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High Density Lipoprotein Subfractions and Physical Activity: Changes After Moderate and Heavy Exercise Training*

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The changes in high density lipoprotein (HDL) subfractions have been studied in 106 young healthy men after two months of physical training at a military base. Forty subjects were placed on a heavy intensity training program (HITP) with a daily average energy expenditure estimated as 3,504 Kcal, and 66 subjects followed a moderate intensity training program (MITP) with an average energy expenditure estimated as 2,942 Kcal/day. The HITP group reduced their body fat while HDL-cholesterol, HDL2-cholesterol and apoprotein (apo) A-I increased by 8.4 %, 30 % and 16.9 % respectively ($p < 0.001$). Body fat of MITP subjects did not change and HDL-cholesterol, HDL2-cholesterol and apo A-I increased by 5.6 % ($p < 0.05$), 17.1 % ($p < 0.001$) and 5.6 % ($p < 0.05$), respectively. The increase in serum apo A-I level was significantly higher ($p < 0.005$) in the heavy intensity training group. The apo A-I/A-II ratio increased significantly in both groups ($p < 0.001$), reflecting an increase in the HDL2/HDL3 ratio. This is in agreement with the significant increase in HDL2-cholesterol in both groups ($p < 0.001$) with no change or decrease in HDL3-cholesterol.

Key-words: Apoprotein A, Cholesterol, Energy expenditure, Physical activity, High density lipoproteins, Triglycerides.

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It is well known that plasma high density lipoprotein (HDL) cholesterol concentration is an independent risk factor for coronary heart disease. The metabolism of HDL is under genetic control but several other factors, such as nutritional effects and physical activity play also an important role in the regulation of plasma HDL levels (12). It has been suggested that physical activity of low intensity is not a major determinant of plasma HDL-cholesterol concentration (13). On the other hand, HDL levels increase in the subjects with increased physical activity, as occurs in marathon runners and soccer and ice hockey players (3, 5, 6, 14, 18, 27). At the present time, there are no convincing data as to whether this increase in HDL after physical exercise is due to the exercise itself, or to the loss of weight and fat associated with it (20, 23, 25, 26). Most of the studies concerning the changes in the plasma concentration of HDL in relation to physical exercise, have been performed on individuals under experimental or laboratory conditions and there are few data on the changes of plasma apoprotein (apo) A-I and apo A-II and lipids in HDL subfractions.

In the present study, the changes in the HDL subfractions, measuring their lipid content, and also the serum concentration of apo A-I and apo A-II in 106 young healthy men before and two months after starting their compulsory military service are investigated. In order to clarify if the intensity of physical exercise has an effect or not in the magnitude of HDL changes, forty, of the individuals were subjected to a heavy intensity training program (HITP) and the remaining 66 to moderate intensity training program (MITP). Changes in body weight, body mass index and body fat were also measured.

Materials and Methods

The study includes 106 men, 17 to 21 years old, who started their compulsory military service in an Air Force base in Southeast Spain (Escuela Militar de Paracaidismo "Méndez Parada", Murcia). All answered a questionnaire that evaluated their consumption of alcohol, coffee and cigarettes over the previous weeks. Serum lipids, apoproteins and lipids in HDL subfractions were measured during the first week of their stay at the military base. Their weight and height, as well as subscapular, triceps, suprailiac, abdominal and sural skinfolds were also measured.

Blood samples were always obtained on Thursday or Friday morning, after and overnight fast, subjects were seated during phlebotomy and had no exercised during the preceding ten hours. Serum cholesterol and triglycerides were assayed enzymatically using reagents supplied by Boehringer Mannheim (Mannheim, F.R.G.). Lipids in HDL subfractions were measured following precipitation with polyethylenglycol (Immuno AG, Vienna, Austria) as described by KOSTNER *et al.* (11). Serum apo A-I and apo A-II levels were determined by an immunoturbidimetric technique (Boehringer Mannheim).

Forty subjects were enroled in a group to join a parachute division (HITP group), and the remaining 66 followed the standard Air Force programme (MITP group). All of them lived together during the two months of the study period. Food intake was not restricted and an average diet of 3,514 Kcal/day containing 52.3 % carbohydrate, 14.9 % protein, and 32.8 % fat was provided. Saturated, monounsaturated and polyunsaturated fats accounted for 12 %, 17 % and 4 % of total calories respectively, with a polyunsaturated/saturated ratio of 0.33. Cholesterol content was 0.65 g/day and the amount of dietary fiber was 17.8 g/day. This schedule did not differ from the usual diet in our geographic area (2,17). According to the daily activity in HITP and MITP, the average energy expenditure (FAO/WHO/UNU Expert Consultation, 21) was estimated as 3,504 Kcal and 2,942 Kcal, respectively.

Two months after starting the training period, all subjects answered a questionnaire to evaluate their consumption of alcohol, coffee and cigarettes during this period. Body weight was determined as well as the sum of skinfolds, lipids and apoproteins in the same conditions as the baseline.

Results are given as means ± SEM. Baseline data between the groups, and baseline and after training data within the groups were compared using Student two-tailed independent and paired sample t-test respectively. Pearson correlation analysis and chi-square test were also used when appropriate.

Results

No significant differences in height, body weight, body mass index and the sum of skinfolds were observed between the two groups at the beginning of the study (table I). Table I also shows the changes in body weight, body mass index and the sum of skinfolds in both groups at the end of the study. There were no significant differences between the two groups at the start of the study as regards the coffee consumption and smoking. Alcohol consumption was similar in both groups at the beginning of the study, however it increased from 26.8 ± 3.1 to 40.7 ± 4.0 g/day ($p < 0.001$) in the MITP at the end of the study.

Table I. *Age, height, body weight, body mass index and sum of skinfolds at baseline (A) and after training (B) (mean ± SEM).*

	HITP group (n = 40)		MITP group (n = 66)	
	A	B	A	B
Age (years)	18.2 ± 0.2	—	17.9 ± 0.2	—
Height (cm)	171.4 ± 1.1	—	171.7 ± 0.8	—
Body weight (kg)	60.7 ± 1.2	61.9 ± 1.1[a]	63.5 ± 1.3	63.7 ± 1.1
Body mass index	20.6 ± 0.3	21.1 ± 0.3[a]	21.5 ± 0.4	21.6 ± 0.3
Sum of skinfolds (mm)*	54.0 ± 2.5	46.8 ± 2.8[a]	61.7 ± 8.1	62.2 ± 8.1

* Based on thickness of the subscapular, triceps, suprailiac, abdomen and sural skinfolds. a: $p < 0.001$ respect baseline.

Table II. *Baseline and after training lipids (mmol/l) and apoprotein (g/l) concentrations in the heavy intensity training group (mean ± SEM/n = 40).*

	Baseline	After training	p <	% change
Serum cholesterol	4.06 ± 0.11	3.70 ± 0.08	0.001	−8.9
Serum triglycerides	0.87 ± 0.05	0.69 ± 0.04	0.001	−20.7
Apoprotein A-I	1.24 ± 0.04	1.45 ± 0.04	0.001	16.9
Apoprotein A-II	0.44 ± 0.01	0.39 ± 0.01	0.001	−11.4
HDL-cholesterol	1.31 ± 0.04	1.42 ± 0.03	0.001	8.4
HDL-triglycerides	0.26 ± 0.01	0.19 ± 0.01	0.001	−26.9
HDL2-cholesterol	0.50 ± 0.03	0.65 ± 0.03	0.001	30.0
HDL2-triglycerides	0.07 ± 0.01	0.05 ± 0.01	0.005	−28.6
HDL3-cholesterol	0.81 ± 0.02	0.77 ± 0.02	0.05	−4.9
HDL3-triglycerides	0.18 ± 0.01	0.13 ± 0.01	0.001	−27.7

HDL: high density lipoproteins.

Table III. *Baseline and after training lipids (mmol/l) and apoprotein (g/l) concentrations in the moderate intensity training group (mean ± SEM/n = 66).*

	Baseline	After training	p <	% change
Serum cholesterol	3.95 ± 0.10	3.64 ± 0.08	0.001	−7.9
Serum triglycerides	0.89 ± 0.04	0.82 ± 0.05	NS	−7.9
Apoprotein A-I	1.26 ± 0.04	1.34 ± 0.04	0.05	5.6
Apoprotein A-II	0.42 ± 0.01	0.36 ± 0.01	0.001	−14.3
HDL-cholesterol	1.24 ± 0.03	1.31 ± 0.04	0.05	5.6
HDL-triglycerides	0.24 ± 0.01	0.19 ± 0.01	0.001	−20.8
HDL2-cholesterol	0.47 ± 0.02	0.55 ± 0.03	0.001	17.1
HDL2-triglycerides	0.07 ± 0.01	0.08 ± 0.01	0.05	14.3
HDL3-cholesterol	0.76 ± 0.02	0.75 ± 0.02	NS	−1.3
HDL3-triglycerides	0.17 ± 0.01	0.11 ± 0.01	0.001	−35.3

HDL: high density lipoproteins; NS: not significant

There were no significant differences in the serum lipids, apoproteins and HDL lipids between the two groups at the beginning of the study. Tables II and III show the serum lipids, apoproteins and HDL lipid values in both groups at the beginning and after the training period. The apo A-I/apo A-II ratio in the HITP and MITP groups increased from 2.9 ± 0.1 to 3.8 ± 0.1 ($p < 0.001$), and from 3.1 ± 0.1 to 3.9 ± 0.2 ($p < 0.001$), respectively. Table IV shows the correlation coefficients between changes in serum and HDL lipids and apoproteins after training period.

Table IV. *Pearson correlation coefficients between changes in serum and HDL lipids, and apoproteins after training.*

	HITP (n=40)	MITP (n=66)
Serum TG and HDL-C	−0.02	−0.06
Serum TG and HDL2-C	−0.12	0.07
Serum TG and HDL3-C	0.18	−0.20
Apo A-I and HDL-C	0.21	−0.14
Apo A-II and HDL-C	0.28	0.34[a]
HDL-C and HDL-TG	0.24	0.07
HDL-C and HDL2-C	0.83[b]	0.79[b]
HDL-C and HDL3-C	0.27	0.56[b]
HDL2-C and HDL2-TG	0.36	−0.13
HDL3-C and HDL3-TG	−0.03	−0.10

TG: triglycerides; C: cholesterol; HDL: high density lipoproteins; Apo: apoprotein; a: $p < 0.01$, b: $p < 0.001$.

No correlations were found between changes in lipoproteins and changes in the body composition in both groups. Only when all 106 individuals of both groups were considered as a whole, we found a correlationship ($r = 0.24$, $p < 0.01$) between the changes in the sum of skinfolds and the changes in serum triglycerides after the training period.

Discussion

A decrease in the serum cholesterol and triglycerides, and a significant increase in HDL-cholesterol, HDL2-cholesterol and apo A-I after two months of physical training was observed in the present study. It is noteworthy that subjects who followed the HITP showed a significantly greater decrease of triglycerides and a significantly higher increase in apo A-I than that observed in those who followed the MITP. HDL-cholesterol and HDL2-cholesterol also showed a higher increase after the HITP than those observed after MITP, although the differences between both groups were not statistically significant. In fact, these changes are modest and similar to others previously described (8, 15, 16, 19, 22, 23, 25). Nevertheless, other authors such as SUTHERLAND and WOODHOUSE (24) have observed a larger increase in HDL-cholesterol. With regards to serum apo A-I levels, an increase of 5.6 % after MITP and 16.9 % after HITP have been observed. Our results in subjects following MITP are similar to those described by others, whereas in the case of subjects with HITP it is larger than those previously described (10,22). In studies by HUTTUNEN *et al.* (8) and THOMPSON *et al.* (25), no significant changes were observed in the serum apo A-I levels, whereas in the present study, it increased considerably, much more than could be expected from the "modest" increase in HDL-cholesterol.

In overweight men, the HDL-cholesterol and HDL2-cholesterol increased similarly after weight loss either through dieting or by increasing physical activity (26), whereas an increase in HDL-cholesterol of 13 % after training despite the lack of changes in body weight has been observed (25). In the present study, subjects after the MITP in whom HDL-cholesterol and apo A-I increased both by 5.6 % and HDL2-cholesterol by 17.1 %, the body mass index and the sum of skinfolds did not change. In subjects who followed the HITP, the increase in HDL-cholesterol, HDL2-cholesterol and apo A-I was 8.4 %, 30 % and 16.9 %, respectively. In this group a significant decrease was observed in the body fat after HITP, although no correlation could be found between the decrease in body fat and the increase in HDL. These data suggest that changes in serum HDL induced by exercise do not necessarily result from body fat loss.

It is well known that alcohol can induce changes in plasma lipoprotein concentrations (1,7). We believe that these changes are not related to alcohol consumption. Firstly, because no correlation has been found between the changes in alcohol consumption and changes in lipoproteins, and secondly because the alcohol consumption increased significantly in the group of subjects in whom the lipoprotein changes were less important.

The changes in total HDL after training period correlate well with the changes in the HDL2 subfraction. This is not surprising since it is well admitted that there is a good correlation between the total HDL-cholesterol and HDL2-cholesterol concentration (4,9). Furthermore, the significant increase in the apo A-I/apo A-II ratio after the training period reflects an increase in the HDL2/HDL3 ratio (4), which agree with the significant increase in HDL2-cholesterol in both groups with no change or a decrease in HDL3-cholesterol.

In summary, physical activity induces an increase in serum apo A-I and HDL, mainly at the expenses of the HDL2 subfraction. These changes are larger after HITP than that in MITP. If these changes reduce the coronary heart disease risk, it seems that this beneficial effect is better achieved when the exercise is more intense.

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Resumen

Se estudian los cambios en las lipoproteínas de alta densidad (HDL) en 106 hombres jóvenes y sanos, después de dos meses de entrenamiento físico en una base militar. Cuarenta de ellos se someten a un programa de actividad física intensa (PAFI), con gasto energético diario estimado en 3.504 kcal, y los 66 restantes siguen un programa de actividad física mode-

rada (PAFM), con un gasto energético de 2.942 kcal/día. En los individuos con PAFI disminuye la masa grasa, mientras que el colesterol-HDL, el colesterol-HDL2 y la apoproteína (apo) A-I aumentan un 8,4 %, 30 % y 16,9 % (p < 0,001), respectivamente. En los sujetos con PAFM no se modifica la masa grasa, y aumenta el colesterol-HDL, colesterol-HDL2 y apo A-I un 5,6 % (p < 0,05), 17,1 % (p < 0,001) y 5,6 % (p < 0,05), respectivamente. El aumento de apo A-I sérica es significativamente mayor (p < 0,005) en los sujetos PAFI. El cociente apo A-I/A-II aumenta significativamente en ambos grupos (p < 0,001), reflejando un aumento en el cociente HDL2/HDL3, resultado concordante con el significativo aumento del colesterol-HDL2 en ambos grupos, sin cambios o con disminución en el colesterol-HDL3.

Palabras clave: Actividad física, Apoproteína A, Colesterol, Gasto energético, Lipoproteínas de alta densidad, Triglicéridos.

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