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Superiority of traditional village diet and lifestyle in minimizing cardiovascular disease risk in Papua New Guineans

MERE KENDE[1,2]

Port Moresby General Hospital, Papua New Guinea

SUMMARY

In the traditional society of Papua New Guinea (PNG) atherosclerotic cardiovascular diseases (CVD) are rare. However, among the urban population reports of cases of atheroma-related CVD are increasing. The purpose of this study was therefore to compare the CVD risk factors in a homogeneous population of the Southern Highlands Province living in both rural and urban areas differing only in their diet and lifestyle. A total of 221 Samberigi people over the age of 25 years were selected for the survey. These included 123 individuals from remote villages of Samberigi and 98 of their relatives who had lived in Port Moresby city continuously for a minimum of 5 years. The anthropometric measurements, blood lipid, blood glucose and glycosylated haemoglobin (HbA1c) levels were measured and compared. The rural diets were mainly of vegetarian type, limited in variety and low in fat and protein content. In the urban subjects, the typical meal comprised refined foods with high fat and protein content. The urban men and women had significantly ($p<0.05$) greater body weight, body mass index (BMI), and waist and hip circumferences than their rural counterparts. In Port Moresby, 57% of the men and 67% of the women were overweight or obese compared to 28% of their rural counterparts. Similarly, the mean plasma total cholesterol, low-density lipoprotein cholesterol (LDLC), high-density lipoprotein cholesterol (HDLC), fasting blood glucose and HbA1c were significantly higher in the urban group. However, no significant differences were demonstrated for waist to hip ratio, LDLC/HDLC ratio and lipoprotein (a) levels between the two groups. The total cholesterol, LDLC and HbA1c were positively associated with age and BMI in both rural and urban locations. In conclusion, there were significant increases in CVD risk factors in the urban population compared to the rural residents. This was predominantly due to the adoption of a western lifestyle and diet as people moved from rural villages to the city of Port Moresby.

Background

The risk of developing atherosclerotic cardiovascular disease (CVD) increases with obesity, hyperlipidaemia, hypertension, diabetes mellitus, smoking and lack of physical activity in genetically predisposed individuals. Cardiovascular disease is the major cause of morbidity and mortality in the developed world (1). As with any developing country, infectious diseases are still the major causes of morbidity and mortality in Papua New Guinea (PNG). However, with the increasing urbanization and adoption of western lifestyles, this pattern is changing and the incidence of degenerative illnesses such as cardiovascular disease and diabetes is on the rise (2-4).

Many groups of people in the highlands of PNG are known for their isolation from towns and cities, living predominantly traditional lifestyles, hunting and subsistence farming, often with air transport as the only means of communication with the outside world. However, in the last 10 to 15 years many villagers have migrated into towns and cities in search of work and to enjoy a modern lifestyle. The dietary patterns of the rural dwellers are

1 Department of Pathology, Port Moresby General Hospital, Free Mail Bag, Boroko, NCD 111, Papua New Guinea

2 Present address: Division of Chemical Pathology, Queensland Health Pathology Services, Royal Brisbane Hospital Campus, Queensland 4029, Australia

different from those in towns and cities; traditional diets are predominantly vegetarian (5,6), comprising vegetables, fruits and crops high in carbohydrate. In towns and cities, rice, tinned fish or meat, dairy products and other refined foods (high in fat) make up the bulk of the diet. A common attitude among urban dwellers, which associates overweight and obesity with good health, encourages many to cook and consume large amounts of fatty food daily (particularly lamb meat and dairy products) in order to gain weight. Furthermore, compared to rural dwellers who are physically more active (4), the urban people generally live a less active and less vigorous lifestyle. Given these dietary views, practices and lifestyles, it is to be expected that the incidence of CVD and other degenerative diseases will rapidly increase in these urban communities.

To date, few studies (7-10) have looked at cardiovascular risk factors in the Papua New Guinean population. Moreover, none of these studies has focused on the highland population who generally have a very low incidence of CVD (11), and no study has investigated CVD risk factors in populations on predominantly traditional diets. While cultural and ethnic diversity (with over 800 different native languages) is well known even among the highland population, previous researchers have compared prevalence of CVD risk factors between genetically heterogeneous groups of individuals in PNG. Thus any differences in the prevalence of risk factors between village and urban dwellers could be the result of both environmental and genetic influences.

The present study was designed to define the exact role of environmental influences (diet and lifestyle) as CVD risk factors in a genetically homogeneous highland population of PNG by comparing rural residents with their relatives who had left 'home' and live permanently in Port Moresby city.

Materials and methods

Demography of study population

Samberigi is a remote location in the lowlands of the Southern Highlands Province of Papua New Guinea. It is situated at an altitude of 400 to 600 metres above sea level and has a population of approximately 5000 people. The first white man to explore the area was Staniforth Smith around 1911 although it was not until the 1930s that a western influence was first accepted through missionaries who were able to establish a health centre and a school. Since then, many individuals have migrated to live and work in towns and cities.

Although recently rice and tinned fish from locally owned trade stores do occasionally supplement daily meals, the traditional Samberigian diet is predominantly vegetarian – taro, sweet potato, banana, green leafy vegetables, pineapples, corn and tomatoes. Meat is a rarity since, although pigs are universally owned, they are largely kept for prestige, bride price and compensation payments and are slaughtered in large numbers only at feasts and 'sing sing' (social parties). Wild meats from birds, cuscus, tree kangaroo, wallaby, fish, snakes and bush rats are eaten more frequently, but only in small amounts as game is very scarce. Large amounts of starch are consumed in order to obtain an adequate energy supply. Frank malnutrition is rare.

Physical activity among the villagers is substantial, often involving a walk of 5 to 10 km daily to the garden or bush to fetch firewood or materials for building houses. Individuals work on average 5 to 7 hours per day in their gardens, using bush knives, axes and sharpened wooden digging sticks for planting. Interestingly, villagers would prefer to use their spare time gardening or bush walking rather than staying at home, which is regarded as boring. There are no sedentary jobs in the village.

The stresses of the modern urban society is much less evident in the village – no television to tell of international tensions, no cars to rush about, no clocks to watch anxiously and no bills to pay. In addition, obesity, diabetes, hypertension and heart diseases are also less apparent.

In comparison, the urban Samberigians' lives are similar to those of modern city dwellers everywhere with relatively high stress levels, less physical activity and a diet high in protein and saturated fats (Table 1).

TABLE 1

SUMMARY OF THE COMMON FOOD CONSUMPTION AND HABITS OF RURAL AND URBAN SAMBERIGI HIGHLANDERS OF PAPUA NEW GUINEA

Food type	Village	Port Moresby
Carbohydrates	sweet potato†, banana†, taro†, rice*	rice†, bread†, scone†, biscuits‡, banana†, sweet potato†, cassava*
Protein	pork‡, wild meat*, fish*, tinned fish*, snake*	chicken†, lamb/pork†, eggs‡, sausage‡, tinned fish/meat‡, seafood*
Fat	mainly from meat	margarine†, butter‡, milk‡, cheese*
Vegetables and fruits	green leaves†, pawpaw‡, oranges*, wild nuts*, ripe bananas‡, pumpkin‡	green leaves†, cabbages‡, aibika†, pumpkin‡
Flavours	ginger‡, salt*	salt†, coconut soups†
Drinks	tea*, water†	tea†, soft drinks†, alcohol‡§
Other	cigarette smoking*§	cigarette smoking†§

Food consumption: †daily, ‡ weekly, *monthly, §habit

Study design and subjects

The survey was carried out in September and October 1997. A total of 221 volunteers born in the Samberigi area of Southern Highlands Province of Papua New Guinea were studied. There were two study groups. The first group of 98 subjects (46 men and 52 women) had migrated to Port Moresby and lived there for more than 5 years. The second group of 123 volunteers (58 men and 65 women) were permanent residents of the remote region of Samberigi including Hamoteke (Niae), Pawahale, Masiki, Kadi, Sumbudei, Hatelome, Popouateke, Sao, Endeliteke, Paotokoule (Pawabi) and Yoleateke villages located along the border of Gulf and Southern Highlands Provinces.

In Port Moresby, volunteers were invited to participate by announcements in 3 major church services in the city attended by over 90% of Samberigi Christians. There were no specific dietary restrictions imposed by the church. In the remote Samberigi villages, initial awareness of the survey was by an announcement a week in advance over Radio Southern Highlands, the provincial radio station. Subsequent messages were communicated over 3 days from person to person throughout the villages, spread over approximately 5 to10 km.

Conduct of survey and risk factor assessment

Information was obtained from self-administered questionnaires and an interview. The purpose of the interview was to assess the overall health status and obtain specific information on anthropometry, glycaemia status, blood lipids and history of heart disease. A one-to-one interview was performed with the help of two trained college students. All interviews were conducted using the local Samberigi language (fluently spoken by 100% of the participants) and Melanesian Pidgin. General dietary patterns and frequency were also assessed using food questionnaires.

Many subjects were assisted in estimating their date or year of birth indirectly, taking account of the ages of their children, grandchildren and age-mates, and a calendar of local historical events. The anthropometric measurements, which I made, took 5 to 10 minutes. A non-stretch measuring tape was used to measure height and abdominal circumferences and a Beaver digital scale was used to measure weight. The body mass index (BMI) is an indicator of total body fatness and is calculated as body weight in kilograms divided by the height in metres squared. For the assessment of obesity, the classification based on BMI proposed by the Australian National Health and Medical Research Council (NHMRC) (12,13) was used. These recommendations are: a BMI of 20-25 is an acceptable (ideal) body mass, less than 20 is underweight, >25-30 is overweight and more than 30 obese.

The waist was measured at the level of the umbilicus and the hip circumference at the level of anterior superior iliac spine in the upright position, females lightly clothed and males without shirts. Each measurement was checked twice. The survey was conducted between 8 am and 11 am every day for 6 days at each location. In both village and urban locations, volunteers were instructed to fast from 9 pm till 8 am before attendance, at which time blood was collected and a questionnaire was completed.

The blood samples collected (one heparin and one EDTA tube from each volunteer) were processed as follows. In Port Moresby, heparin tubes were immediately centrifuged and all samples frozen and stored at -20^{o}C in the Port Moresby General Hospital Biochemistry Department. In Samberigi, heparinized blood samples were similarly separated and plasma stored together with the EDTA tubes at 4^{o}C. After 6 days the samples were transported on dry ice by air over 3 hours to Port Moresby where they were kept frozen at -20^{o}C. Subsequently, all samples were transported frozen by air to Melbourne to be assayed at the Monash Medical Centre Biochemistry Department.

Laboratory assays

The total plasma cholesterol, triglyceride and fasting blood glucose concentrations were analyzed on a Dupont Dimension instrument using cholesterol esterase/oxidase, lipase/glycerol oxidase and hexose kinase methods respectively. The high-density lipoprotein cholesterol (HDLC) was determined by selective gel filtration (14) using Dupont Dimension. Low-density lipoprotein cholesterol (LDLC) was calculated using the Friedewald formula (15): LDLC = total cholesterol – HDLC – triglycerides (mmol/l)/2.19 where triglycerides are ≤4.5 mmol/l.

Glycosylated haemoglobin (HbA1c) was determined on the EDTA blood by TOSOH – high performance liquid chromatography (HPLC) based on cation exchange. HbA1c kept at 4^{o}C or frozen was shown to be stable for up to a month using this method, which gave reproducible results at concentrations between 3% and 8%. Plasma lipoprotein (a) (Lp (a)) was measured on a Behring Nephelometer using polystyrene latex particles coated with antibody to human Lp (a) and Behring N Lp (a) standard (human), Code No OQCV.

Statistics

The Statistical Package for the Social Sciences (SPSS) (16) was used for the statistical analyses. All initial comparisons between the rural and urban populations as well as between sexes were made using an independent-sample t-test for unequal variances, after checking for normality of distribution. For variables such as age, Lp (a), triglycerides and HDLC, which showed some skewing of distribution, the group comparisons were repeated using the Mann-Whitney U test and Wilcoxon Rank Sum W test. However, no changes in p values or significant differences were observed.

Comparisons were made between village and urban groups for the same sex and within each group between males and females. Similar comparisons were also made for each of the age groups 25-34, 35-44, 45-54, 55-64 and ≥ 65 years.

The independence and the degree of association of anthropometric variables with lipid measurements and glycaemic indicators were further examined using a partial correlation coefficient test. This test enables examination of the relationship between two variables while controlling for confounding variable(s). In all calculations, $p<0.05$ was considered to be statistically significant.

Results

The food types and habits of the rural and urban Samberigi people are summarized in Table 1. Generally, the rural dwellers' diets comprised carbohydrate crops and vegetables with small amounts of fat and protein. For the urban dwellers, foods high in fat and protein, mainly refined store foods, were common daily meals. Alcohol consumption and smoking were more frequent among the urban than the rural group. In both locations, more males than females smoked and took alcohol.

Anthropometry

The mean ages of female volunteers in urban (37 years) and rural (41 years) settings were similar. In contrast, rural male participants were relatively older (48 years) than the urban men (42 years). This difference was significant ($p<0.05$). This was because of the absence of many younger village men who were recruited to work as labourers or semiskilled workers at a newly discovered oil-field (Gobe) located approximately 40 kilometres from the area.

The mean anthropometric measurements of the village and urban Samberigians and their statistical analyses are shown in Tables 2 and 3. In both men and women, urban residents had significantly greater mean values for weight ($p<0.01$), BMI ($p<0.01$), waist circumference ($p<0.001$) and hip circumference ($p<0.001$) than their rural counterparts. However, no significant difference in the waist to hip ratio between the urban and rural residents was noted. In addition, urban women were significantly taller ($p<0.01$) than their rural counterparts, while no such difference in height was noted among the men. Females were generally shorter than their male counterparts ($p<0.001$) at each location. In the urban group, women had larger hip size ($p<0.001$) than their male counterparts, while no significant sex difference in hip size was observed among the rural residents. While urban volunteers showed no difference in weight between sexes, rural men weighed significantly more ($p<0.001$) than their female counterparts. However, in neither location was there any significant sex difference for BMI, waist circumference or waist to hip ratio.

Figures 1 to 4 show scatter graphs of age versus plasma cholesterol concentration and BMI versus plasma cholesterol concentration of rural and urban volunteers. Employing the NHMRC criteria, overweight (BMI>25) and obesity (BMI>30) were more prevalent among urban than rural residents of both sexes. Around 57% of men (26 out of 46) and 67% of women (35 out of 52) in the urban group were either overweight or obese compared to only 28% (16 out of 58 men and 18 out of 65 women) of the rural group (Table 4).

Of the overweight and obese subjects, only 1 male and 4 females in the villages compared to 10 males and 11 females in Port Moresby had an associated plasma cholesterol level above the risk value (>5.5 mmol/l). Overall, the proportion of volunteers with plasma cholesterol concentration of greater than 5.5 mmol/l was 28% for men and 29% for women in the urban group, and 6% and 11%, respectively, for rural men and women. In both locations, individuals with high plasma cholesterol levels were aged between 30 and 55 years.

Lipids and glucose

Among both men and women, urban residents had significantly higher mean values of total plasma cholesterol ($p<0.001$), LDLC ($p<0.001$), HDLC ($p<0.05$), fasting blood glucose ($p<0.02$) and HbA1c ($p<0.02$) than the rural residents. However, no statistical differences were demonstrated for the LDLC/HDLC ratio and plasma Lp (a) level when the urban residents were compared with the rural residents of both sexes. Only women showed significant differences in plasma triglyceride levels between the urban and the rural residents. Mean plasma triglyceride levels in rural women were higher than in their urban counterparts.

When men and women were compared at each location, no significant differences were demonstrated in the mean levels of total plasma cholesterol, LDL cholesterol, HDLC, LDLC/HDLC ratio, Lp (a), glucose and

TABLE 2

SUMMARY OF ANTHROPOMETRY, TOTAL CHOLESTEROL, LDL AND HDL CHOLESTEROL, LDLC/HDLC RATIO, TRIGLYCERIDES, LIPOPROTEIN (A), FASTING BLOOD GLUCOSE AND HBA1C IN MELANESIAN MALE HIGHLANDERS OF PAPUA NEW GUINEA IN 1997

	Number	Mean	SD	s.e.	p value
Age (years)					
Rural	58	48.1	14	1.8	0.026
Urban	46	42.3	12.2	1.8	
Weight (kg)					
Rural	58	60.9	9.2	1.2	<0.002
Urban	46	68.1	12.4	1.8	
Height (cm)					
Rural	58	159.8	6.8	0.9	0.18
Urban	46	161.5	6.1	0.9	
Body mass index (kg/m^2)					
Rural	58	23.8	2.7	0.4	0.002
Urban	46	26	4	0.6	
Waist circumference (cm)					
Rural	58	78.7	6.8	0.9	<0.001
Urban	46	86.1	11.4	1.7	
Hip circumference (cm)					
Rural	58	82.3	5.9	0.8	<0.001
Urban	46	91.1	6.2	0.9	
Waist/hip ratio					
Rural	58	1	0	0	0.521
Urban	46	0.9	0.1	0	
Total cholesterol (mmol/l)					
Rural	50	4.1	1.2	0.2	<0.001
Urban	46	5	1.2	0.2	
Triglycerides (mmol/l)					
Rural	50	1.1	0.6	0.1	0.14
Urban	46	1.3	0.8	0.1	
LDL cholesterol (mmol/l)					
Rural	50	2.8	1.1	0.16	<0.001
Urban	46	3.5	1.1	0.17	
HDL cholesterol (mmol/l)					
Rural	50	0.8	0.3	0	0.026
Urban	46	0.9	0.2	0	
LDLC/HDLC ratio					
Rural	50	3.9	2	0.3	0.478
Urban	46	4.2	1.6	0.2	

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TABLE 2 *(Continued)*

	Number	Mean	SD	s.e.	p value
Lipoprotein (a) (mg/l)					
Rural	52	147.6	230	31.9	0.863
Urban	46	155.7	230.5	34	
Blood glucose (mmol/l)					
Rural	48	4.5	1	0.1	<0.001
Urban	46	5.2	0.9	0.1	
HbA1c %					
Rural	50	4.7	0.4	0.1	0.019
Urban	46	5	0.5	0.1	

SD = standard deviation
s.e. = standard error of the mean
LDL = low-density lipoprotein
HDL = high-density lipoprotein
LDLC = low-density lipoprotein cholesterol
HDLC = high-density lipoprotein cholesterol
HbA1c = glycosylated haemoglobin

TABLE 3

SUMMARY OF ANTHROPOMETRY, TOTAL CHOLESTEROL, LDL AND HDL CHOLESTEROL, LDLC/HDLC RATIO, TRIGLYCERIDES, LIPOPROTEIN (A), FASTING BLOOD GLUCOSE AND HBA1C IN MELANESIAN FEMALE HIGHLANDERS OF PAPUA NEW GUINEA IN 1997

	Number	Mean	SD	s.e.	p value
Age (years)					
Rural	65	41	14.8	1.8	0.333
Urban	52	37.4	11.3	1.6	
Weight (kg)					
Rural	65	55.4	9.5	1.2	<0.001
Urban	52	66.1	11.7	1.6	
Height (cm)					
Rural	65	152.5	5.8	0.7	<0.01
Urban	52	155.5	5.3	0.7	
Body mass index (kg/m^2)					
Rural	65	23.7	3.2	0.4	<0.001
Urban	52	27.3	4.5	0.6	
Waist circumference (cm)					
Rural	65	79.3	8.4	1	<0.001
Urban	52	88.2	11.4	1.6	

Continued on next page

TABLE 3 *(Continued)*

	Number	Mean	SD	s.e.	p value
Hip circumference (cm)					
Rural	65	84.2	7.9	1	<0.001
Urban	52	95.7	6	0.8	
Waist/hip ratio					
Rural	65	0.9	0	0	0.332
Urban	52	0.9	0.1	0	
Total cholesterol (mmol/l)					
Rural	62	4.2	1.2	0.2	<0.001
Urban	52	5.1	0.8	0.1	
Triglycerides (mmol/l)					
Rural	61	1.1	0.6	0.1	<0.001
Urban	52	0.8	0.4	0.1	
LDL cholesterol (mmol/l)					
Rural	60	2.8	1.1	0.1	<0.001
Urban	52	3.6	0.9	0.1	
HDL cholesterol (mmol/l)					
Rural	61	0.9	0.3	0.1	0.003
Urban	52	1.1	0.2	0	
LDLC/HDLC ratio					
Rural	60	3.5	1.6	0.2	0.576
Urban	52	3.7	1.4	0.2	
Lipoprotein (a) (mg/l)					
Rural	63	124.2	174.8	22	0.299
Urban	52	136.7	178.6	24.8	
Blood glucose (mmol/l)					
Rural	61	4.6	0.9	0.1	0.014
Urban	52	4.9	0.7	0.1	
HbA1c (%)					
Rural	54	4.8	0.6	0.1	0.005
Urban	52	5.1	0.4	0.1	

SD = standard deviation
s.e. = standard error of the mean
LDL = low-density lipoprotein
HDL = high-density lipoprotein
LDLC = low-density lipoprotein cholesterol
HDLC = high-density lipoprotein cholesterol
HbA1c = glycosylated haemoglobin

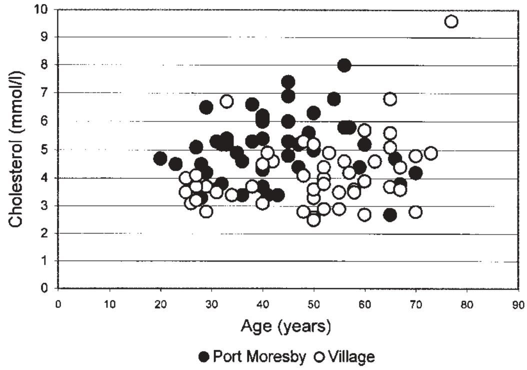

Figure 1. Age versus plasma total cholesterol in Melanesian males of Papua New Guinea.

Figure 2. Age versus plasma total cholesterol in Melanesian females of Papua New Guinea.

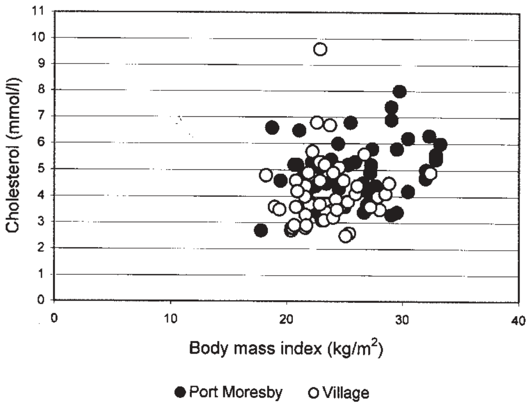

Figure 3. Body mass index versus plasma total cholesterol in Melanesian males of Papua New Guinea.

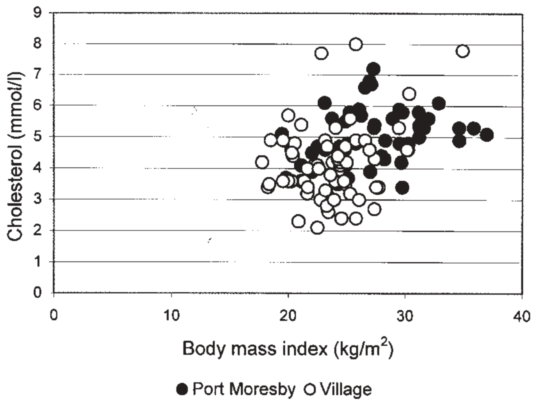

Figure 4. Body mass index versus plasma total cholesterol in Melanesian females of Papua New Guinea.

HbA1c. Only the rural group showed significant differences in mean plasma triglyceride level between men and women.

A histogram of distribution of total levels of Lp (a) is shown in Figure 5. In both sexes in both villagers and city-dwelling highlanders, the plasma Lp (a) levels were highly positively skewed. Overall the 90th and 95th percentile values were 426 mg/l and 626 mg/l, respectively, while the total mean concentration was 142 mg/l (151 mg/l in males and 130 mg/l in females).

Correlation tests

A partial correlation test was used to test for independence and degree of association between plasma lipids, glucose and HbA1c and the anthropometric measurements. The calculated adjusted coefficients for plasma lipids, glucose and HbA1c versus anthropometry for the urban and rural residents of both sexes are summarized in Tables 5 and 6.

In general, total plasma cholesterol, LDLC, LDLC/HDLC ratio and HbA1c in men were all positively associated with age, weight, height and BMI in the rural and urban groups. There was no definite pattern of association of the plasma lipids and glycaemic indicators with the other anthropometric measurements, such as waist and hip circumferences and the waist:hip ratio.

In men, only rural residents demonstrated a significant association of total plasma cholesterol, LDLC and HbA1c with age. For urban men, in contrast, the associations of HDLC and the LDLC/HDLC ratio with age, and HbA1c with weight and BMI were statistically significant. The findings were similar in women, with the addition that in them, but not in men, the associations between

TABLE 4

BODY MASS INDEX IN URBAN AND RURAL PAPUA NEW GUINEANS IN 1997 ACCORDING TO THE NATIONAL HEALTH AND MEDICAL RESEARCH COUNCIL OF AUSTRALIA CLASSIFICATION

BMI (kg/m^2)	Males				Females			
	Port Moresby		Village		Port Moresby		Village	
	N	%	N	%	N	%	N	%
Obese (>30)	7	15.2	1	1.7	14	26.9	3	4.6
Overweight (>25-30)	19	41.3	15	25.9	21	40.4	15	23.1
Ideal (20-25)	18	39.1	39	67.2	14	26.9	39	60
Underweight (<20)	2	4.3	3	5.2	3	5.8	8	12.3
Total	46	100	58	100	52	100	65	100

BMI = Body mass index

BMI and total plasma cholesterol, LDLC, LDLC/HDLC ratio and HbA1c were all statistically significant in both rural and urban groups. Although plasma triglyceride concentrations generally showed a positive correlation with all variables among both males and females from urban and rural areas, statistical significance was only demonstrated with age in urban women. Plasma Lp (a) levels showed variable relationships with weight, height and hip and waist measurements. For example, although a significant positive association was seen with waist and hip circumferences in rural females, a negative association was noted in their male counterparts, and no significant relationship of Lp (a) was shown in either sex with age, weight, BMI or waist to hip ratio in either location.

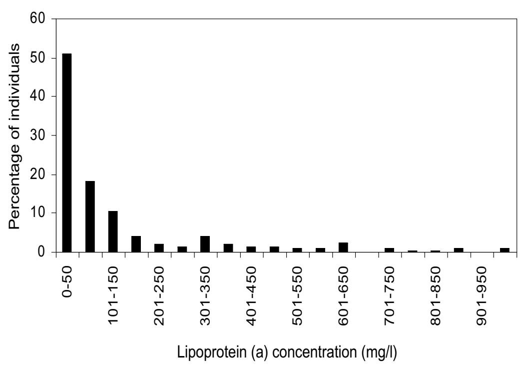

Figure 5. Plasma lipoprotein (a) distribution in Melanesian adults of Papua New Guinea.

The sample size was small when the data were analyzed according to the different age categories. However, the pattern of change in CVD risk factors was similar to that demonstrated for the whole group.

Discussion

This study reports significantly greater CVD risk factors in a homogeneous ethnic group living in urban Papua New Guinea compared with an ethnically similar rural group. These changes have been attributed to shifts over the years in dietary patterns and lifestyles of the villagers upon moving into towns and cities.

Ideal weight is not defined for Papua New Guineans. Although the Port Moresby residents were significantly taller, they were also more frequently overweight and obese than the villagers, using the standards established by the NHMRC (12,13). 21% of urban versus 3% of rural dwellers had a BMI ≥ 30 and the urban residents had larger waist and hip circumferences than the village residents.

Diabetes mellitus is very rare in the highlanders of Papua New Guinea (17). The findings of significant increases in blood glucose and HbA1c in this survey as villagers moved from a rural to an urban setting are interesting. Whether or not these findings do indicate a possible 'metabolic transition' for the subsequent development of glucose intolerance and eventually diabetes mellitus and its complications, is yet to be determined.

TABLE 5

ADJUSTED PARTIAL CORRELATION COEFFICIENTS OF FACTORS ASSOCIATED WITH TOTAL CHOLESTEROL, LDL AND HDL CHOLESTEROL, LDLC/HDLC RATIOS, TRIGLYCERIDES, LIPOPROTEIN (A), BLOOD GLUCOSE AND HBA1C OF RURAL AND URBAN MALE MELANESIANS OF PAPUA NEW GUINEA IN 1997

	Total cholesterol		**LDL cholesterol**		**HDL cholesterol**		**LDLC/HDLC ratio**		**Triglycerides**		**Lp (a)**		**Blood glucose**		**HbA1c**	
	Rural	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**
Number	35	42	35	42	35	42	35	42	35	42	35	42	35	42	35	42
Age – years	0.3220*	0.0374	0.3036*	0.1444	0.2199	0.5017†	0.1938	0.3922‡	0.0071	-0.0205	-0.0472	-0.1219	-0.0302	0.1407	0.3324*	0.0817
Weight – kg	0.2866	0.2045	0.2556	0.1223	0.0417	0.0430	0.0498	0.0145	0.2246	0.2604	-0.3130	-0.2149	-0.2124	-0.0706	0.3062	0.2975*
Height – cm	0.3552*	0.0990	0.3514*	0.0804	0.1233	-0.0471	0.0738	0.0475	0.0149	0.1158	-0.4000‡	0.3143*	-0.2161	-0.1185	0.2678	0.0198
Body mass index – kg/m^2	0.1046	0.1652	0.0690	0.0695	-0.0539	0.0876	0.0127	-0.0395	0.2910	0.2583	-0.1041	-0.0785	-0.1225	-0.0208	0.1828	0.3211*
Waist circumference – cm	0.0668	-0.1094	-0.0147	-0.1210	0.1274	-0.0775	-0.0898	-0.0331	0.2939	0.1318	-0.3881*	-0.0734	0.2856	-0.1003	0.0651	-0.2932
Hip circumference – cm	0.0132	-0.1259	-0.0233	-0.1683	-0.0433	0.0759	0.0249	-0.2043	0.2606	0.0934	-0.4148‡	-0.1365	0.2467	-0.1995	0.1478	-0.0189
Waist/hip ratio	0.1037	-0.0164	0.0109	0.0101	0.3229	-0.1439	-0.2123	0.1314	0.1056	0.0441	-0.0440	0.0294	0.1200	0.0738	-0.1222	-0.2904

*p<0.05, ‡p<0.01, †p<0.001
LDL = low-density lipoprotein
HDL = high-density lipoprotein
LDLC = low-density lipoprotein cholesterol
HDLC = high-density lipoprotein cholesterol
Lp (a) = lipoprotein (a)
HbA1c = glycosylated haemoglobin

TABLE 6

ADJUSTED PARTIAL CORRELATION COEFFICIENTS OF FACTORS ASSOCIATED WITH TOTAL CHOLESTEROL, LDL AND HDL CHOLESTEROL, LDLC/HDLC RATIOS, TRIGLYCERIDES, LIPOPROTEIN (A), BLOOD GLUCOSE AND HBA1C OF RURAL AND URBAN FEMALE MELANESIANS OF PAPUA NEW GUINEA IN 1997

	Total cholesterol		LDL cholesterol		HDL cholesterol		LDLC/HDLC ratio		Triglycerides		Lp (a)		Blood glucose		HbA1c	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Number	46	48	46	48	46	48	46	48	46	48	46	48	46	48	46	48
Age – years	0.3681‡	0.2034	0.4065‡	0.1534	-0.2115	-0.1195	0.5286†	0.1983	0.2694	0.3605‡	-0.0698	0.1261	0.0842	0.1037	0.4460†	0.2177
Weight – kg	0.3320*	0.2005	0.3412*	0.2322	0.0409	-0.2164	0.3518*	0.2787*	0.0444	0.1221	-0.1284	0.1114	-0.0484	0.1673	0.3549*	0.1344
Height – cm	0.1586	-0.2417	0.1273	-0.2215	0.0877	-0.0398	0.0894	-0.0640	0.1123	0.0195	0.0316	0.1456	-0.0354	-0.2615	0.3048*	-0.1198
Body mass index – kg/m^2	0.3416*	0.2856*	0.3631‡	0.2884*	0.0167	-0.2196	0.3926‡	0.2900*	0.0148	0.2566	-0.1716	0.1498	-0.0340	0.3631‡	0.2956*	0.3295*
Waist circumference – cm	0.0406	-0.2640	-0.0272	-0.2559	0.0608	-0.0192	-0.0579	-0.1259	0.2034	-0.0063	0.4101‡	-0.0088	0.3328*	-0.1552	0.0645	-0.1471
Hip circumference – cm	0.0781	-0.1736	0.0488	-0.2192	0.0521	0.1465	0.0224	-0.2389	0.0582	0.0617	0.3774‡	0.1051	0.2006	-0.0453	0.1756	-0.2307
Waist/hip ratio	-0.0820	-0.1712	-0.1325	-0.1770	-0.0004	-0.0293	-0.1252	-0.0641	0.1937	0.0718	0.0426	-0.0564	0.1718	-0.1712	-0.1978	-0.0782

*$p<0.05$, ‡$p<0.01$, †$p<0.001$
LDL = low-density lipoprotein
HDL = high-density lipoprotein
LDLC = low-density lipoprotein cholesterol
HDLC = high-density lipoprotein cholesterol
Lp (a) = lipoprotein (a)
HbA1c = glycosylated haemoglobin

A more recent study showed unexpectedly high insulin response to glucose load, a possible precursor of glucose intolerance in a periurban highlander population of Papua New Guinea (18).

Early surveys in Papua New Guineans showed no differences in plasma lipid levels between rural and urban residents (19-21). However, more recent studies have reported increasing levels of CVD risk factors including raised plasma lipids in urban Papua New Guineans (8,10,17,22,23), as observed in the present survey.

Unlike previous studies that compared different ethnic groups, the present survey aimed to examine CVD risk factors in a genetically homogeneous group of individuals, thus eliminating the influence of genetic factors, while investigating the effects of diet and lifestyle only.

A recent epidemiological survey by Hodge et al. (10) demonstrated increasing evidence of hypercholesterolaemia with increasing age and BMI in urban Papua New Guineans. The present findings were similar although the association with age was only statistically significant among the rural Samberigi villagers. The absence of significant age-related increases in plasma total cholesterol in the urban group could be due to the narrow age spectrum of volunteers recruited. In addition, the sample size in each age group was too small to make any meaningful statistical analysis. In Port Moresby, the older volunteers also tended to retain some of the characteristics of village residents, as they generally appeared to have lower plasma total cholesterol and BMI than the younger subjects.

Mean fasting plasma triglyceride concentrations in both the rural and urban subjects lay between 0.8 and 1.3 mmol/l (Tables 2 and 3) with a range from 0.5 to 4.2 mmol/l. Previous studies (10,24) have reported much higher mean plasma triglyceride levels in highlanders than in coastal subjects. This was attributed to the high (95% of energy) carbohydrate content of their sweet-potato-based diet. In these Samberigi people, relatively lower plasma triglyceride levels were observed than those seen in these earlier surveys. Since subjects in the previous studies were not fasted, this could be responsible for the higher levels reported. Every attempt was made in this present study to ensure that the volunteers were properly fasted.

Furthermore, while urban women tended to have lower levels of plasma triglyceride concentrations than the rural women, the mean levels in rural and urban men were very similar. This could be explained by similarities in the composition of carbohydrate-containing foods, namely sweet potato and banana, which make up the bulk of the daily meal in both locations (Table 1), although the possibility of a genetic component in the ability to metabolize food can not be excluded.

The mean plasma HDLC concentration in the villagers was significantly lower than in the Port Moresby residents. A plasma HDLC level below 0.9 mmol/l has been shown to be an independent risk factor for ischaemic heart disease in the western world (25,26). In the Melanesians of Fiji (27) and in Western Samoans (28), a predominant vegetarian diet was associated with low plasma apoprotein A-1, a major determinant of plasma HDLC concentration. Urbanization with increased dietary fat and alcohol intake was associated with an increase in plasma apoprotein A-1 levels. This pattern was also seen in the present study, since the villagers had lower mean plasma HDLC concentration than the urban residents.

The significance of the low plasma levels of HDLC observed in these Melanesians in relation to risk of CVD remains unknown. The increases in plasma total cholesterol in the urban group were accompanied by similar increases in plasma HDLC levels. Therefore, the extent to which such change in plasma HDLC would compensate for any risk of CVD that may be associated with the low plasma HDLC levels in these Melanesians requires further study.

The pattern of distribution of plasma Lp (a) in this study was similar to that reported for caucasians (29). However, the mean and median values were slightly lower than those of caucasians: the mean was 142 mg/l versus 150 mg/l and the median was 53 mg/l versus 80 mg/l. This is the first study reporting the pattern of distribution of plasma Lp (a) in any

Melanesian population. Plasma level of Lp (a) is genetically influenced and does not vary significantly throughout life except for the emergence of disease states, particularly those affecting the liver, kidney and thyroid gland (30). Ethnic differences in its pattern of distribution have also been reported (31). The Chinese have a highly positively skewed distribution followed by caucasians, while the pattern in black Africans approaches normal with a mean level approximately twice that of whites (29, 32). In people from the Indian subcontinent the distribution of plasma Lp (a) is intermediate in shape between those of caucasians and blacks (33). More recently, the plasma Lp (a) distribution in the Japanese population has been reported to show a pattern similar to that of caucasians rather than that observed in other Asian countries (34). An assay for plasma Lp (a) is yet to be standardized because of the existence of different immunological forms. A working group has therefore been established by the International Federation of Clinical Chemistry (IFCC) to facilitate this standardization (35). Meanwhile limitations resulting from methodological differences should be considered when comparing plasma Lp (a) levels in different studies or ethnic groups.

Raised plasma Lp (a) is a well-recognized independent risk factor for atherosclerosis (30, 36). While the risk of CVD and high plasma Lp (a) levels is well recognized in the presence of hyperlipidaemia, this is uncertain in the normolipidaemic patient (36). The present study revealed no gross clinical evidence of underlying cardiovascular diseases among this survey population. This was despite 20% of the volunteers having total plasma Lp (a) level above the CVD risk value (Figure 5). Plasma Lp (a) levels more than 300 mg/l are independently associated with increased risk of atherosclerotic vascular diseases (29-31,36). Thus, in the absence of other lipid abnormalities or additional CVD risk factors such as obesity, smoking, hypertension and family history of CVD, the risk of atherosclerotic disorders from raised plasma Lp (a) levels in this population is perhaps negligible.

The positive association of fasting plasma lipids and glycaemic indicators with anthropometry and particularly the relationship between cholesterol and age or BMI was not unexpected since they have been previously described. As the weight or BMI of a person increases so does the plasma total cholesterol. Similarly, the plasma cholesterol level generally increases with age. In Papua New Guinea, earlier studies by De Wolfe and Whyte (19), Wyatt et al. (20) and Scrimgeour et al. (21) demonstrated lack of association of cholesterol with age. The finding of low plasma cholesterol in older Papua New Guineans in their study compelled them to conclude that Papua New Guineans may be protected from atheroma-related CVD. However, more recent work suggests otherwise. Increasing numbers of cases of atheroma-related heart diseases are already reported amongst the urban population of Papua New Guinea (2,3).

The present findings differ from the early reports about Papua New Guineans that showed lack of increased CVD risk factors with urbanization. The increase in CVD risk factors observed in this study, however, is similar to that reported more recently in other urban Papua New Guineans, including the studies by Hodge et al. in coastal residents and Eastern Highlanders (10), by Iser and Avera in Bougainvillians (8) and by Kevau et al. (23) in young public servants. All these studies showed significant increases in CVD risk factors in the urban populations, related to changing activity, dietary patterns and adoption of western lifestyles.

In spite of these significant changes with modernization, the calculated mean levels of lipids, blood glucose and HbA1c are still below those recognized in the developed world to be associated with significant risk of CVD. One reason for this finding may be that all of the urban volunteers still retained residual effects of rural life, having spent their childhood and young adult lives in rural villages before migrating to the city. The society is also in a transitional stage with a mixture of western and traditional lifestyles including dietary patterns, even in the urban setting. However, if their current urban lifestyle and dietary patterns continue, one could reasonably predict an average increase in significant hyperlipidaemia, glucose intolerance and obesity among the Samberigi urban dwellers.

Since this study is limited by its focus on a single ethnic group and a small sample size, no general statement on the pattern of changes of CVD risk factors in Papua New Guineans can be deduced from it. However, the evidence is mounting since the other epidemiological surveys of this population do show similar trends, with increasing reports of atherosclerotic CVD among the urban dwellers. The findings are likely to demonstrate what is happening all over the country. The burden on the nation's scarce health resources will be large, since the demand for more relevant and modern health care facilities will increase with the changing pattern of diseases. The increases in the CVD risk factors are likely to foreshadow many new disorders such as ischaemic heart disease, diabetes, stroke and hypertensive disorders which have previously been typical of western populations.

While it is not too late, urgent attention is now required at all levels of the health care system to address this issue if we are to prevent these degenerative disorders from ever becoming endemic.

Conclusion

The current study has shown that there is a significant increase in plasma total cholesterol, LDLC, HDLC, blood glucose and HbA1c with urbanization and adoption of western lifestyles and dietary habits in the Samberigi people of the Southern Highlands Province of Papua New Guinea. The Samberigi people have a positively skewed Lp (a) pattern with 20% of them having plasma levels higher than 300 mg/l. There is increased risk of overweight, hyperlipidaemia and glucose intolerance in this population. The village lifestyle with its more vegetarian diet, greater physical activity and low fat intake appears to be a better way to live if one is to reduce the risk of CVD.

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