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Apolipoprotein B levels and related factors in a rural white South African community — the CORIS study

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Objective. In a survey of the Coronary Risk Factor Study (CORIS), apolipoprotein B (apoB) levels were determined to ascertain their impact on coronary heart disease (CHD) risk. Other CHD risk factors associated with apoB were also identified.

Design. Cross-sectional analytical study, which included CHD risk factor and dietary questionnaires, electrocardiography, anthropometric and blood pressure measurements, and a blood sample for a lipid profile.

Setting and participants. The three districts of Riversdale, Robertson and Swellendam in the south-western Cape; a 25% random sample of 1 528 white respondents aged 15 - 68 years.

Results. Men tended to have higher mean apoB levels than women. Classification of CHD risk by apoB levels and total cholesterol (TC) levels did not correspond, as only 61% of men and 58.5% of women were classified in the same risk categories. Respondents in the highest apoB risk category reported a medical history of hypercholesterolaemia and hypertension more frequently than those in lower categories.

There was a significant increase from the low to the high apoB risk category of TC, low-density lipoprotein (LDL) cholesterol, triglyceride levels, body mass index and percentage body fat. Using stepwise multiple regression, 84.9% of the variation in apoB of men and 85.8% in apoB of women were accounted for by significantly associated variables.

Conclusion. Although apoB may be a better predictor of CHD than TC or LDL cholesterol concentrations, its easy approximation with the formula (TC - HDLC)/2+20, high cost, measurement variability and an approach in management similar to that for raised TC discourage its routine use in the screening of patients for CHD.

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A variety of studies,[1-5] but not all,[3] have shown the association between raised apolipoprotein B (apoB) levels and coronary heart disease (CHD). There is some evidence that it may even be a better predictor of CHD than low-density lipoprotein cholesterol (LDLC), and sufficient data are emerging that may prove a causal link between raised apoB levels and CHD.[6,7] In 1990 Vega and Grundy[8] concluded that in view of the available information it could not be recommended that apolipoprotein B-100 be measured routinely in the management of hypercholesterolaemia, although they conceded that it may prove to be a valuable measure in the future, when more prospective data become available or once standardisation of the methodology for apoB measurements has been achieved. In contrast, Sniderman and Silberberg[9] cautiously suggested that the practising clinician could improve the management of hyperlipidaemic patients if their apoB levels were known. They based their argument on the finding that the apoB levels of people with CHD were diagnostically more accurate than their LDLC levels.[10,11] Raised apoB and LDLC levels associated with DNA mutations of the apoB gene, known as familial defective apolipoprotein B-100, have proved to be associated with premature atherosclerosis.[12-14]

CHD, along with cerebrovascular diseases (CVD), is the main cause of death from circulatory disease among adults of all South African groups other than the black population (in which circulatory disease was nevertheless the third-commonest cause of death reported in 1988).[15] A review of the CHD risk factor profile of South Africans estimated that approximately 4.8 million South Africans aged 15 - 64 years had hypercholesterolaemia, with the highest prevalence being among whites.[16] The lack of knowledge of the significance of apoB levels in whites prompted this study with the purpose of determining these levels in a rural white South African community, to ascertain the impact they have on CHD as a risk factor, and to identify other CHD risk factors associated with apoB levels in this community.

Methods

A long-term study, the Coronary Risk Factor Intervention Study (CORIS), was conducted in three south-western Cape communities and included white men and women aged 15 - 64 years. The baseline study was followed by a 4-year intervention period. After the 4-year intervention period, a resurvey of the whole population aged 15 - 68 years was conducted. The source of data for this apoB study was a 25% random sub-sample of those who had participated in the CORIS baseline survey, and yielded 1 528 respondents.

Detailed methodology for the CORIS study is described elsewhere.[17] All respondents completed a general risk factor questionnaire including the standardised and validated London School of Hygiene questionnaire on chest pain.[18] Resting 12-lead electrocardiograms (ECGs) were taken in the recumbent position with a Hewlett-Packard (HP) model No. 1516 ECG tape terminal. Height was measured with a rigid rod anthropometer and weight on a beam balance. Skinfolds were measured with Harpenden skinfold callipers at four sites (biceps, triceps, subscapular and supra-iliac). Blood pressures were taken according to the American Heart Association guidelines.[19]

A 30 ml non-fasting blood sample was taken from the 1 528 respondents, who also completed a 24-hour dietary recall interview conducted by registered dieticians and computer coded. Serum was separated within 2 hours and analysed on a Gilford auto-analyser for total cholesterol (TC) and high-density lipoprotein cholesterol (HDLC) using the Boehringer CHOD-PAP enzymatic method after precipitation of the apoB-containing lipoproteins with dextran sulphate-magnesium chloride. The Gilford auto-analyser was calibrated against control sera (Boehringer Mannheim GmbH Precilip, batch No. 3-305) and two control samples were also included as numbers 20 and 40 of each batch analysed. The balance of the sera were frozen at –20°C for later determination of triglyceride levels (TGs) by the Boehringer enzymatic Peridochrom method and uric acid levels by the Boehringer uric acid Peridochrom method. In each case the Gilford auto-analyser was calibrated against Precilip or Precilip EL control sera, which were corrected by Boehringer Mannheim for the specific test kit in question.

More detailed lipid and apolipoprotein analyses on frozen sera (at –70°C) were done within 1 week of collection of the blood samples. These included: (*i*) assaying of serum apolipoprotein A-I, A-II and B by end-point laser immunonephelometric assays;[20] and (*ii*) use of monospecific antibodies to human apolipoproteins (Boehringer Mannheim apoB catalogue No. 726 494). The apoprotein assays were standardised routinely with standardised serum samples obtained from Behring and Immuno (Vienna). Two control samples were used for each batch analysed. Total HDLC and the HDL_3 subfraction were separated by a differential precipitation procedure,[21] with two control samples also included in each batch analysed.

Analyses of the data

To specify low, moderate and high CHD risk categories of apoB levels, the participants were classified as having apoB levels below the 20th percentile, between the 20th and 80th percentiles, and equal to or above the 80th percentile for each sex and age decile category. To specify low, moderate and high CHD risk categories of TC levels the cholesterol action limits of the Heart Foundation of Southern Africa were used.[22]

Hard copies of ECGs were obtained by playback through an HP 5600 ECG Management System. These were measured and classified according to the Minnesota criteria[23] by two independent observers to identify participants with Q waves that indicated previous myocardial infarctions (MIs).

Body mass index (BMI) was calculated as weight (kg)/height $(m)^2$. Cut-off points for 'obesity' (BMI $\geq$ 30) and 'overweight' (BMI $\geq$ 25 for men and $\geq$ 24 for women) were those used by Bray.[24] Percentage body fat was calculated according to Durnin and Rahaman's[25] recommendation based on the biceps, triceps, subscapular and supra-iliac skinfold thicknesses.

For cumulative tobacco use, past and present smoking was considered by multiplying the number of cigarettes smoked per day by the number of years a person had been smoking.

An arbitrary overall risk score defined by Rossouw *et al.*[26] was computed as the sum of points by age- and sex-specific deciles of the TC/HDLC ratio and systolic blood pressure, respectively, and of tobacco consumption (g/d). Decile cut-off points were derived from the baseline study population aged 15 - 64 years.

Friedewald's equation, LDLC = TC-HDLC-TG/2.18, was used to calculate LDLC (in mmol/l) for those participants whose TG levels were below 4.5 mmol/l, a requirement of this equation.[27] Hyperuricaemia was diagnosed on the basis of Boehringer's normal upper levels of 416 µmol in men and 339 µmol in women.

Univariate analyses identified some variables, which were significantly associated with apoB levels for both men and women. A stepwise regression procedure in the Statistical Analysis System (SAS) package was used to select a subset of the large number of variables using a tolerance level of 0.10 for a regression model with apoB as the independent variable. The regression package (REGPAC)[28] was then used to test for outliers, and influential cases were identified using Cook's D. Outliers and influential cases were deleted from the data set. The REGPAC was used again for final selection of variables using stepwise regression with a tolerance level of 0.05.

Results

The study sample comprised 1 528 participants (761 men and 767 women) aged 15 - 64 years. Table I gives the study population's apoB distribution for men and women. The mean lies slightly to the right of the median (not shown), reflecting a distribution skewed towards high values. ApoB concentrations in women increased steeply across all the age categories, but levelled off in men after the age of 45 years. In the 25 - 54-year age group, men (124.3 mg/dl, SE 1.95) had higher mean apoB values than women (103.3 mg/dl, SE 1.76). The difference between these values (21 mg/dl, 95% CI 15.9 - 26.2) was significant ($P < 0.0001$).

In Table II the low, moderate and high CHD risk categories of apoB levels are compared with those based on the low, moderate and high CHD risk categories of TC levels. Evidently there is limited concordance between the classifications arrived at using the two methods for defining low, moderate and high CHD risk, as only 61% of men and 58.5% of women were classified in the same CHD risk categories.

Table III compares the prevalence rates of the number of medical conditions in the three apoB CHD risk categories. The outcome of the statistical procedure that tested the hypothesis that the distributions in the low, moderate and high CHD apoB risk categories are significantly different

Table I. ApoB (mg/dl) in men and women aged 15 - 64 years (means, SDs and percentiles)

Age groups (yrs)	No.	Mean	SD	Percentiles 5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
							Men (N = 761)							
15 - 24	219	80.8	21.8	52.7	58.0	64.3	69.0	72.7	76.0	80.5	86.7	98.0	107.7	120.2
25 - 34	107	112.0	35.9	60.5	73.3	85.8	90.8	97.4	104.8	113.5	119.6	137.7	165.8	187.3
35 - 44	121	126.6	48.9	71.0	81.7	92.5	98.6	105.5	112.8	122.2	134.9	158.9	184.4	229.7
45 - 54	181	130.1	32.3	83.7	94.2	104.1	112.7	120.1	130.3	135.7	142.6	152.9	167.2	182.3
55 - 64	133	126.7	36.8	75.7	85.3	99.0	104.9	115.6	121.6	128.1	137.5	149.8	177.6	200.7
							Women (N = 767)							
15 - 24	171	83.7	20.1	55.1	59.7	68.8	72.8	76.0	80.5	84.0	90.7	99.7	110.8	123.2
25 - 34	116	91.6	28.8	56.5	61.8	67.4	75.4	82.2	88.0	93.1	100.5	107.1	128.5	146.5
35 - 44	149	97.0	25.3	62.5	69.4	74.8	81.4	86.8	93.4	99.5	105.7	116.6	133.0	152.5
45 - 54	168	116.9	45.0	72.2	76.1	83.6	92.2	100.5	107.7	114.7	124.5	139.5	168.7	196.0
55 - 64	163	131.1	44.8	80.4	85.2	98.9	107.5	118.6	125.6	132.0	140.0	155.2	178.2	205.3

Table II. Comparison of the classification of participants based on the serum apoB levels and the total cholesterol levels

ApoB levels	Men (N = 761), classified by TC level* Low CHD risk	Moderate CHD risk	High CHD risk	Women (N = 767), classified by TC level* Low CHD risk	Moderate CHD risk	High CHD risk
< 20th percentile	109	42	1	85	66	2
	14.3%	5.5%	0.1%	11.1%	8.6%	0.3%
⩾ 20th - < 80th percentile	113	301	43	109	297	55
	14.9%	39.6%	5.7%	14.2%	38.7%	7.2%
⩾ 80th percentile	15	83	54	8	78	67
	1.9%	10.9%	7.1%	1.0%	10.2%	8.7%

* The Heart Foundation's TC action limits were used to categorise the participants in low, moderate and high CHD risk categories.[22]

Table III. Medical history of CHD and its risk factors by apoB percentile categories

	Men							Women						
			ApoB percentiles							ApoB percentiles				
	N	%	< 20th	⩾ 20th-80th	⩾ 80th	χ^2	P-value	N	%	< 20th	⩾ 20th-80th	⩾ 80th	χ^2	P-value
Total No.	761		151	459	151			767		152	463	152		
Mean age (yrs)			37.3	37.6	37.6					39.4	39.7	39.9		
Reported CHD history	50	6.6	2.6	6.3	11.3	9.24	0.010	26	3.4	1.3	2.8	7.2	9.34	0.009
Reported CHD history before 50 years	32	4.2	1.3	3.7	8.6	10.67	0.005	14	1.8	0	1.5	4.6	9.64	0.008
ECG or medically confirmed CHD*	57	7.5	4.6	7.4	10.6	3.88	0.144	29	3.8	1.3	3.2	7.9	9.98	0.007
Reported suffering from hypertension	89	11.7	6.0	11.1	19.2	13.21	0.001	127	16.6	8.6	14.2	31.6	33.65	< 0.001
Measured blood pressure ⩾ 160/95 mmHg ± treatment	177	23.3	15.9	22.9	31.8	10.78	0.005	164	21.4	12.5	20.1	34.2	22.48	< 0.001
Reported history of hypercholesterolaemia	108	14.2	4.0	12.2	30.5	47.27	< 0.001	115	15.0	4.6	12.7	32.2	50.17	< 0.001

* Minnesota ECG Codes[23] Q-1.1 or 1.2 and/or angina or myocardial infarction diagnosis confirmed by medical practitioner.

from the expected 1:3:1 ratios is also given. Such significantly different distributions were observed for both men and women who have a reported history of CHD and premature CHD (before age 50 years), and a positive ECG and/or medically confirmed ECG (only for women). Similarly a reported history of hypercholesterolaemia and hypertension, as well as hypertensives who had actually been measured, were more frequently reported for both men and women in the highest apoB category than in the lower categories. This was not so for a reported history of diabetes and stroke (data not shown).

In Table IV, a comparison is given of the mean levels of a variety of risk factors in the low, moderate and high apoB CHD risk categories. As expected there was a significant increase from the low to the high apoB CHD risk categories of TC, LDLC, TG levels, BMI and percentage body fat. There was a decrease across the apoB categories of HDLC and HDL_3 but not for HDL_2 cholesterol. There was a significant increase in both diastolic and systolic blood pressure in both men and women with increasing apoB categories. Uric acid levels and the overall CHD risk score also increased with increasing apoB levels.

Table IV. Comparison of cardiovascular disease risk factors in three apoB risk categories

	Men, apoB percentiles						Women, apoB percentiles					
	≤ 20th	> 20th- < 80th	≥ 80th	*P*-values for comparison			≤ 20th	> 20th- < 80th	≥ 80th	*P*-values for comparison		
Mean levels of variables	(1)	(2)	(3)	1:2	2:3	1:3	(1)	(2)	(3)	1:2	2:3	1:3
TC (mmol/l)	4.4	5.5	6.6	< 0.000	< 0.000	< 0.000	4.7	5.6	7.0	< 0.000	< 0.000	< 0.000
LDL cholesterol (mmol/l)	2.6	3.5	4.3	< 0.000	< 0.000	< 0.000	2.7	3.6	4.7	< 0.000	< 0.000	< 0.000
HDL cholesterol (mmol/l)	1.2	1.1	1.0	< 0.000	< 0.000	< 0.000	1.6	1.4	1.2	< 0.000	< 0.000	< 0.000
HDL_2 cholesterol (mmol/l)	0.5	0.4	0.4	0.0341	NS	0.0813	0.7	0.7	0.5	0.1445	< 0.000	< 0.000
HDL_3 cholesterol (mmol/l)	1.0	0.9	0.8	0.0365	0.0006	0.0001	1.1	1.0	0.9	0.0002	< 0.000	< 0.000
ApoA1 (mg/dl)	83.2	87.0	100.4	NS	0.0016	0.0004	86.8	92.8	100.9	0.1130	0.0409	0.0035
ApoA2 (mg/dl)	33.4	34.9	38.9	NS	0.0037	0.0005	30.0	34.1	37.8	0.0011	0.0045	< 0.000
TGs (mmol/l)	1.3	1.9	3.5	< 0.000	< 0.000	< 0.000	1.2	1.4	2.7	0.097	< 0.000	< 0.000
BMI[24]	24.3	25.4	27.6	0.003	< 0.000	< 0.000	23.6	24.6	27.2	0.0102	< 0.000	< 0.000
% body fat[25]	21.6	24.2	27.1	0.0003	< 0.000	< 0.000	34.2	35.7	38.7	0.0211	< 0.000	< 0.000
Systolic blood pressure (mmHg)	127.8	131.9	137.4	0.0123	0.0007	0.0001	124.5	129.5	134.3	0.0039	0.0060	0.0001
Diastolic blood pressure (mmHg)	83.4	85.6	88.5	0.0467	0.0069	0.0001	81.3	83.1	85.9	0.0787	0.0044	0.0002
Uric acid (mmol/l)	0.33	0.35	0.38	0.0143	< 0.000	< 0.000	0.25	0.26	0.28	NS	< 0.000	< 0.000
Cumulative tobacco use[26]	387.9	462.8	396.3	NS	NS	NS	331.6	324.3	286.1	NS	NS	NS
Overall risk score[26]	4.49	5.57	6.88	< 0.000	< 0.000	< 0.000	3.96	4.85	6.44	< 0.000	< 0.000	< 0.000
LDLC/apoB ratio	1.34	1.28	1.13	0.0309	< 0.000	< 0.000	1.75	1.63	1.48	< 0.000	< 0.000	<0.000
TC-HDLC/apoB ratio	1.64	1.57	1.35	0.0112	< 0.000	< 0.000	1.51	1.39	1.28	< 0.000	< 0.000	< 0.000

* Least square means (standard errors).

Table V. Variables that contribute significantly to regression of apoB in men and women

Variable	Coefficient	Standard error of the mean	Standardised coefficient*	Partial correlation	Probability	Adjusted R^2†
Men (39 cases omitted) (*N* = 622)						
Cholesterol level	0.3985	0.0128	0.5790	0.7816	< 0.0001	0.6169
TG level	0.1484	0.0061	0.4510	0.7026	< 0.0001	0.8276
HDL_3 cholesterol	–0.4416	0.0573	–0.1235	–0.2967	< 0.0001	0.8424
BMI	0.4011	0.0922	0.0831	0.1727	< 0.0001	0.8466
Total energy expenditure	–0.00332	0.00106	–0.0490	–0.1248	0.0019	0.8488
Women (47 cases omitted) (*N* = 720)						
Cholesterol level	0.4351	0.0110	0.6752	0.8291	< 0.0001	0.6766
TG level	0.1285	0.0075	0.3160	0.5421	< 0.0001	0.8140
HDL_3 cholesterol	–0.6483	0.0451	–0.2179	–0.4737	< 0.0001	0.8482
HDL_2 cholesterol	–0.1952	0.0335	–0.0887	–0.2132	< 0.0001	0.8551
Total energy expenditure	–0.00519	0.00142	–0.0519	–0.1360	< 0.0003	0.8572
BMI	0.1888	0.0776	0.0414	0.0908	0.0152	0.8582

* Coefficient of standardised variables.
† Proportion of variation in dependent variable accounted for by the predictor variables adjusted for degrees of freedom.

Table V indicates the significantly associated variables, which accounted for 84.9% and 85.8% of the variation in apoB levels in men and women respectively, in the stepwise multiple regression analyses. In men, serum cholesterol level, serum TG levels, the inverse of the HDL_3 cholesterol level, the BMI and the inverse of the total energy expenditure contributed independently (in this order of precedence) to the variation in apoB levels. In women the variables, in order of their independent contribution to apoB levels, were TC, TG, the inverse of HDL_3 cholesterol, HDL_2 cholesterol and total energy expenditure, and BMI.

There is a strong correlation between apoB and TC levels for both men (Spearman rank correlation of 0.78) and women (Spearman rank correlation of 0.82). As there is but one apoB molecule per LDL particle[29] or its precursors, the amount of cholesterol per apoB molecule was estimated. The ratio of LDLC to serum apoB level and the ratio of TC minus HDLC to apoB, together with the increasing apoB categories, are shown in Table IV. For both sexes, the higher the apoB CHD risk category was, the significantly lower the LDLC/apoB and TC-HDLC/apoB ratios. The higher apoB levels indicated relatively less cholesterol per LDL particle, as the number of LDL particles increased.

Fig. 1 shows the estimated linear relationship between apoB and apoB-associated cholesterol (TC-HDLC) with a Pearson correlation of $r = 0.863$ ($P < 0.0001$).

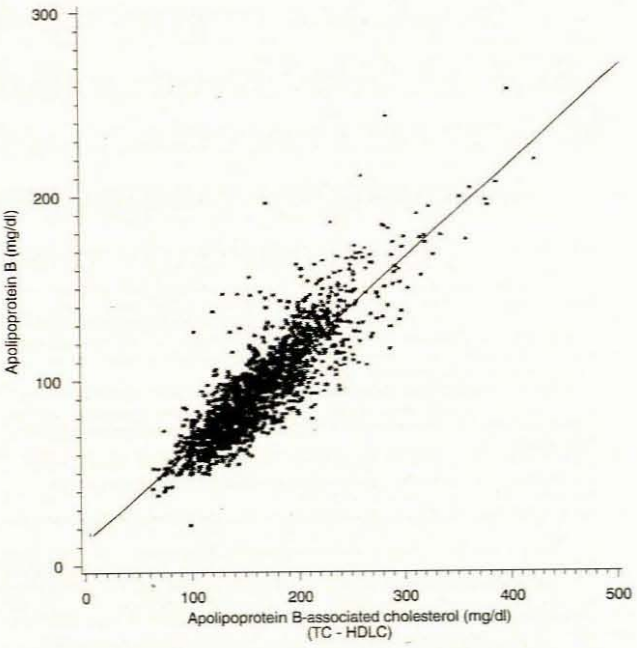

Fig. 1. Linear relationship between apoB and apoB-associated cholesterol.

Discussion

In this study, the total serum apoB level, consisting of both apoB-48 and apoB-100, was determined. Young, in his review, points out that apoB-48 has a normal residence time of only 5 - 10 minutes in the circulation.[30] Consequently the concentration of apoB-48 in the plasma is very low, probably only a few micrograms per millilitre and perhaps only 0.1% that of apoB-100 levels (lower than the error of the method). Normal plasma levels of the latter range from 60 to 120 mg/dl, and more than 90% of the apoB-100 within the plasma of normocholesterolaemic individuals is contained within the LDL fraction.[30] Hence there is normally little difference between the total plasma apoB and LDL apoB levels. In addition, each LDL particle contains a single apoB molecule and the apoB level therefore provides an assessment of the number of LDL particles in the plasma.

According to Vega and Grundy[8] the methodology for absolute measurement of apoB levels constitutes a significant problem in so far as the measurements are inaccurate and unreliable. A variety of immunological techniques without accurate calibration standards are currently in use. This not only constitutes a problem for clinical use of apoB levels but also for interpopulation comparisons of apoB levels. It is therefore with caution that such a comparison is offered.

In 1985 Rossouw *et al.*[31] published the distribution of TC values in the same population from which these apoB levels are now reported. Vermaak *et al.*[29] pointed out that the TC distribution in another white community in two industrial towns in South Africa was markedly similar to that reported in the CORIS study.[31] Both studies used immunonephelometric assays to determine serum apoB levels. The levels of apoB reported here in a rural community of the south-western Cape during the CORIS study are slightly lower than those found by Vermaak *et al.*[29] in the industrial white population.

Table II proves that the definition of low, moderate and high CHD risk based on apoB levels does not correspond very well with the definition based on TC levels; CHD risk classification based on apoB levels may therefore yield different information from that based on TC levels.[22] Table III compares the prevalence of several medical conditions in the three apoB CHD risk categories. A similar comparison of the three TC CHD risk categories was also conducted (data not shown). The higher overall apoB risk categories were significantly associated with all three measures of CHD (Table III). This was not true for the higher TC CHD risk categories, suggesting that apoB levels could identify CHD patients more effectively in this rural South African community. This finding is in line with a few studies[1,4,6,7] and that of Durrington *et al.*,[32] who found that with stepwise discriminate analyses, which included a family history of CHD, TC, TG, apoA-I, Lp (a) and apoB, apoB emerged as the best predictor of CHD in a group of men who had suffered MI compared with a matched group of men. Freedman *et al.*[33] showed that apoB and A-I could significantly distinguish between children whose fathers had suffered an MI and those children whose fathers had not.

Tables IV and V show the variables that were significantly related to apoB levels. The association of apoB with TC and LDLC levels is expected in terms of the apoB molecules associated with LDL, intermediate-density lipoprotein and very-low-density lipoprotein particles. The finding that apoB levels are associated with TG levels, and inversely with the HDLC, HDL_3 and HDL_2 (in women) cholesterol levels, relates to the finding of Austin *et al.*[34,35] that small dense LDL particles are associated with raised TG and decreased HDLC levels.

A number of studies have also found an association between apoB levels and indicators of obesity (Tables IV and V).[33,36,37] Nestel[37] suggested that this was because of diminished removal of very-low-density lipoprotein rather than overproduction. The association found between blood pressure, uric acid and apoB categories of increasing levels was not found in a literature search dating from 1985. Table V also shows that, in addition to other plasma constituents and BMI, the total physical energy expenditure (inversely, independently and marginally) explains the variation of apoB observed in this study. The inverse association between apoB and total physical energy expenditure is to be expected, as a high physical activity level was reported to be associated with reduced apoB-containing lipoprotein particles.[38,39]

It has been amply demonstrated that LDL particles are heterogeneous and differ in size, density and lipid content. A number of studies suggest that the plasma of patients with CHD tend to contain an increased number of small dense particles (pattern B), which are depleted in cholesterol esters, compared with patients without CHD who produce larger LDL particles (pattern A) that are more buoyant and cholesterol ester-rich.[35] The metabolic basis for this finding is incomplete, but it has been shown that the heavy dense LDL particles were removed at a slower rate than the light particles.[40] A possible explanation for this finding is that the dense LDLC may bind less well to the LDL receptor than the

light LDLC.[29] In addition, Chait *et al.*[41] demonstrated that the small dense LDL particles are also more prone to oxidative modification than the larger, more buoyant, LDL particles, and are therefore potentially more atherogenic.

From these data (Table IV) it has been calculated that the LDLC/apoB ratio as well as the TC minus HDLC/apoB ratio significantly decreased across the increasing apoB CHD risk categories for both men and women. This suggests that participants with higher apoB levels have smaller, heavy and dense LDL particles, while those with low apoB levels have lighter, larger LDL particles. Austin *et al.*[34,35] suggested that apoB levels were associated with increased TG and decreased HDLC levels. Multiple regression analyses of our data showed that the apoB level was associated with increased TG levels and decreased HDLC and its subfractions. This further strengthens the suggestion that the high level of apoB in this community is associated with small dense LDL particles. In addition, if the LDLC/apoB ratios of men in all the CHD risk categories are compared with those of women it suggests that the women have lighter, larger LDL particles in all three apoB risk categories. This would imply that women have fewer LDL particles and that these are less atherogenic than those of men.

Finally, routine measurement of apoB for screening purposes and the management of hypercholesterolaemic patients remain an issue in the primary health care setting. This question was raised by Vega and Grundy,[8] and also by Sniderman and Silberberg.[9] Part of Vega and Grundy's argument was based on their data that apoB levels could be approximated from the apoB-associated cholesterol (TC-HDLC) by multiplying the latter by 0.65 on condition that the TG level was below 300 mg/dl.[8] A similar relationship was shown between apoB levels and apoB-associated cholesterol levels in our study (Fig. 1): this is expressed by the formula apoB = 17.0125 + 0.5248 (TC-HDLC). The apoB levels could be approximated by dividing the (TC-HDLC) level in half and adding 20.

Several factors support Vega and Grundy's[8] proposal discouraging apoB measurements in the regular screening of hypercholesterolaemic patients in South Africa. These are the cost involved, lack of availability, difficulty in accurately determining apoB levels as well as the similarity in the management of patients with raised apoB levels and hypercholesterolaemia. This observation must be made, although apoB levels appear to be more strongly associated with known history of CHD and other variables more closely linked to CHD than TC concentrations.

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