High Prevalence of NIDDM and Impaired Glucose Tolerance in Indian, Creole, and Chinese Mauritians

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Mauritius, a multiethnic island nation in the southwestern Indian Ocean, has one of the world's highest diabetes mortality rates. The prevalence of both impaired glucose tolerance (IGT) and non-insulin-dependent diabetes mellitus (NIDDM) was investigated in 5080 Muslim and Hindu Indian, Creole (mixed African, European, and Indian origin), and Chinese Mauritian adults aged 25–74 yr who were selected by random cluster sampling. Based on a 75-g oral glucose tolerance test and World Health Organization criteria, the age-standardized prevalence of IGT was significantly greater in women (19.7%, 95% confidence interval [CI] 18.1–21.2) than in men (11.7%, CI 10.5–12.8). By contrast, the prevalence of NIDDM was similar in men (12.1%, CI 10.9–13.4) and women (11.7%, CI 10.5–12.8) for all ethnic groups combined. The sex difference in IGT prevalence was seen in all ethnic groups, but for NIDDM, the sex difference was not consistent across ethnic groups. However, age- and sex-standardized prevalence of IGT and NIDDM was remarkably similar across ethnic groups (16.2 and 12.4% in Hindu Indians, 15.3 and 13.3% in Muslim Indians, 17.5 and 10.4% in Creoles, and 16.6 and 11.9% in Chinese, respectively). Three new cases of diabetes were diagnosed for every two known cases. The high prevalence of abnormal glucose tolerance in Indian subjects is consistent with studies of other migrant Indian communities, but the findings in Creole and, in particular, Chinese subjects are unexpected. Potent environmental factors shared between ethnic groups in Mauritius may be responsible for the epidemic of glucose intolerance. *Diabetes* 39:390–96, 1990

The prevalence of both non-insulin-dependent diabetes mellitus (NIDDM) and impaired glucose tolerance (IGT) varies considerably between populations. This variability has been attributed to differences in genetic susceptibility, population age structure, degree of socioeconomic development, diet, level of risk factors (e.g., obesity and physical activity), and study methodology (1). Widespread use of similar diagnostic criteria recommended by the World Health Organization (WHO; 2) and the National Diabetes Data Group (NDDG; 3) over the last decade has allowed the prevalence of glucose intolerance to be compared between populations with greater accuracy (1). Such comparisons have been important in the development and testing of hypotheses regarding the relative importance of genetic and environmental risk factors for glucose intolerance.

Certain ethnic groups, particularly North American Indians (4,5), Mexican Americans (6), Australian Aborigines (7), Micronesian and Polynesian Pacific Islanders (8–10), and migrant Asian Indians (11–14), are highly susceptible to developing glucose intolerance when their life-style changes from a traditional to a more developed Western pattern (1). Less is known about the susceptibility of other ethnic groups.

The southern Indian Ocean island of Mauritius is populated by Asian Indian, Creole (mixed African, European, and Indian), and Chinese ethnic groups. Since World War II, Mauritius has experienced a rising standard of living associated with industrialization. There has been a marked change in the mortality profile from predominantly infectious to chronic noncommunicable diseases (15). Concerned by this phenomenon, the government of Mauritius has launched a Noncommunicable Disease Intervention Program aimed at the prevention and control of these diseases. A baseline study of disease and risk-factor prevalence formed the initial phase

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of the program. This first report describes the prevalence of IGT and NIDDM in this multiethnic community.

RESEARCH DESIGN AND METHODS

Mauritius. The subtropical island of Mauritius (1864 sq km) is situated in the southwestern Indian Ocean at latitude 20° S and longitude 57° 30′ E, ~800 km east of Madagascar. Originally uninhabited, the island was first settled by the Dutch in 1638 and passed through lengthy periods of French and British rule before attaining independence in 1968. The ethnic composition of the population reflects its history: French settlers brought African slaves from Madagascar and the African mainland (mostly West Africa) to work in the sugar plantations; the British ceased this practice but introduced indentured laborers from India (Madras, Bombay, and Calcutta areas) in 1834. Seventy percent of the population is of Indian origin (53.6% Hindu and 16.4% Muslim), 2.1% are Chinese, and 27.9% are of the general population, which mainly comprises people with mixed African, European, and Indian ancestry (Creoles). The gross national product per capita is approximately U.S.$1200, and the past 3 decades have witnessed considerable economic growth associated with industrialization. Most overseas earnings are derived from sugarcane production, tourism, and textile manufacture.

The total population of just over 1 million people enjoy reasonable standards of health. In 1986, the infant mortality rate was 26.3/1000 live births, and diseases of the circulatory system comprised 44.5% of total deaths. In the period between 1982 and 1986, there was a dramatic threefold rise in deaths attributed to diabetes mellitus (DM) from 13.4 to 43.6 deaths/100,000 population (2.0 and 6.5% of total deaths, respectively).

Sampling and response. The target population for the survey was Mauritian adults between the ages of 25 and 74 yr. A two-stage cluster-sampling scheme based on existing census divisions was used to randomly select (with probability proportional to size) 10 areas, each with a population of between 500 and 600 subjects. All adults aged 25–74 yr living within the study areas were included in the sample. Because of the small proportion of ethnic Chinese in the population and their uneven distribution across the country, a specific area of the capital city Port Louis, known to have a high density of Chinese residents, was selected to increase the number of Chinese in the sample. Hence, 11 areas were enumerated.

Among those eligible to participate (5892 individuals), the response rate was 83.4% for men and 88.9% for women. The response rate was high in both Hindu (90.4%) and Muslim (89.1%) Indians, moderate in Creoles (80.4%), and relatively low in Chinese (77.6%). The random sample and random-sample responder populations (excluding the extra Chinese sample) closely mirrored the actual distribution of age and ethnic groups in Mauritius. With the extra Chinese sample included, the Chinese were proportionately overrepresented (8.2 vs. 2.1% in the total population). Comparison of socioeconomic characteristics and medical history data did not reveal major differences between responders and nonresponders, suggesting that prevalence estimates determined from this survey are probably reliable for the 25- to 74-yr-old population of Mauritius.

Oral glucose tolerance test (OGTT) procedure. The study was conducted over a 4-wk period during April and May 1987, with two teams working concurrently at different survey sites. Strict standardization of methodology was sought through pretraining and in-survey checks. All eligible subjects in each of the defined census areas were given appointments to attend a central survey site near their homes between 0800 and 1000 after an overnight fast. Subjects who did not report a history of DM had an oral glucose load consisting of 75 g of glucose monohydrate dissolved in 250 ml of water. Individuals currently taking either insulin or oral hypoglycemic therapy did not have an OGTT. Reported diabetic subjects not on pharmacological treatment had a fasting glucose level determined immediately on whole blood. If this value was ≥7.8 mM, the diagnosis was accepted, and they were not submitted to an OGTT; if the value was <7.8 mM, they proceeded with the test.

Blood for glucose determination was collected into heparinized fluoridated tubes directly preceding and 2 h after glucose ingestion. These specimens were centrifuged immediately, and plasma glucose was determined on site within 3 h with a YSI glucose analyzer (Yellow Springs, OH), which uses a glucose oxidase method (16). Rigorous quality-control procedures for glucose measurement were followed throughout the survey. The two YSI machines were calibrated with high and low standard solutions after every 10th sample, and standard Sugar-Chex (Alpha, Eastleigh, UK) solutions of low, medium, and high glucose concentration were assessed three times each day (coefficient of variation [C.V.] 3.4 and 5.0%, 4.5 and 2.0%, and 3.3 and 2.2%, respectively for 2 operators). Every 10th specimen was assayed in duplicate in the field (C.V. 1.1% for fasting and 0.9% for 2-h samples) and subsequently on stored plasma by YSI analyzer (r = 0.995, mean difference 0.22 mM, NS) and autoanalyzer (r = 0.985, mean difference 0.008 mM, NS) in Newcastle upon Tyne.

Classification of glucose tolerance. This was based on current WHO criteria modified for epidemiological studies (2). Subjects reporting a history of DM had known DM if they were currently taking oral agents or insulin or if they had a fasting plasma glucose (FPG) ≥7.8 mM or a 2-h plasma glucose (2PG) ≥11.1 mM. New diabetic subjects were those without a history who had 2PG ≥11.1 mM. One subject with a missing 2PG value and an FPG of 15.3 mM was classified as diabetic. IGT was defined by 2PG ≥7.8 and <11.1 mM together with FPG <7.8 mM. Subjects with normal glucose tolerance (NGT) had both FPG and 2PG <7.8 mM.

There were 4931 subjects with classifiable glucose tolerance after excluding 39 individuals with missing 2PG, 47 subjects who were ≥15 min late for the 2PG, 1 subject whose fasting time was <8 h, 18 subjects with FPG ≥7.8 mM and 2PG <11.1 mM, and 44 pregnant women.

Statistical methodology. For this study, basic descriptive statistics are presented. Age-standardized prevalence and associated 95% confidence intervals (CIs) were calculated by the direct method (17) with the total and sex-specific Mauritian population estimated for 30 June 1986. Because there are many potential statistical comparisons within and between age, sex, and ethnic-group subcategories, we preferred not to perform individual tests of significance. The

95% CIs afford a conservative indication of significant differences between particular observations.

RESULTS

Prevalence of glucose intolerance. The overall crude prevalence of DM in the total sample was 12.8% (12.9 and 12.8% in men and women, respectively) and of IGT was 17.3% (14.1 and 20.1%). Prevalence calculated for the random sample alone (excluding the extra Chinese sample) was almost identical: 12.6% for DM and 17.1% for IGT overall. The age- and sex-adjusted national prevalence was 11.9% for DM and 16.6% for IGT (Table 1).

Of 275 subjects with known diabetes, 19 were currently receiving insulin therapy. Of these, only 2 reported onset of their diabetes before 30 yr of age (22 and 29 yr). Although further information to distinguish between IDDM and NIDDM in these 19 cases is not available, it is more than likely that most, and possibly all, have NIDDM. Thus, this survey suggests that NIDDM constitutes somewhere between 97 (619 of 638 cases) and 100% of all cases of diabetes (known and newly detected) in Mauritian adults.

Age standardized to the total population structure, 25.6% of men and 31.4% of women in Mauritius aged 25–74 yr were estimated to have abnormal glucose tolerance (IGT and DM combined). The age-standardized prevalence of IGT for all ethnic groups combined was significantly lower in men (13.5%, CI 12.2–14.9) than in women (19.7%, CI 18.1–21.2). This sex difference in IGT prevalence was seen in all ethnic groups. By contrast, the overall age-standardized prevalence of DM was similar in men (12.1%, CI 10.9–13.4) and women (11.7%, CI 10.5–12.8) in the four ethnicities combined, but the pattern was not consistent across the ethnic groups. Hindu and Chinese men had a higher prevalence than their female counterparts, whereas the rates were similar in Muslims; Creole men (7.7%, CI 5.7–9.7) had a significantly lower prevalence than Creole women (13.0%, CI 10.8–15.3).

There were no major differences in age-standardized (within each sex) or age- and sex-standardized prevalence of IGT between ethnic groups. The prevalence of IGT was almost identical in women of all four ethnic groups, varying from 19.3 in Chinese to 19.7% in Hindus. In men, rates varied from 11.1 in Muslims to 15.4% in Creoles. The age-standardized prevalence of DM was also more constant in women, varying from 9.5 in Chinese to 13.8% in Muslim Indians. In men, however, Creoles (7.7%, CI 5.7–9.7) had a significantly lower prevalence than Hindus (14.0%, CI 12.1–15.8). The age- and sex-standardized prevalence of DM did not show any major interethnic difference, varying from 10.4% in Creoles to 13.3% in Muslim Indians, with intermediate rates in Hindu Indian and Chinese subjects.

The overall prevalence of abnormal glucose tolerance (IGT and DM combined) was similar across ethnic groups within both sexes (Table 1). The age-specific prevalence of DM rose with age in all ethnic groups and both sexes, except in Muslim men, who showed a decline in the older age group, and in Hindu women, for whom the prevalence leveled off. For all ethnic groups, 52.0% of men and 57.7% of women aged 65–74 yr had either IGT or DM.

The prevalence of DM determined with WHO criteria (with some modifications) in other populations was compared with results from Mauritius (Table 2). Prevalence was standardized to the Mauritius age distribution, except for the studies in Chinese, in which it was necessary to standardize to original survey populations. Results for Mauritian Indians are similar to those of migrant Indians in Fiji and an urban population in South India. Prevalence in Mauritian Creoles is markedly higher than that seen in rural Tanzanians but is of similar magnitude to that seen in the Creole population of Surinam and in U.S. Blacks. The prevalence in Chinese Mauritians is considerably higher than that seen in Chinese from Singapore and Taiwan.

Case ascertainment. For every 10 known cases of DM, there were 14 men and 13 women who were newly diagnosed during the survey (Table 3). In subjects aged 25–34 yr, the ratio was 3.0 and 7.7 in men and women, respectively, indicating a considerable reservoir of undiagnosed cases. The proportion of total cases who were known increased with age, although it declined again in elderly men. Ascertainment was most complete in Muslims, with a ratio of 1.1 in new to known cases for both men and women. Hindus, with ratios of 1.6 in men and 1.3 in women, contributed most to the population pool of undiagnosed cases, whereas Creole men (1.5) and Chinese women (1.9) also had low rates of case ascertainment.

Treatment and control. Of 302 subjects who reported that they had DM, 90.7% were confirmed as cases because of diagnostic plasma glucose values and/or current oral hypoglycemic or insulin treatment. Of the remainder who were not on treatment, 4% had IGT, and 5.3% had NGT.

In the total sample, 82.9 and 84.5% of confirmed diabetic men and women, respectively, were currently on pharmacological treatment. The lowest proportion was seen in Creoles (75.0% of men and 80.8% of women). Of those on treatment, 36.3% of men and 38.4% of women had FPG values $\geq$11.1 mM. The Hindu and Creole groups had the highest proportion of poorly controlled treated diabetic subjects (40.7 and 38.6%, respectively) as opposed to Muslims (30.6%) and Chinese (30.8%).

DISCUSSION

This study demonstrated a high prevalence of glucose intolerance in all three major ethnic groups in Mauritius. The overall age- and sex-standardized prevalence of 16.6% for IGT and 11.9% for DM (almost exclusively NIDDM) in adults aged 25–74 yr represent the highest national rates reported, except for the small nation of Nauru (8). As in other population studies (8,18), there is a considerable reservoir of undetected diabetic subjects in Mauritius—~60% of total cases. The ratio of new to known cases declined with increasing age, probably due to the development of symptomatic disease and greater case finding in older age-groups. The age, sex, and ethnic differences in case ascertainment and control of DM may reflect differences in access to and quality of medical care received and in culturally determined response to illness and compliance with treatment. The relatively high prevalence of DM in the 25- to 34-yr age-group (3% in both sexes) indicates the severity of the NIDDM epidemic in Mauritius.

The prevalence of NIDDM in Indian subjects is similar to that in migrant Asian Indian populations in Fiji (11), South Africa (13), and Surinam (14). The prevalence of known DM

TABLE 1
Age-specific and standardized prevalence (%) of impaired glucose tolerance (IGT) and diabetes mellitus (DM) in Mauritius by sex and ethnic group

	Hindu			Muslim			Creole			Chinese			Total		
	n	IGT	DM	*n*	IGT	DM	*n*	IGT	DM	*n*	IGT	DM	*n*	IGT	DM
Men (age in yr)															
25–34	422	6.2	4.3	110	8.2	3.6	190	7.9	0.5	42	4.8	2.4	764	6.8	3.1
35–44	356	17.1	12.9	96	14.6	4.1	126	17.5	7.9	43	9.3	14.0	621	16.3	10.6
45–54	208	14.4	24.5	57	10.5	28.1	108	16.7	13.0	48	25.0	20.8	421	15.7	21.6
55–64	152	17.1	23.7	29	3.4	34.5	107	24.3	11.2	45	26.7	24.4	333	19.5	20.7
65–74	83	19.3	27.7	13	30.8	15.4	48	29.2	27.1	31	25.8	35.5	175	24.0	28.0
All ages	1221	13.0	14.3	305	11.1	11.8	579	16.4	8.6	209	18.2	18.7	2314	14.1	12.9
Age-standardized prevalence		12.6	14.0		11.1	12.7		15.4	7.7		13.6	13.5		13.5	12.1
95% CI		10.8–14.5	12.1–15.8		7.6–14.6	9.0–16.4		12.5–18.3	5.7–9.7		9.2–17.9	9.4–17.7		12.2–14.9	10.9–13.4
Women (age in yr)															
25–34	464	14.9	3.4	138	18.1	2.2	218	15.6	2.8	43	14.0	2.3	863	15.5	3.0
35–44	367	20.7	7.6	96	18.8	8.3	158	18.4	12.0	54	20.4	7.4	675	19.9	8.7
45–54	217	21.7	15.2	63	19.0	15.9	137	22.6	21.2	44	27.3	9.1	461	22.1	16.5
55–64	160	24.4	25.6	46	23.9	37.0	142	25.4	23.9	29	24.1	20.7	377	24.7	26.0
65–74	114	28.9	25.4	23	21.7	47.8	72	27.8	33.3	30	16.7	36.7	239	26.4	31.4
All ages	1322	20.0	11.1	366	19.4	13.4	727	20.6	15.4	200	20.5	13.0	2615	20.1	12.8
Age-standardized prevalence		19.7	10.9		19.5	13.8		19.6	13.0		19.3	9.5		19.7	11.7
95% CI		17.6–21.8	9.3–12.5		15.4–23.5	10.5–17.0		16.7–22.5	10.8–15.3		13.6–25.0	5.9–13.2		18.1–21.2	10.5–12.8
Total															
Age- and sex-standardized prevalence		16.2	12.4		15.3	13.3		17.5	10.4		16.4	11.5		16.6	11.9
95% CI		14.8–17.6	11.2–13.6		12.6–17.9	10.9–15.8		15.4–19.5	8.9–11.9		12.8–20.0	8.8–14.3		15.6–17.6	11.1–12.8

CI, confidence interval.

TABLE 2
Age-standardized comparisons of diabetes prevalence with other studies

	Age range (yr)†	Prevalence (%)*			Ref.
		Men	Women	Both	
Standard: Mauritius total population 1986					
Indians					
Mauritius					
Hindu	25–74	14.0	10.9		
Muslim		12.7	13.8		
Fiji					
Rural	25–74	15.4	11.9		11
Urban		16.4	15.7		
South India, Urban	25–74	10.3	12.3		26
African origin					
Mauritius, Creole	25–74	7.7	13.0		
Surinam, Creole	30–79	4.8	10.9		14
USA, Black	20–74	7.6	10.0		18
Tanzania, Rural	25+	1.1	0.9		19
European origin					
USA, White	20–74	4.5	6.0		18
Standard: Taiwan survey population					
Chinese					
Mauritius	40+			23.0	
Taiwan					
Rural	40+			5.1	30
Urban				8.1	
Standard: Singapore survey population					
Chinese					
Mauritius	30+	14.7	10.7		
Singapore	30+	6.0	5.4		32

*All estimates based on WHO criteria, although refs. 30 and 32 will be underestimates because of use of screening tests before oral glucose tolerance test.
†Because of differences in age groupings, some minor extrapolations were necessary during standardization.

is also similar to that found in Indians living in the United Kingdom (20). Migrant Indian populations have consistently had much higher prevalence of NIDDM than both their ethnic cohabitants (11,12,14,20–22) and Indians in India (23,24). Recent data from India indicate, however, that rates there are either rising or may have been underestimated in the past (25,26).

Along with genetic factors (27), durable Indian life-style habits (in particular, diet) may be invoked to explain their susceptibility to glucose intolerance. The higher rates in migrant populations may be related to loss of protective factors (e.g., high levels of habitual physical activity) rather than adopted environmental risks. This notion is supported by findings in migrant Indians in Fiji, where physically active individuals had around half the risk of DM of those who were physically inactive (28).

Studies in China (29) and in Singaporean Chinese (21) have shown low rates of glucose intolerance. The high prevalence found in this study is surprising. Indian or other genetic admixture is probably not responsible because the Mauritian Chinese remain a close community, and there has been no appreciable intermarriage with other groups. Most Chinese immigration to Mauritius took place in the early part of this century, and the Chinese community currently numbers ~21,000. Coupled with traditional restrictions on marriage between related individuals, a founder effect is unlikely. Moreover, the similarity of socioeconomic characteristics and disease rates reported by responding and nonresponding Chinese suggests that response bias cannot explain this high prevalence. This study, recent reports of moderately high prevalence in middle-aged and elderly Chinese in Taiwan (30) and Hong Kong (31), and reports of a rising prevalence in Singaporean Chinese (32) indicate that perceptions of Chinese having low genetic susceptibility (12) to glucose intolerance are not correct.

Little population-based prevalence data are available for native Africans. Based on results from South Africa (22), Tanzania (19,33), and Mali (34), African susceptibility does not appear to be high, but these populations were not affluent. Moderately high rates are seen in people of African origin in the United States (18), the United Kingdom (35), and the Carribean (36), although the extent to which this may be due to admixture with other races is unclear. Mixed-race Creoles (predominantly descended from Africans) of Surinam (14) have also been found to have a high prevalence of glucose intolerance, but their ethnic mixture is probably not comparable to that of Mauritian Creoles. High rates in Creoles may be related to Indian genetic admixture. However, preliminary HLA data from this study suggest that there has been relatively little Indian admixture (S.W. Serjeantson, unpublished observations).

In conclusion, similarly high prevalence of both IGT and NIDDM has been found in all three major ethnic groups in Mauritius. The exceptionally high prevalence of IGT may reflect a recent origin to the NIDDM epidemic in Mauritius and suggests that NIDDM prevalence is likely to continue to rise in the foreseeable future. On the basis of previous studies, high rates in mixed-race Creoles and particularly migrant Chinese were unexpected and suggest the action of strong environmental factors. Preliminary analyses have shown that

TABLE 3
Prevalence (%) of newly diagnosed and known cases of diabetes for all ethnic groups studied

	Men				Women			
Age-group	*n*	New	Known	New-known ratio†	*n*	New	Known	New-known ratio†
25–34	764	2.4	0.8	3.0	863	2.7	0.3	7.7
35–44	621	7.1	3.5	2.0	675	5.8	3.0	2.0
45–54	421	11.6	10.0	1.2	461	9.3	7.2	1.3
55–64	333	10.5	10.2	1.0	377	12.2	13.8	0.9
65–74	175	17.1	10.9	1.6	237	15.1	16.3	0.9
Total	2314	7.6	5.3	1.4	2615	7.2	5.6	1.3

*Total number of individuals within age-group for each sex.
†Number of new cases divided by number of known cases. Because of rounding, dividing prevalence figures may not give same ratio.

important factors determining diabetes prevalence in Mauritius include age, ethnic group, physical activity, body mass index (BMI), waist-hip ratio, and family history (37). Certainly, by international standards, the population is not excessively obese: only 13% of men had a BMI ≥27 kg/m², although 38% of women had a BMI ≥25 kg/m². Of other factors that may explain the high prevalence in all ethnic groups, the most plausible would appear to be dietary and cooking practices that have been adapted by the Chinese and Creole populations from those of the Indian population. Complete analysis of risk factors and their relationship with glucose intolerance in the various ethnic groups in Mauritius will be presented separately.

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APPENDIX: MAURITIUS NONCOMMUNICABLE DISEASE STUDY GROUP

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