

Relationship between Relative Body Weight and Serum Lipid Levels

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A relationship between blood lipid levels and adiposity has been suggested by several workers. For example, Gofman and Jones (1952) observed a good positive correlation between obesity and levels of the S_1 35-100, and, to a less extent, the S_1 12-20 plasma-lipoprotein fractions; they found a low-grade correlation between obesity and cholesterol levels. Lewis *et al.* (1957) also found the positive correlation between blood lipid levels and relative weight to be highest for the S_1 20-100 fraction, and lowest for cholesterol, though none of the correlations was impressive. They reported substantially higher levels of S_1 20-100 and S_1 12-20 lipoproteins in overweight compared with normal subjects, but not of cholesterol.

The S_1 20-100 (or S_1 35-100) lipoprotein fraction is rich in triglyceride but not in cholesterol, which is found mainly in the S_1 0-12 fraction. It might therefore be expected that plasma triglyceride levels are correlated with obesity; however, we are aware of only one report of triglyceride levels in relation to relative body weight (Albrink and Meigs, 1964). It has been shown that triglyceride levels, as well as cholesterol, are often elevated in subjects with ischaemic heart disease (Antonis and Bersohn, 1960; Carlson, 1960a, Schrade *et al.*, 1960; Albrink *et al.*, 1961; Hayes and Neill, 1964). Since obesity is thought by many to predispose to ischaemic heart disease, it may be asked whether it does so by an effect on triglyceride and other lipid levels. The present study concerns the relationship of levels of several plasma lipid components, including the triglycerides, and relative body weight.

Materials and Methods

Three groups of subjects were studied. Group 1 consisted of 97 male out-patients with occlusive vascular disease (peripheral vascular disease) of the lower limbs. Subjects with diabetes mellitus, gangrene, a history of angina, or myocardial infarction had been excluded from this group. These patients were participating in another study, and the decision to use them in this investigation was based on their availability rather than a wish to study peripheral vascular disease in particular. The patients fasted and abstained from smoking from the previous night until a sample of their venous blood was obtained. This procedure was followed on three occasions at weekly intervals. Group 2 consisted of 285 apparently healthy male volunteers from three local factories (carpet manufacturers, printing works, cigarette factory) studied by B. M. R. under conditions similar to the peripheral vascular disease group, except that they were seen once only. Group 3 consisted of 116 healthy male volunteers from a sewing-machine factory studied by T. B., and seen once only.

Levels of the following blood lipids were estimated on some or all of the specimens.

Serum cholesterol: by a ferric chloride technique with the Auto-Analyzer¹ in groups 1 and 3 or by Henley's (1957) modification of the method of Zlatkis *et al.* (1953) in group 2.

Serum triglyceride: by modifications of the method of Van Handel and Zilversmit (1957).

Serum phospholipid: by the method of Bartlett (1959).

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Serum total beta-lipoprotein: by the "immunocrit" technique Heiskell *et al.*, 1961).

The weight of each subject was measured in pounds and his height in inches. Relative weights were calculated from the table of Kemsley *et al.* (1962). They were uncorrected for age, being based on standards for young adults, and were expressed as a percentage of standard weight.

Results

Cholesterol and triglyceride levels were estimated in the three blood samples obtained from each patient with peripheral vascular disease, and the mean values of the results were used for the calculations. Results for the healthy subjects, for these lipids, are based on the analysis of one blood sample only, as are those for phospholipids and beta-lipoproteins in the respective groups. Since plasma lipid levels have a lognormal distribution in the population (Carlson, 1960b; Walton and Scott, 1964), in the subsequent correlations the calculations were performed with the logarithm₁₀ of the lipid levels.

Serum Cholesterol.—Correlation coefficients were calculated for cholesterol levels and relative weight, the subjects having been divided, according to age, into decades (Table I). A significant positive correlation was found in all three groups for the 40-49 decade and in two of the three groups for the 50-59 decade, but not for the 60-69 decade in any group, nor for the 30-39 decade in the healthy subjects.

TABLE I.—Correlations Between \log_{10} Cholesterol Level (mg./100 ml.) and Relative Body Weight in Patients with Peripheral Vascular Disease and Healthy Subjects

Age	Peripheral Vascular Disease (Group 1)		Healthy Subjects (Group 2)		Healthy Subjects (Group 3)	
	No. of Subjects	r	No. of Subjects	r	No. of Subjects	r
30-39	—	—	53	0.170	—	—
40-49	21	0.425*	44	0.510†	33	0.502†
50-59	41	0.379*	68	0.274*	54	0.122
60-69	35	0.030	13	0.001	29	0.052

r = Correlation coefficient.

* $P \leq 0.05$. † $P < 0.01$. ‡ $P < 0.001$.

Serum Triglyceride.—Correlation coefficients between triglyceride levels and relative weight for the various decades in peripheral vascular disease and healthy subjects are shown in Table II. In every decade in groups 1 and 2 a significant positive correlation was found, apart from the 60-69 decade in group 2, where only 10 subjects were studied. For group 3 no significant correlations were obtained within the individual decades, but a significant low-grade correlation was found for the group when taken as a whole. The correlation coefficients were, in general, higher than those for the corresponding data for cholesterol.

Serum Beta-lipoprotein.—Correlation coefficients for levels of this lipid component and relative weight in several decades are shown in Table III; a highly significant correlation was observed in the 40-49 and 50-59 decades, but not in the youngest (30-39) and oldest (60-69) decades. Beta-lipoprotein levels were not estimated in the peripheral vascular disease

¹ Technicon AutoAnalyzer method N-24p.

group. The correlation coefficients are greater than those for cholesterol.

Serum Phospholipid.—No significant correlations were obtained between phospholipid levels and relative weight in either of the two groups studied (Table IV).

TABLE II.—Correlations Between \log_{10} Triglyceride Level (mg./100 ml.) and Relative Body Weight in Patients with Peripheral Vascular Disease and Healthy Subjects

Age	Peripheral Vascular Disease (Group 1)		Healthy Subjects (Group 2)		Healthy Subjects (Group 3)	
	No. of Subjects	r	No. of Subjects	r	No. of Subjects	r
40-49	21	0.519*	55	0.480‡	33	0.286
50-59	41	0.510†	42	0.465†	54	0.168
60-69	35	0.399*	10	-0.314	29	0.170
40-69					116	0.197*

* $P < 0.05$. † $P < 0.01$. ‡ $P < 0.001$.

TABLE III.—Correlations Between \log_{10} Beta-lipoprotein Level ("Immunocrit" Units) and Relative Body Weight in Healthy Subjects

Age	Healthy Subjects (Group 2)	
	No. of Subjects	r
30-39	53	0.180
40-49	44	0.437*
50-59	68	0.573†
60-69	13	0.001

* $P < 0.01$. † $P < 0.001$.

TABLE IV.—Correlations Between \log_{10} Phospholipid Level (mg./100 ml.) and Relative Body Weight in Patients with Peripheral Vascular Disease and Healthy Subjects

Age	Peripheral Vascular Disease (Group 1)		Healthy Subjects (Group 3)	
	No. of Subjects	r	No. of Subjects	r
40-49	11	0.137	33	0.118
50-59	22	0.139	54	0.002
60-69	23	0.356	29	0.122
40-69	56	0.145	116	0.003

In Figs. 1 and 2 the relative weights of the subjects have been plotted against four arbitrarily selected ranges of cholesterol and triglyceride levels. Analysis of these data, the results from the three groups of subjects having been pooled, and the corresponding data for the other lipid fractions reveals that the relationship between blood lipid levels and relative body weight is not a simple linear one.

The following are the main findings.

1. The majority of subjects with cholesterol, triglyceride, or beta-lipoprotein levels within the highest of their respective lipid ranges are overweight, as is shown in Table V, which also demonstrates the increase in relative weight of the subjects as their lipid levels rise. The dividing line of 110% rather than 100% standard weight was chosen in this and other calculations, since relatively few of our subjects were under 100% standard weight.

2. Heavier subjects are more likely to have high lipid levels than are lighter subjects (Table VI). For example, heavy subjects (>110% standard weight) are almost twice as likely to have chole-

TABLE V.—Percentage of Total Subjects Within a Given Lipid Range Whose Relative Weight Exceeds 110% Standard Weight. Figures in Parentheses Refer to Total Numbers of Subjects Within a Given Category

Relative Weight: > 110%		Relative Weight: > 110%	
Cholesterol:		Beta-lipoprotein:	
< 225 mg./100 ml.	36 (100)	< 2.4 "immunocrit" units	51 (67)
225-250 "	46 (92)	2.4-2.8 "	68 (53)
251-275 "	68 (68)	2.9-3.2 "	81 (43)
> 275 "	69 (131)	> 3.2 "	86 (14)
Triglyceride:		Phospholipid:	
< 100 mg./100 ml.	35 (144)	< 225 mg./100 ml.	35 (82)
100-125 "	42 (74)	225-250 "	45 (31)
126-150 "	59 (46)	251-275 "	59 (27)
> 150 "	80 (56)	> 275 "	50 (32)

sterol levels exceeding 275 mg./100 ml. and more than four times as likely to have triglyceride levels exceeding 150 mg./100 ml. This trend is seen for all lipid fractions. However, it is apparent from Figs. 1 and 2 that by no means all heavy subjects have high lipid

TABLE VI.—Percentage of Total Subjects Above or Below 110% Standard Weight with High Lipid Levels. Figures in Parentheses Refer to Total Number of Subjects Within a Given Category

Relative Weight:		≤ 110%	> 110%
Cholesterol {	≥ 251 mg./100 ml.	36 (177)	64 (214)
	> 275 "	23	42
Triglyceride {	≥ 126 "	18 (169)	47 (154)
	> 150 "	7	29
Beta-lipoprotein {	≥ 2.9 "immunocrit" units	17 (60)	40 (117)
	> 3.2 "	3	10
Phospholipid {	≥ 251 mg./100 ml.	28 (97)	43 (75)
	> 275 "	17	21

SERUM CHOLESTEROL (mg/100ml)

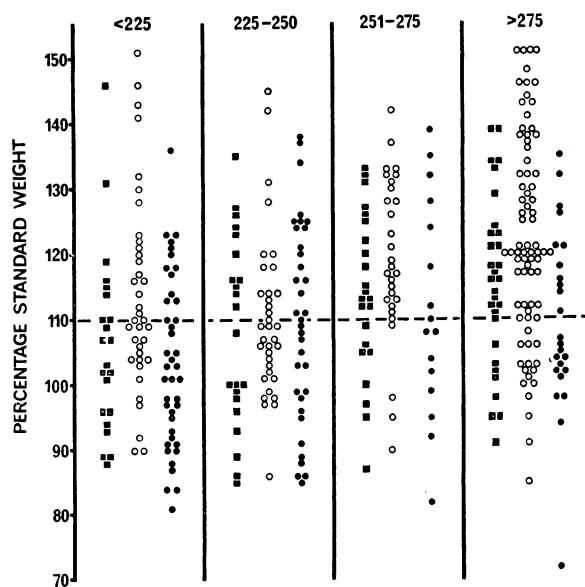


FIG. 1.—Relative weight plotted against four ranges of cholesterol levels. Key to symbols: group 1, ■; group 2, ●; group 3, ○.

SERUM TRIGLYCERIDE (mg/100ml)

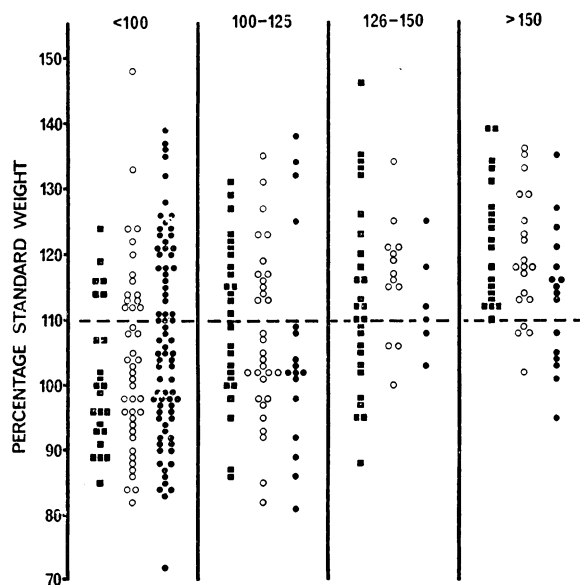


FIG. 2.—Relative weight plotted against four ranges of triglyceride levels. Key to symbols: group 1, ■; group 2, ●; group 3, ○.

levels, and that, on the contrary, some of the heaviest subjects maintain low lipid levels.

3. Most subjects equal to or less than 110% standard weight have lipid levels within the lower ranges, and this is especially striking for the lightest subjects; of these subjects equal to or less than 90% standard weight only 3% have triglyceride levels exceeding 125 mg./100 ml., and 16% cholesterol levels exceeding 250 mg./100 ml. The corresponding figures for men over 110% standard weight are 47% and 64% respectively.

These conclusions are derived from pooled data from the three groups of subjects. They do not take into account the variations in the lipid techniques employed and other variables. However, the trends noted for the whole group were also observed for the individual groups, though they were least apparent in group 3.

Discussion

The present results show a positive relationship between blood lipid levels and relative body weight. In general, the highest correlation coefficients were observed in the peripheral vascular disease group. This probably reflects the more accurate measure of serum lipid values in this group afforded by the estimations of cholesterol and triglyceride having been performed on three separate blood samples. This would be of particular importance in the case of the triglycerides, since fasting levels often show variation, particularly when they are high. The results for the triglycerides are in harmony with the studies previously referred to, which suggested that it is the triglyceride-rich lipoprotein fraction which shows the best correlation with relative body weight. Albrink and Meigs (1964), using an indirect method for triglyceride estimation, found correlation coefficients of 0.60 and 0.53 in 13 subjects aged 30–39 and 36 subjects aged 60–69 respectively; significant correlations were not observed by them for other decades. The present study utilized a direct method for estimating triglyceride levels. Albrink and Meigs (1964) also found significant but low-grade correlations for cholesterol and relative weight in some decades. The present study found, in general, higher values, though there was some variation between the several groups studied.

Although the statistical analysis demonstrates that there is a significant linear relationship between lipid levels and relative body weight within various groups of subjects, it is clear from inspection of the figures that for many individuals such a relationship does not hold. In particular, this applies to obese subjects; while most subjects with high triglyceride levels are above their standard weight, not all overweight subjects have high lipid levels. Albrink and Meigs (1964) have presented data suggesting that obese subjects with high triglyceride levels differ in the pattern of their body-fat distribution from such subjects with lower triglyceride levels; they interpret this as indicating that there are two forms of obesity—namely, the inherited and acquired, the latter being associated with the higher lipid levels.

The degree of obesity in an individual is normally determined by the balance between calorie intake and utilization, large variations in the latter usually being a function of the extent of his physical activity. The present findings suggest that increased caloric intake or diminished physical activity may in some subjects lead to a rise in plasma triglyceride, cholesterol, total beta-lipoprotein, and possibly phospholipid levels. It must not be ruled out, however, that some dietary constituent, the levels of which change *pari passu* with the caloric intake, is the main dietary factor influencing lipid levels.

It has been established that subjects with high cholesterol levels more often develop myocardial infarction than those with

lower lipid levels (Dawber *et al.*, 1962; Paul *et al.*, 1963). Since the present data indicate that a higher proportion of overweight as compared with lighter subjects have high cholesterol (and other lipid) levels, they might be expected to provide a large pool from which future victims of myocardial infarction would be drawn. The tendency for recent prospective studies to minimize (Dawber *et al.*, 1962) or doubt (Paul *et al.*, 1963) the role of obesity in ischaemic heart disease may in part be explained by the observation that many obese subjects maintain low lipid levels.

Although measurement of relative body weight provides a simple index of adiposity, in a number of subjects deviation from standard weight may be due to other factors. It is likely that a more accurate measurement of the degree of adiposity in subjects would reveal a greater correlation between it and lipid levels than the moderate values found in the present and other studies.

Summary

The relationship between blood lipid levels and relative body weight was studied in 97 male subjects with peripheral vascular disease and in two groups of 285 and 116 healthy men.

Significant positive correlations were observed between cholesterol, triglyceride, or total beta-lipoprotein levels and relative body weight.

Most subjects with high cholesterol, triglyceride, or beta-lipoprotein levels exceeded 110% standard weight, though many obese subjects had low or average lipid levels.

Nearly all lean subjects had low lipid levels.

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