical exercise on serum lipoproteins. A controlled clinical trial with special reference to serum high-density lipoproteins. Circulation 60: 1220–1229

Kennedy AL, Lappin TRJ, Lavery TD, Hadden DR, Weaver JA (1978) Relation of high-density lipoprotein cholesterol concentration to type of diabetes and its control. Br Med J 2: 1191–1194

Lehtonen A, Viikari J (1978) Serum triglycerides and cholesterol and high-density lipoprotein cholesterol in highly physically active men. Acta Med Scand 204: 111–114

Lehtonen A, Viikari J (1980) Serum lipids in soccer and ice-hockey players. Metabolism 29: 36–39

Lehtonen A, Viikari J, Ehnholm C (1979) The effect of exercise on high density (HDL) lipoprotein apoproteins. Acta Physiol Scand 106: 487–488

Levy RI, Lees RS, Fredrickson DS (1966) The nature of pre-beta (very low density) lipoproteins. J Clin Invest 45: 63–77

Lopez-S A, Vial R, Balart L, Arroyave G (1974) Effect of exercise and physical fitness on serum lipids and lipoproteins. Atherosclerosis 20: 1–9

Martin RP, Haskell WL, Wood PD (1977) Blood chemistry and lipid profiles of elite distance runners. Ann NY Acad Sci 301: 346–360

Miller NE, Förde OH, Thelle DS, Mjös OD (1977) Tromsø heart-study. High-density lipoprotein and coronary heart-disease: A prospective case-control study. Lancet 1: 965–968

Miller NE, Rao S, Lewis B, Björsvik G, Myhre K, Mjös OD (1979) High-density lipoprotein and physical activity. Lancet 1: 111

Musshoff K, Reindell H (1956) Zur Röntgenuntersuchung des Herzens in horizontaler und vertikaler Körperstellung. I. Mitteilung: Der Einfluß der Körperstellung auf das Herzvolumen. Dtsch Med Wochenschr 81: 1001

Neubeck W, Wieland H, Habenicht A, Müller P, Baggio G, Seidel D (1977) Improved assessment of plasma lipoprotein patterns. III. Direct measurement of lipoproteins after gel-electrophoresis. Clin Chem 23: 1296–1300

Nikkilä EA, Hormila P (1978) Serum lipids and lipoproteins in insulin-treated diabetes. Demonstration of increased high density lipoprotein concentrations. Diabetes 27: 1078–1086

Rhoads GG, Gulbrandsen CL, Kagan A (1976) Serum lipoproteins and coronary heart disease in a population study of Hawaii Japanese men. N Engl J Med 294: 293–298

Seidel D, Wieland H, Ruppert C (1973) Improved techniques for assessment of plasma lipoprotein patterns. I. Precipitation in gels after electrophoresis with polyanionic compounds. Clin Chem 19: 737–739

Steinberg D (1978) The rediscovery of high density lipoprotein: A negative risk factor in atherosclerosis. Eur J Clin Invest 8: 107–109

Strauzenberg SE, Schneider F, Donath R, Zerbes H, Köhler E (1979) The problem of dieting in training and athletic performance. In: Nutritional aspects of physical performance. Bibl Nutr Dieta, vol 27. Karger, Basel, pp 133–142

Vodak PA, Wood PD, Haskell WL, Williams PT (1980) HDL-cholesterol and other plasma lipoprotein concentrations in middle-aged male and female tennis players. Metabolism 29: 745–752

Weltman A, Stamford BA, Matter S, Levy R, Short G, Fulco C (1979) Caloric restriction and/or mild exercise: Effects on body composition and lipoprotein cholesterol. Med Sci Sports 11: 109

Williams P, Robinson D, Bailey A (1979) High-density lipoprotein and coronary risk factors in normal men. Lancet 1: 72–75

Wilson DE, Lees RS (1972) Metabolic relationships among the plasma lipoproteins. Reciprocal changes in the concentrations of very low and low density lipoproteins in man. J Clin Invest 51: 1051–1057

Womersley J, Durnin JVGA (1977) A comparison of the skinfold method with extent of "overweight" and various weight-height relationships in the assessment of obesity. Br J Nutr 38: 271–284

Wood PD, Haskell W, Klein H, Lewis S, Stern MP, Farquhar JW (1976) The distribution of plasma lipoproteins in middle-aged male runners. Metabolism 25: 1249–1257

Wood PD, Haskell WL, Stern SL, Perry C (1977) Plasma lipoprotein distribution in male and female runners. Ann NY Acad Sci 301: 748–763

Zimmer F, Riebeling V, Benke B, Schuster J, Roskamm H (1980) Das LDL-HDL-Verhältnis bei Patienten mit Koronarsklerose. Z Kardiol 69: 149–153

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