

# Epidemiologic Studies of Serum Glucose Levels among Micronesians

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## SUMMARY

Data from epidemiologic studies of Chamorro and Palauan populations of Micronesia were analyzed for associations of serum glucose levels with other characteristics of the population.

The frequency distribution patterns of serum glucose levels were similar to those reported for large United States populations, being unimodal and slightly skewed toward higher values.

Analysis by geographic subgroups showed differences in age- and sex-specific mean serum glucose levels, and in prevalence ratios of hyperglycemia. The general tendency was for the higher values to occur among the subgroups living in the relatively modern areas, as indicated by measures of education, occupation, sociocultural attitudes, and nutritional intakes of a high fat "Western type" diet.

Correlation analysis of individual characteristics indicated that serum glucose levels were positively associated with age, blood pressure, serum cholesterol and triglyceride levels, and body weight. There was no consistent association with electrocardiogram abnormalities, an inventory of symptoms, cigarette use, or with sociocultural measures of education, occupation, traditional attitudes, and residential mobility.

The over-all implication was that high serum glucose levels, high serum lipid levels and obesity were interrelated within these Micronesian populations. *DIABETES* 22: 129-36, February, 1973.

The WHO Expert Committee on Diabetes has emphasized the need for epidemiologic studies of variables related to diabetes in groups of people living in different environmental situations.<sup>1</sup> This is a report of studies of two groups of Micronesians, the Chamorro

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people of the Mariana Islands, and the Palauan people of the Western Caroline Islands. The data used for this analysis were collected as part of two larger studies of the health effects of culture change, and emphasis was placed upon examining subgroups which were exposed to different degrees of modernization.<sup>2,3</sup>

## BACKGROUND

As seen in figure 1, the Chamorros and the Palauans live within 700 miles of each other and probably have common ancestry in the Malay Archipelago.<sup>4</sup> At present, however, they are both physically and culturally different. Many of the differences are related to the Spanish occupation of the Mariana Islands for over 300 years, and the use of Guam as a supply station for shipping. These led to both cultural change and genetic mixing on Guam and nearby islands, while the other areas of Micronesia remained relatively isolated.

In 1898, the United States acquired Guam. The Spanish sold the rest of the Mariana and Caroline Islands to Germany, which lost them to Japan in 1914. Japan developed these islands until World War II. In 1947, Guam became an official U.S. Territory, and the Mariana and Caroline Islands became part of the United Nations Trust Territory of the Pacific Islands under U.S. administration.

There are subgroups of these two populations which have experienced different degrees of exposure to modernization. Among the Chamorros, the people of the island of Rota have most nearly retained their traditional forms of social organization and agricultural economy. The natives of Guam have undergone a rapid change from their traditional way of life, especially following the establishment of U.S. military bases at the end of World War II. A third group of Chamorros, from Guam, has experienced an even greater change, in migrating to California.

In the Palau District, the inhabitants of Ngerchelung, an isolated village, still live a traditional, subsistence way of life. The people of Koror, the District

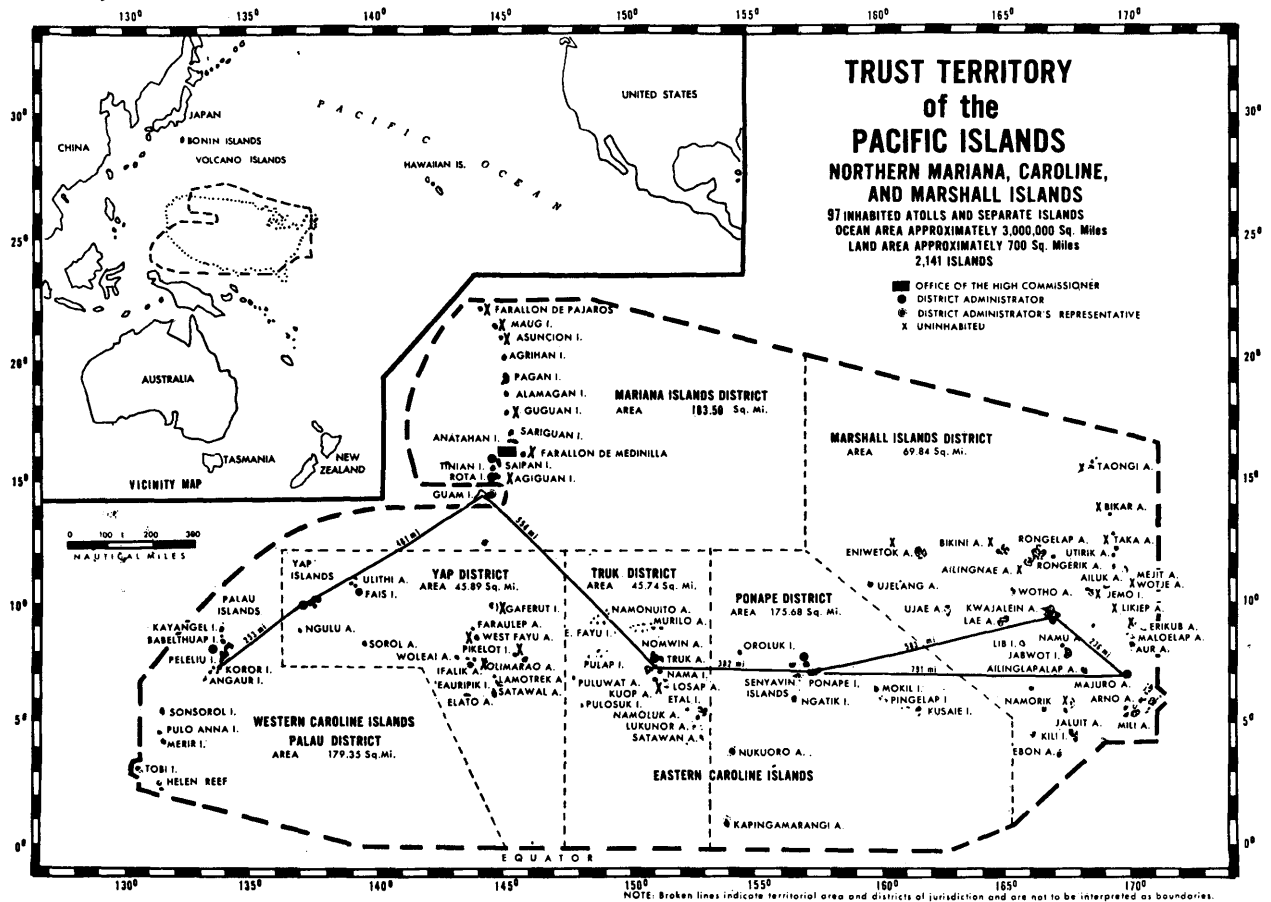


FIG. 1. Map of the Trust Territory of the Pacific Islands.

center, have been exposed to increasing modern influence during both the Japanese and the Trust Territory administrations. Between these two extremes were the inhabitants of Peleliu; while still dependent upon agriculture and fishing for subsistence, they often visited and worked part time in the District center.

**METHODS**

Detailed methods were described in the earlier reports.<sup>2,3</sup> Briefly, the study was completed in two phases. The Chamorros in Rota, Guam, and California, and the Palauans in Ngerchelung were examined between December 1967 and June 1968. The Palauans in Koror and Peleliu were examined in March and April of 1970. The examining physicians and equipment used were the same throughout the study, but a few interview items were changed for the second phase in Palau.

The sampling procedure was based upon household units. Where the population was small (Rota, California, and Ngerchelung), we included the total popu-

lation. Where the population was large, we selected a random sample of households; only persons twenty years of age and older in the selected households were examined.

As each examinee arrived at the examination site, we explained the procedure and served a carbonated drink containing 50 gm. of dextrose (Dextrose 50, USPHS), unless the person reported current treatment of diabetes. The subject was then interviewed concerning symptoms and illnesses, personal habits, sociocultural attitudes, and residential mobility. A nurse then measured height, weight, and triceps, and subscapular skinfolds. A standard 12-lead electrocardiogram (ECG) was then recorded and checked by an examining physician, who then completed a screening physical examination, and determined the casual sitting blood pressure.

A 15 ml. blood specimen was taken for all examinees approximately one hour after administration of the dextrose. Serum was separated about two hours after bleeding and kept frozen until shipment on dry ice to

the laboratory of the Heart Disease and Stroke Control Program in San Francisco. The laboratory used Technicon AutoAnalyzer methods to determine serum glucose values.<sup>5</sup>

We defined hyperglycemia in our samples taken one hour after a 50 gm. glucose challenge, as a serum glucose level of 205 mg./100 ml. Following the suggested conversion of McDonald et al.,<sup>6</sup> this is equivalent to a whole blood level of 170 mg./100 ml.

*Dietary survey*

To describe the dietary patterns of the subgroups, we selected random subsamples of approximately ninety persons in each of the six areas. A standard interview was developed to obtain a twenty-four-hour dietary recall from each person. Our nutritionist compiled composition values of food items in terms of total calories, protein, carbohydrate, and both saturated and polyunsaturated fat, as previously described.<sup>7</sup>

*Computations and scores*

The estimation of per cent body fat was calculated from an average of the triceps and subscapular skinfolds as proposed by Damon and Goldman.<sup>8</sup> A "symptom score" was derived from the number of positive answers to questions for histories of high blood pressure, paralysis, joint disease, numbness, angina pectoris, present health problems, limited activities, recent hospitalization, and medications.

Measures of sociocultural attitudes included a "food preference score" and a "traditional attitude score." Preference for traditional foods and attitudes received high scores while preference for Western foods and attitudes received low scores. Occupations were categorized as subsistence, blue collar and white collar, and scored from low to high in that order.

Geographic mobility was recorded both in terms of the number of residential changes during the previous five years, and the number of years a person had lived away from his village of birth.

For the second phase of the examination, we included a "modernization score" developed from the questionnaire of Smith and Inkeles,<sup>9</sup> and a "cultural mobility score" to represent a combination of occupational, geographic, and generational mobility.

**RESULTS**

Analyses reported elsewhere<sup>2,3</sup> supported our general impression of differences in the degrees of modernization among the geographic subgroups. All sociocultural indices, including preference for traditional attitudes and food, measures of geographic mobility, education, and occupation showed the Chamorros of California and

Guam to be more modern than those of Rota, and the Palauans of Koror to be more modern than those of Peleliu and Ngerchelung.

Table 1 shows the examined populations by age, sex, and area. We completed examinations for 1,214 Chamorros and 510 Palauans. Of the people selected for examination, the response ratios were 44 per cent in California, 74 per cent in Guam, 81 per cent in Rota, 81 per cent in Koror, 85 per cent in Peleliu, and 91 per cent in Ngerchelung. Because of the different age distributions, all group rates were age-adjusted to the 1968 Micronesian Trust Territory Population.<sup>4</sup>

Because of the low response rate in California, we completed the questionnaire part of the examination for 100 of the California Chamorros who did not respond to the examination. Age-specific comparisons of the questionnaire items for the examined and unexamined groups in California revealed no significant differences. The great majority of persons who did not respond in California lived more than twenty-five miles from the examination centers.

Figure 2 shows the percentage frequency distributions of the serum glucose values for the total Chamorro and Palauan groups by sex and three age groups. In the youngest age group, the distributions were similar for the two study populations. In the older age groups, the distributions for all but the Palauan females were increasingly skewed toward higher serum glucose values.

Table 2 and figure 3 show the mean serum glucose values by age, sex, and area. For all subgroups, the values increased with age. Among the Chamorros, the females had consistently higher values than the males;

TABLE 1  
Study population by age, sex, and area

Age group	Chamorros					
	Males			Females		
	Calif.	Guam	Rota	Calif.	Guam	Rota
20-29	21	61	24	31	94	38
30-39	44	56	29	38	61	33
40-49	57	59	23	50	72	25
50-59	33	50	26	21	68	32
60+	9	47	20	11	60	21
Total	164	273	122	151	355	149

Age group	Palauans					
	Males			Females		
	Koror	Peleliu	Nger.	Koror	Peleliu	Nger.
20-29	23	9	4	28	8	11
30-39	23	5	5	45	6	17
40-49	32	4	18	38	12	23
50-59	18	7	18	20	12	22
60+	13	16	24	14	19	16
Total	109	41	69	145	57	89

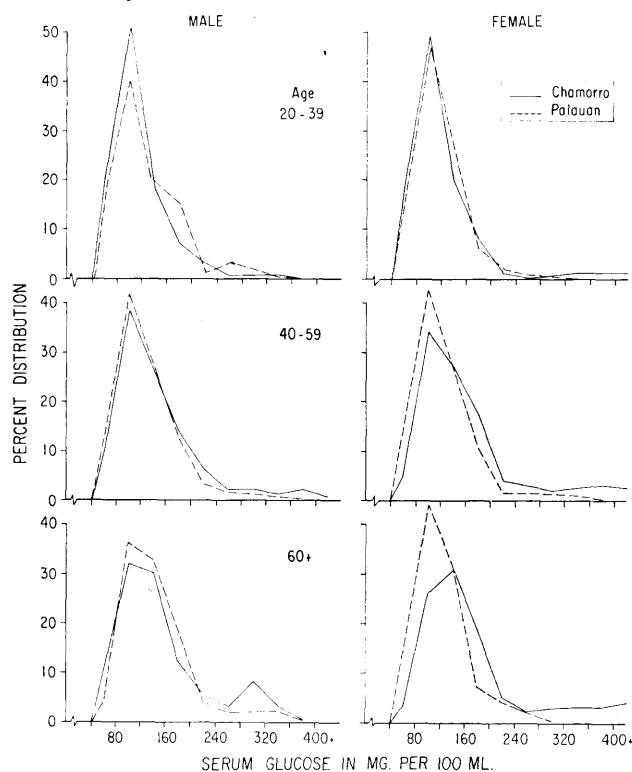


FIG. 2. Frequency distributions of serum glucose levels by age and sex.

for Paluans there was no consistent difference by sex.

The mean serum glucose values were generally higher

TABLE 2

Mean serum glucose values in milligrams per 100 milliliters by age, sex, and area

Chamorros						
Age group	Males			Females		
	Calif.	Guam	Rota	Calif.	Guam	Rota
20-29	100	106	96	104	114	97
30-39	119	121	111	123	124	121
40-49	136	139	115	139	149	159
50-59	150	165	118	190	195	155
60+	164	142	142	224	170	162
Age adjusted mean* ± 1 S.D.	128 ±63	129 ±69	113 ±43	145 ±67	142 ±71	132 ±65
Palauans						
Age group	Males			Females		
	Koror	Peleliu	Nger.	Koror	Peleliu	Nger.
20-29	115	104	86	108	99	112
30-39	152	110	105	124	112	109
40-49	129	103	119	115	107	136
50-59	143	110	143	143	118	132
60+	146	135	140	133	111	131
Age adjusted mean* ± 1 S.D.	135 ±57	111 ±35	113 ±43	122 ±48	108 ±27	121 ±51

\* Age adjusted to the 1968 Micronesian Trust Territory population.

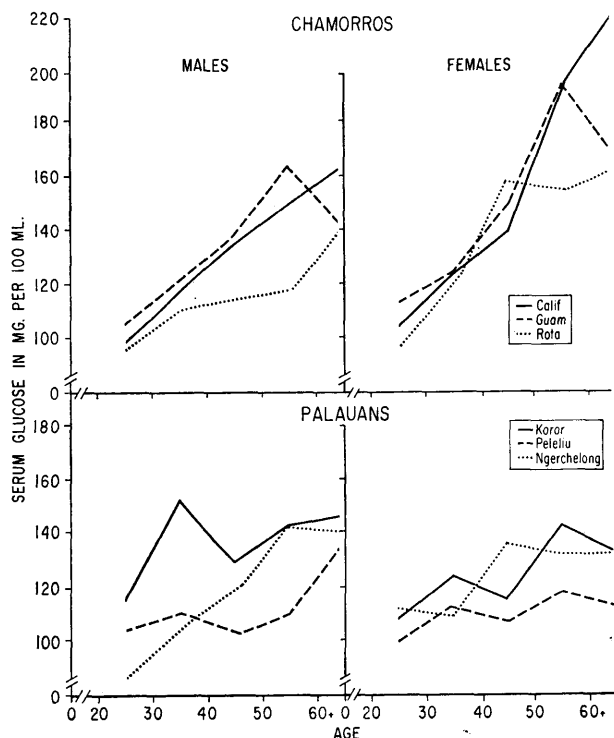


FIG. 3. Age-specific mean serum glucose levels by sex and area.

among the subgroups living in the more modern areas. Thus, the Chamorros in California and Guam had higher mean values than the Chamorros in Rota, and the Palauan males in Koror had higher mean values than the males in Peleliu and Ngerchelong. This pattern was not consistent for Palauan females: the mean value for Koror was higher than for Peleliu, but not for Ngerchelong.

Statistical tests of differences between means indicated that these differences would occur rarely by chance as shown by the following Z values: California vs. Rota males  $Z = 2.4$ ,  $P < 0.05$ ; Guam vs. Rota males  $Z = 2.8$ ,  $P < 0.05$ ; California vs. Rota females  $Z = 1.7$ ,  $P < 0.05$ ; Guam vs. Rota females  $Z = 1.5$ ,  $P < 0.07$ ; Koror vs. Peleliu males  $Z = 3.1$ ,  $P < 0.05$ ; Koror vs. Ngerchelong males  $Z = 3.2$ ,  $P < 0.05$ ; Koror vs. Peleliu females  $Z = 2.4$ ,  $P < 0.05$ .<sup>10</sup>

### Hyperglycemia

Table 3 shows the percentages of the study subjects with serum glucose levels of 205 mg./100 ml. or greater by age, sex, and area. The age-adjusted prevalence ratio of hyperglycemia was 10 per cent for the Chamorros and 5 per cent for the Palauans. Among the Chamorros the ratios generally increased with age, and were higher

TABLE 3

Percentages of subjects with serum glucose values of 205 milligrams per 100 milliliters or greater, by age, sex, and area

Age groups	Chamorros					
	Males			Females		
	Calif.	Guam	Rota	Calif.	Guam	Rota
20-29	0	3	0	0	3	0
30-39	5	9	3	8	7	3
40-49	11	14	0	12	17	16
50-59	21	16	4	29	25	12
60+	22	17	10	36	22	15
Mean*	10	10	3	14	13	8

Age groups	Palauans					
	Males			Females		
	Koror	Peleliu	Nger.	Koror	Peleliu	Nger.
20-29	4	0	0	0	0	0
30-39	13	0	0	4	0	6
40-49	6	0	11	0	0	13
50-59	17	0	6	15	0	5
60+	15	6	4	7	0	13
Mean*	10	1	4	4	0	7

\* Age adjusted to the 1968 Micronesia Trust Territory population.

for females than males. Among the Palauans there were no consistent differences by age or sex.

As with the mean serum glucose values, the frequency of hyperglycemia tended to be higher among the subgroups living in the more modern areas. For both males and females, the Chamorros in California and Guam had higher prevalence ratios than those in Rota (the Z values for tests of differences of proportions were 2.5 and 2.9 for males and 1.7 and 1.8 for females,

$P < 0.05$ ). The prevalence ratio for Koror males was similar to those of Chamorro males in the modern areas and was significantly higher than the ratios for Peleliu and Ngerchelong males (Z values of 2.7,  $P < 0.05$ , and 1.61,  $P < 0.06$ ). Among Palauan females, the prevalence ratio in Koror was higher than in Peleliu ( $Z = 2.4$ ,  $P < 0.05$ ) and lower than in Ngerchelong, although not significantly so ( $Z = .95$ ,  $P < 0.8$ ).

A history of diabetes was reported by eighty-five (7 per cent) of the Chamorros, of whom forty reported current treatment at the time of examination. In Palau, sixteen (3 per cent) of the subjects reported such a history, of whom eleven were taking medication. The age-adjusted prevalence ratio of hyperglycemia for the total group with a history of diabetes was 32 per cent, with little difference between those taking medication and those not.

The examination interview included questions concerning histories of hypertension, numbness, paralysis, joint disease, angina pectoris, hospitalization within one year, and present health problems. An age-adjusted comparison of subjects with and without hyperglycemia for positive responses to these questions revealed a significant difference only for a history of hypertension, which was reported by 22 per cent of those with hyperglycemia and 8 per cent of those without.

*Dietary survey*

Table 4 shows the mean total daily calories and nutrients as per cent of total calories by age and sex. For comparison, mean serum glucose and cholesterol

TABLE 4  
Comparison of mean total daily calories and nutrients as per cent of total calories with laboratory and examination findings, by sex and area

		Males							
		Mean serum glucose	Mean serum cholesterol	Mean per cent body fat	Mean total daily cal.	Per cent protein	Per cent carbohydrate	Per cent total fat	Per cent saturated fat
Chamorro	Calif.	128	213	18	2,421	15	43	42	16
	Guam	129	196	17	2,619	15	50	35	14
	Rota	113	187	21	2,905	15	60	25	10
Palauan	Koror	135	171	25	2,203	20	65	15	5
	Peleliu	111	163	18	1,836	19	60	21	7
	Nger.	113	148	14	2,262	16	58	26	14
		Females							
Chamorro	Calif.	145	211	22	1,611	16	41	43	16
	Guam	142	204	21	1,807	16	49	35	14
	Rota	132	202	30	1,963	15	56	30	11
Palauan	Koror	122	177	30	1,651	17	61	22	8
	Peleliu	108	174	27	1,637	20	64	16	6
	Nger.	121	171	18	1,853	15	57	28	14

\* All values have been age adjusted to the 1968 Micronesia Trust Territory population.

TABLE 5

Age partialled correlation coefficients of serum glucose values with selected characteristics by study groups and sex

Characteristics	Chamorros		Palauans	
	Males	Females	Males	Females
Age	.25*	.32*	.13*	.12*
Weight	.16*	.16*	.16*	.08
Triceps skinfold	.08	.04	.13*	.09
Subscapular skinfold	.08	.06	.16*	.09
Per cent body fat	.08	.05	.15*	.09
Systolic B.P.	.19*	.16*	.15*	.07
Diastolic B.P.	.13*	.16*	.13*	.07
Serum uric acid	.05	-.14*	-.02	.06
Serum cholesterol	.13*	.16*	.20*	.12*
Serum triglyceride	.16*	.23*	.24*	.17*
ECG abnormalities	.02	.03	.01	.02
Symptom score	.01	.04	.02	.04
Cigarettes per day	.01	.01	.06	-.04
Years of school	.04	.00	.09	.01
Years away birthplace	.03	-.12*	.09	.11
Number of places lived	.01	.07	-.04	.00
Traditional attitudes	-.03	-.03	-.02	-.11
Traditional food score	.03	.01	.04	.04
Occupation	.06	.01	.12	.04
Modernization score†	—	—	.20*	.03
Mobility score†	—	—	-.08	.04

\* The magnitude of these coefficients in relation to the sample size have probability values of less than 0.05.

† Not available for the Chamorros.

levels, and calculated mean per cent body fat have been included. The Chamorros of California and Guam reported intakes similar to the "Western type" diet, being relatively high in animal and saturated fat, and low in carbohydrate. In contrast, the Chamorros of Rota and the Palauans reported intakes which were relatively high in carbohydrate and low in fat. There was little variation in the percentages of calories derived from protein, however; the protein source was generally meat in California and Guam, and fish in Rota and Palau.<sup>7</sup> Coconut oil accounted for much of the fat intake in Ngerche-long.

Comparison of reported nutrient intakes with serum glucose and cholesterol levels revealed a general pattern. Those subgroups with relatively high fat (30 per cent or more of total calories) and low carbohydrate intakes had the highest levels of both serum glucose and cholesterol. The Koror males were the one exception, for although they had the highest mean serum glucose level and a higher serum cholesterol level than other Palauan males, they had the lowest reported fat intake.

There was no consistent association of reported dietary intakes with the measure of per cent body fat, nor of total daily calories with serum glucose or cholesterol levels.

*Correlation analysis*

Associations between serum glucose values and other variables tabulated by geographic groupings are difficult to interpret because the group characteristics may not reflect individual experience. We therefore examined the relationships of serum glucose levels and other variables as characteristics of individuals by means of correlation analysis. Table 5 shows the resulting correlation coefficients for all Chamorros and all Palauans by sex. The effect of age upon all variable pairs except the age-serum glucose pair, has been removed by partial correlation. Those coefficients which had a probability of 0.05 or less of occurring by chance were starred.

Serum glucose was positively associated with age, blood pressure, serum cholesterol and triglyceride levels, and body weight for most groups. The correlations with what we considered more specific measures of obesity, the skinfold measurements and calculated per cent body fat, were not consistent. There was no meaningful association with ECG abnormalities, the symptom score, or cigarette use.

Among the sociocultural items, there was no consistent association with any of the measures of education, occupation, traditional attitudes, or residential mobility. Thus, the tendency for the serum glucose values

to be higher in the more modern geographic areas could not be explained by any of the sociocultural measures we used.

For further examination of the interaction of the variables listed on table 5, stepwise multiple regression analyses were done.<sup>11</sup> These analyses indicated that for Chamorro males, the variables which gave significant independent contributions were, in order, age, systolic blood pressure, weight and low uric acid (multiple R = 0.357). For Chamorro females the variables were age, low uric acid, systolic blood pressure and cholesterol (multiple R = 0.391). For Palau males the variables were cholesterol, triglyceride, systolic blood pressure and low traditional food preference score (multiple R = 0.368). For Palau females the variables were cholesterol, low uric acid, triglyceride and low traditional food preference score (multiple R = 0.343).

For each subgroup, these were the variables which best "explained" the variation in observed serum glucose levels. The only one which would not be expected from the correlation analysis was the low traditional food preference score among Palauans.

DISCUSSION

To date, epidemiologic studies of diabetes have reflected a variety of methods, each having its own sampling technic, test methods, and diagnostic criteria. Comparisons, therefore, must be crude in nature, and subject to cautious interpretation.

The U.S. Public Health Service survey reported by Gordon used a one hour, 50 gm. glucose test.<sup>12</sup> Comparison with our results, converted to blood glucose levels,<sup>6</sup> indicated that the age-specific mean values for the U.S. sample were slightly higher than the values we found for the Guamanian and California Chamorros. Thus, the values for the Rota Chamorros and the Palauans, except for the Koror males, were 10 to 30 mg./100 ml. lower than the U.S. sample values.

The age-specific mean levels reported in the Tecumseh study,<sup>13</sup> which used a one hour, 100 gm. glucose test, were 20 to 30 mg./100 ml. higher than those reported by Gordon, and thus higher than the values for all of our study groups. Our frequency distribution curves were similar to those reported for both the U.S. sample and the Tecumseh study.

From these comparisons, the clinical impression held on Guam that the Chamorros have an unusually high prevalence of hyperglycemia was not supported.<sup>14</sup>

On the other hand, the native peoples of the Pacific have often been reported to have a higher prevalence of "diabetic abnormalities" than Caucasians living in the same area. Prior and Davidson reported studies on New Zealand and Cook Islands Maoris and New Zealand Europeans.<sup>15</sup> Their detection methods included Test-Tape urine analysis, followed by glucose tolerance tests for everyone with glycosuria. Diabetic abnormality was defined as a fasting blood sugar of 120 mg./100 ml. or more, and a two-hour level of 130 mg./100 ml. or more.

The prevalence of diabetic abnormality for males and females, respectively, were 9.2 and 7 per cent for New Zealand Maoris, 4.5 and 3.9 per cent for town-dwelling Rarotongans, 0.5 and 2.1 per cent for the isolated Pukapukans, and 1.5 and 3.9 per cent for New Zealand Europeans. The authors reported that the differences between these groups could best be explained by the differences in caloric intakes in relation to energy expenditures and the resulting extent of obesity. The urban-dwelling Maoris had high caloric intakes and a high prevalence of obesity compared to the Pukapukans, while the Rarotongans were midway between the two. The Europeans had little obesity.

This explanation was similar to that reported by West and Kalbfleisch in their studies of diabetes in South America, Malaya, and East Pakistan.<sup>16</sup>

Sloan reported a study of the prevalence of diabetes among different ethnic groups in Hawaii.<sup>17</sup> The method of detection included a blood specimen taken two-and-one-half hours after a meal containing at least 50 gm. of carbohydrate. Diabetes was defined as a blood glu-

cose level above 130 mg./100 ml. The prevalence ratios were approximately 4.9 per cent among Hawaiians, and 0.7 per cent among Caucasians, while the ratios for Filipinos, Japanese and mixed ethnic groups were intermediate.

Thus, these two studies suggested that Hawaiians and Maori Polynesians have higher ratios of diabetes than do Caucasians living in the same areas. The prevalence ratios of hyperglycemia found in our study of Micronesians were comparable to the highest reported for the Maoris and Hawaiians, and yet the distributions of glucose values by age were lower than those reported for U.S. samples. Such discrepancies could be due to methodologic differences, and other explanations would be pure speculation.

A more appropriate focus for discussion is upon the differences among the geographic subgroups in the present study, especially the tendency for serum glucose values to be higher in the more modern areas. This finding was consistent with the reports of diabetes among the Maoris,<sup>15</sup> and in the four countries studied by West and Kalbfleisch.<sup>16</sup>

Modernization implies a number of changes which could theoretically contribute to a diabetic abnormality. Individuals become involved in occupations requiring less physical activity, dietary intakes include a higher proportion of animal fat and protein and a lower proportion of carbohydrate, and the discontinuity between new and traditional life styles may lead to stressful conflict. It is difficult to distinguish meaningful associations in an analysis by geographic area for, as noted by West and Kalbfleisch, one can find a high correlation between the prevalence of diabetes and the number of telephones per capita.<sup>16</sup>

The correlation analysis of individual characteristics, however, offered a means of determining the effect of having modern attributes, in contrast to being in an area where modern attributes were common. In that analysis there was little association between serum glucose levels and those cultural variables which measured modernization (including occupation, education, geographic mobility, and measures of attitudes about traditional values). In the first phase of this study, we also included the twenty questions developed by Leighton for physiological symptoms which commonly occur as a response to stress.<sup>18</sup> There was little correlation between this stress scale and serum glucose levels.<sup>2</sup>

The most interesting patterns we observed were the interrelations among measures of glucose, lipids, and obesity. In addition to the correlations of serum glu-

cose levels with serum cholesterol and triglyceride levels, and with body weight (shown in table 5), separate analysis showed high correlation among the measures of obesity and serum lipid levels.<sup>2,3</sup>

While the observations by geographic subgroup must be viewed cautiously, it is interesting to note that they were in general agreement with the correlation findings. Among the Chamorros, the people of California and Guam had higher intake of fat, higher serum lipid levels<sup>2,3</sup> and higher serum glucose levels than the people of Rota. Among the Palauan subgroups, the females of Koror and Ngerchelung had higher fat intakes, higher serum lipid levels<sup>3</sup> and higher serum glucose levels than the females of Peleliu. Although the males of Koror reported low fat intake, they had higher serum lipid levels<sup>3</sup> and higher serum glucose levels than the males of Peleliu and Ngerchelung.

These observations that high serum glucose levels, high serum lipid levels, and obesity are somehow inter-related, are also in general agreement with the recent review of nutritional factors and diabetes in eleven different countries.<sup>19</sup>

While no cause and effect conclusions can be drawn from survey data, a tentative ordering of the observations suggests clues for future studies. The most direct interpretation of our observations in Micronesia is as follows. Part of the ongoing course of modernization has included a transition from the traditional diet to a Western type diet, proportionally higher in animal and saturated fats. Excess intakes of such a diet were reflected in increased serum glucose and lipid levels, and obesity. Whether or not this is the correct order, the clustering of these variables has unfavorable implications in the broad concern of the development of diabetes and atherosclerotic disease.

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#### REFERENCES

- <sup>1</sup> WHO Technical Report Series: Diabetes Mellitus, No. 310, 1965.
- <sup>2</sup> Reed, D. M., Labarthe, D. R., and Stallones, R. A.: Health effects of westernization and migration among Chamorros. *Am. J. Epidemiol.* 92:94-112, Aug., 1970.
- <sup>3</sup> Labarthe, D. R., Reed, D. M., and Stallones, R. A.: Health effects of modernization among Palauans. Submitted for publication.
- <sup>4</sup> Trust Territory of the Pacific Islands. Washington, D.C., U.S. Government Printing Office, 1968.
- <sup>5</sup> Hoffman, W. S.: A rapid photoelectric method for the determination of glucose in blood and urine. *J. Biol. Chem.* 120:51-55, 1937.
- <sup>6</sup> McDonald, G. W., Fisher, G. F., and Burnham, C. E.: Differences in glucose determinations obtained from plasma or whole blood. *Public Health Reports* 79:515-21, June, 1964.
- <sup>7</sup> Hankin, J. H., Reed, D. M., Labarthe, D. R., Nichaman, M., and Stallones, R. A.: Dietary and disease patterns among Micronesians. *Am. J. Clin. Nutr.* 23:346-57, Mar., 1970.
- <sup>8</sup> Damon, A., and Goldman, R. F.: Predicting fat from body measurements: Densitometric validation of ten anthropometric equations. *Hum. Biol.* 36:32-44, Feb., 1964.
- <sup>9</sup> Smith, D. H., and Inkeles, A.: The OM Scale: A comparative socio-psychologic measure of individual modernity. *Sociometry* 29:353-77, 1966.
- <sup>10</sup> Remington, R. D., and Schork, M. A.: *In Statistics with Applications to the Biological and Health Sciences*. Ch. 8. Englewood Cliffs, Prentice-Hall, 1970.
- <sup>11</sup> BMD Biomedical Computer Programs, Dixon, W. J., Ed. Berkeley, Univ. of Calif. Press, 1970.
- <sup>12</sup> Gordon, T.: Glucose Tolerance of Adults, United States, 1960-62: Diabetes Prevalence and Results of Glucose Tolerance Tests, by Age and Sex. *Vital and Health Statistics*, Ser. 11, No. 2. Washington, D.C., U.S. Govt. Printing Office, 1964.
- <sup>13</sup> Hayner, N. S. et al.: Carbohydrate tolerance and diabetes in a total community, Tecumseh, Michigan. *Diabetes* 14: 413-23, July, 1965.
- <sup>14</sup> Kovacs, J.: *In Abnormal Carbohydrate Metabolism and Pregnancy*, Yen, S. C. *Am. J. Obstet. Gynecol.* 90:468-73, Oct., 1964.
- <sup>15</sup> Prior, I. A., and Davidson, F.: The epidemiology of diabetes in Polynesians and Europeans in New Zealand and the Pacific. *NZ Med. J.* 65:375-83, June, 1966.
- <sup>16</sup> West, K. M., and Kalbfleisch, J. M.: Glucose tolerance, nutrition and diabetes in Uruguay, Venezuela, Malaya, and East Pakistan. *Diabetes* 15:9-18, Jan., 1966.
- <sup>17</sup> Sloan, N. R.: Ethnic distribution of diabetes mellitus in Hawaii. *JAMA* 183:419-24, Feb., 1963.
- <sup>18</sup> Leighton, A. et al.: *Psychiatric Disorder Among the Yoruba*. Ithaca, Cornell Univ. Press, 1963.
- <sup>19</sup> West, K. M., and Kalbfleisch, J. M.: Influence of nutritional factors on prevalence of diabetes. *Diabetes* 20:99-108, Feb., 1971.