Relationship between Total Cholesterol and High-Density Lipoprotein Cholesterol and the Effects of Physical Exercise, Alcohol Consumption, Cigarette Smoking and Body Mass Index

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(Received January 31, 1990)

Summary Despite the fact that high-density lipoprotein cholesterol (HDL) is a part of total cholesterol (TC), the serum level of this portion has been reported to have no or only a weak relationship to the TC level. The present study assessed the relationship between HDL and TC considering alcohol consumption, cigarette smoking, and body mass index (BMI) in 366 male workers classified into three groups by the habitual physical exercise. The results showed the different effects of alcohol consumption, cigarette smoking, and BMI on the level of HDL among these three groups, and alcohol consumption lowered the LDL level only in the exercise group. The closest relationship between HDL and TC was seen in the exercise group, even after taking other factors into account. The result suggests that the HDL level must be evaluated relative to the level of TC. As an indicator of serum lipid patterns the validity of the ratio of HDL to TC (HDL/TC) was discussed.

Key Words alcohol consumption, body mass index, cigarette smoking, HDL-cholesterol, LDL-cholesterol, physical exercise, total cholesterol

The inverse relationship between total serum cholesterol (TC) and high-density lipoprotein cholesterol (HDL) in coronary heart disease (*i.e.*, high TC and low HDL relate to the development of the disease) has been well recognized (1,2). Although HDL is a part of serum cholesterol, the level of HDL has been reported to have no or only a weak relationship with the level of TC (3–5).

The factors affecting these cholesterol levels are different. Genetic determinants have a greater influence on the level of TC than HDL (6), and TC is further

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affected by dietary cholesterol intake (7–9) and amount and kinds of dietary fats (9–11), which do not affect the HDLC level (9,11). On the other hand, the HDLC level positively correlates with physical exercise (12,13) and alcohol consumption (14–16), and is inversely related to cigarette smoking (15,16) and the amount of body fat (17).

Low-density lipoprotein cholesterol (LDLC) is the major part of serum cholesterol and the level of TC generally reflects this portion. The purpose of this paper is to examine the effects of physical exercise, body mass index (BMI), alcohol intake, and cigarette smoking on the cholesterol levels of LDL and HDL and to discuss the appropriate indicators to evaluate the effects of these factors on the lipid patterns.

SUBJECTS AND METHODS

Participants for the study were 366 males aged 40 to 61 years involved in sedentary or manual labor in an electric appliance factory in Japan. Measurement of body height and weight for calculation of BMI (weight for height²), and a questionnaire for habitual alcohol consumption, cigarette smoking, and physical exercise, were conducted in January, 1987.

Blood samples were taken in the morning before breakfast using vacuum tubes without any anticoagulants. The samples were then centrifuged to separate sera and stored at 4°C. All analyses were completed within one week. HDLC was measured using the heparin-manganese precipitation method (HDL-cholesterol-Test, Wako). TC and triglycerides (TG) were assayed with enzymatic colorimetric methods (Cholesterol C-Test, Wako, and Triglyceride-Test, Wako). The level of LDLC was estimated from TC, HDLC and TG with the formula of Friedewald ($LDLC = TC - HDLC - TG/5$).

The participants were classified into three groups according to the frequency and intensity of their physical exercises. The kind of exercise and its duration (minutes) and frequency (days per week) were obtained from the questionnaire (18). Subjects not participating in habitual exercise were classified into the non-exercise group (225 men). The remaining subjects performed a total of 19 kinds of physical exercises. These exercises were divided into two groups according to the intensity expressed by the relative metabolic rate (RMR) (19); *i.e.*, a moderate or more intensive exercise (*e.g.* jogging or swimming) group ($RMR > 5$), and a mild exercise (*e.g.* walking) group ($RMR < 5$). Since the elevated levels of HDLC have been reported in subjects who performed moderate exercise for at least 30 min per day and 3 days per week (20–25), the subjects who met these criteria were classified into the exercise group (28 men). The other 113 men who were practicing mild and/or moderate exercise infrequently (less than 3 days per week) or of short duration (less than 30 min) were classified into the intermediate exercise group.

In the questionnaire the kind of alcoholic beverages, the quantity per day, and

the frequency per week were asked. The quantity was asked using common consumer's measures such as glasses or bottles. A bottle of beer, 180 ml of Japanese saké, and two glasses of single whisky were regarded to contain the same quantity of alcohol and were each counted as 1 unit of consumption. Weekly intake of alcohol was calculated with this unit and the consumption was expressed by the average unit per day.

The analysis of variance was used for comparison of the means of the three groups, and *t*-test with the Ryan method was used for comparison of two means, if necessary. The chi-square test was used for comparison of the frequency distribution of alcohol drinking and cigarette smoking of the three groups. The multiple regression analysis was used to examine the relationship between the cholesterol levels and the affecting factors.

RESULTS

Frequency distribution of each group by alcohol consumption is shown in Table 1. In any group, one-fourth or -fifth were non-drinkers and the most of the drinkers consumed less than 2 units of alcohol per day. The distribution pattern of each group did not differ from each other. Table 2 shows the frequency distribution of the number of cigarettes smoked by the three groups. The percentage of non-smokers was relatively higher in the exercise group than in the other two

Table 1. Frequency distributions of habitual alcohol intake of the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Alcohol	NON	INT	EXE
0	56 (24.9%)	29 (25.7%)	6 (21.4%)
< 2	109 (48.4%)	62 (54.9%)	17 (60.7%)
2-	60 (26.7%)	22 (19.5%)	5 (17.9%)
Total	225	113	28

Alcohol (units/day): A bottle of beer, 180 ml of Japanese saké, and two glasses of single whiskey are regarded to contain the same quantity of alcohol and are counted as 1 unit each. Chi-square value=3.37 ($p=0.498$).

Table 2. Frequency distributions of habitual cigarette smoking of the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Cigarettes	NON	INT	EXE
0	90 (40.0%)	56 (49.6%)	19 (67.9%)
1-19	35 (15.6%)	16 (14.2%)	3 (10.7%)
20-	100 (44.4%)	41 (36.3%)	6 (21.4%)
Total	225	113	28

Chi-square value=9.34 ($p=0.06$).

Table 3. The means and standard deviations of age, body mass index (BMI), total cholesterol (TC), LDL-cholesterol (LDLC), HDL-cholesterol (HDL), triglycerides (TG), and the proportion of LDL-cholesterol to total cholesterol (LDLC/TC) and of HDL-cholesterol to total cholesterol (HDL/TC) in the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Variable	NON (<i>n</i> = 225)	INT (<i>n</i> = 113)	EXE (<i>n</i> = 28)	<i>F</i> -value
Age	46.2 ± 4.9	45.1 ± 4.7	45.6 ± 4.3	1.96
BMI	22.5 ± 2.5	23.2 ± 2.9	21.7 ± 1.9	4.72 [#]
TC	203.6 ± 39.2	193.2 ± 33.0	186.5 ± 22.7	4.90 [#]
LDLC	126.6 ± 36.6	117.4 ± 27.8	111.0 ± 16.8	4.77 [#]
HDL	49.5 ± 13.3	50.1 ± 16.2	57.8 ± 14.4*	4.17 [#]
TG	137.6 ± 79.2	128.4 ± 63.2	88.6 ± 35.5*	5.87 [#]
LDLC/TC	61.3 ± 8.9	60.4 ± 7.2	59.5 ± 4.9	0.86
HDL/TC	25.3 ± 8.5	26.3 ± 8.3	30.9 ± 6.5*	5.81 [#]

*The difference is significant at $p < 0.05$ in comparison with the non-exercise and intermediate groups (*t*-test with the Ryan method). [#]*F*-value is significant at $p < 0.05$ (analysis of variance). ^{##}significant at $p < 0.01$.

Table 4. The correlation coefficients between total cholesterol (TC), HDL-cholesterol (HDL), LDL-cholesterol (LDLC), and triglycerides (TG) in the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Relation	NON (<i>n</i> = 225)	INT (<i>n</i> = 113)	EXE (<i>n</i> = 28)
LDLC-TC	0.914***	0.875***	0.843***
LDLC-TG	0.156*	0.185*	0.086
HDL-TC	-0.055	0.271**	0.563**
HDL-TG	-0.414**	-0.404**	-0.510**
LDLC-HDL	-0.244**	-0.077	0.117

*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

groups; however, the difference of the distribution patterns was not statistically significant.

The mean values and standard deviations of age, BMI, serum TC, HDL, LDL, and TG are shown in Table 3. Mean age did not differ among the three groups. The levels of BMI, TC, and LDL of the exercise group were relatively low, but not statistically significant. The exercise group was significantly higher in HDL and lower in TG than the other two groups (*t*-test with the Ryan method). The proportion of HDL to TC (HDL/TC) was significantly higher in the exercise group than in the other two groups. However, the proportion of LDL to TC (LDL/TC) showed almost the same value in each group. The *F*-value of HDL/TC among the three groups was greater than that of HDL itself. The intermediate group indicated similar lipid values to the non-exercise group.

As Table 4 shows, LDL strongly correlated with TC in all groups. The relationship between LDL and TG was weak and also no significance was

Table 5. Standardized regression coefficients (beta) in the multiple regression analysis of HDL-cholesterol (HDLC) with total cholesterol (TC), alcohol consumption, cigarette smoking, and body mass index (BMI) in the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Variable	NON (<i>n</i> = 225)	INT (<i>n</i> = 113)	EXE (<i>n</i> = 28)
TC	0.018	0.323**	0.604**
Alcohol	0.242**	0.199*	0.410*
Smoking	-0.106*	-0.295*	0.023
BMI	-0.351**	-0.393**	-0.053
<i>R</i>	0.408	0.531	0.704

R: Multiple correlation coefficient. *, $p < 0.05$; **, $p < 0.01$.

obtained in the exercise group. The coefficient value between HDLC and TG of each group showed similar result, in which HDLC correlates inversely with TG. However, the relationship between HDLC and TC differed from each other. HDLC did not correlate with TC in the non-exercise group, weakly correlated with TC in the intermediate group, and substantially correlated with TC in the exercise group. The inverse relationship between LDLC and HDLC was obtained only in the non-exercise group and no significant relation was shown in the other two groups.

The result of multiple regression analysis of HDLC with TC, alcohol consumption, cigarette smoking, and BMI is shown in Table 5. In the exercise group it was indicated that the level of TC was substantially important for determining the level of HDLC, and also in the intermediate group HDLC related slightly with the level of TC. However, in the non-exercise group the level of HDLC was not determined by the level of TC even after the effects of alcohol consumption, cigarette smoking, and BMI were taken into consideration.

The standardized correlation coefficients of alcohol consumption were positive and significant in all groups and the highest coefficient was obtained in the exercise group. Both cigarette smoking and BMI inversely affected the level of HDLC in the non-exercise and intermediate groups; however, this was not the case in the exercise group.

Table 6 shows the result of multiple regression analysis of LDLC with TC, alcohol consumption, cigarette smoking, and BMI in the three groups. The result showed that the level of LDLC was practically determined by only the level of TC in all groups. The other factors did not affect the level of LDLC except for alcohol consumption in the exercise group, where the level of LDLC decreased with the habitual intake of alcohol.

The distribution pattern of HDLC to TC was compared between the non-exercise group (dots) and the exercise group (circles) in Fig. 1. The non-exercise group was scattered diffusely, reflecting no relationship between HDLC and TC, while the exercise group showed a positive relationship.

Table 6. Standardized regression coefficients (beta) in the multiple regression analysis of LDL-cholesterol (LDLC) with total cholesterol (TC), alcohol consumption, cigarette smoking, and body mass index (BMI) in the non-exercise (NON), intermediate (INT), and exercise (EXE) groups.

Variable	NON (<i>n</i> = 225)	INT (<i>n</i> = 113)	EXE (<i>n</i> = 28)
TC	0.914***	0.865***	0.823***
Alcohol	-0.112	-0.041	-0.323**
Smoking	0.028	0.037	0.090
BMI	0.020	0.086	0.012
<i>R</i>	0.920	0.880	0.904

R: Multiple correlation coefficient. **, $p < 0.01$; ***, $p < 0.001$.

Fig. 1. Scattergram of total cholesterol and HDL-cholesterol in non-exercise (dots) and exercise (circles) groups, and the proportion lines of HDL-cholesterol to total cholesterol.

The lines drawn in the figure indicate the respective ratio of HDLC to TC. Most of the individuals of both groups were below the 40% line. The figure seems to indicate that the 40% is the limit of the proportion of HDLC to the respective level of TC. The proportion of HDLC of the exercise group rose near to the limit line, while the non-exercise group was distributed widely between 10% and 40% lines.

DISCUSSION

The habitual intake of alcohol, cigarette smoking, and BMI have been known as determinants of the HDLC level (14-17). The present results showed the different effects of these factors on the level of HDLC among the three groups by the habitual physical exercise. Cigarette smoking and BMI did not affect the HDLC level in the exercise group. Alcohol consumption raised the HDLC level more effectively in the exercise group than in the non-exercise and intermediate

groups, and also lowered the LDLC level in the exercise group. Furthermore, the three groups differed in the relationship between HDLC and TC.

Although an inter-population study (26) has demonstrated a positive relationship between population averages of HDLC and TC, several lipid studies conducted within a single population have observed no or only a weak relationship between HDLC and TC (3-5). Sato *et al.* (27) have reported the positive correlations ($r=0.317$ and 0.222) only in low TC subgroups (less than 180 mg/dl). In the present study the exercise group showed closer relationship between HDLC and TC ($r=0.563$), and the TC level of the group was not necessarily limited in low level, but ranged from 156 to 241 mg/dl.

As low-density lipoprotein accounts for a greater portion of serum cholesterol and HDLC forms a part of TC, there must be a limit in the proportion of HDLC to TC. When HDLC increases and reaches the upper limit of the proportion, the HDLC level will be determined exclusively by the level of TC. As shown in Fig. 1, both non-exercise and exercise groups hardly exceed the 40% ratio line, which appears to be an upper limit of the proportion of HDLC to TC. In the exercise group, HDLC increased and nearly reached the upper limit, by which the positive relationship between TC and HDLC would be explained.

Figure 1 suggests that the level of HDLC must be evaluated in reference to the level of TC. The HDLC to TC ratio is considered useful as a referring method for the TC level. The ratio of HDLC/TC has already been used operationally to evaluate the effect of exercise on lipid patterns (22,23) and also as an inverse predictor of the development of coronary heart disease (2,28-30). The present study supports the significance of the HDLC/TC ratio for evaluating the effects of various factors on the lipid patterns.

The present study was financially supported by a grant from Uehara Life Science Foundation.

We thank Tai-ichiro Takemoto and Kazuhiko Moji, for their useful advice.

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