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Type 2 diabetes mellitus in Papua New Guinea - an historical perspective

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SUMMARY

Type 2 diabetes mellitus is an increasing problem in Papua New Guinea (PNG). Five dominant themes emerge from the literature on diabetes in PNG: 1) The concept of the 'thrifty genotype' predisposing Papua New Guineans, like many other traditional populations, to type 2 diabetes, 2) Some coastal ethnic groups (particularly with Wanigelans and Tolais) appear to be more predisposed than others, 3) Prevalence of type 2 diabetes markedly rises with urbanization and adoption of a more western lifestyle, 4) Morbidity and mortality associated with the disease is high, and 5) Type 2 diabetes is overwhelmingly the most common type, with other types being rare. The literature is reviewed within the framework of these themes.

Introduction

The medical literature of Papua New Guinea (PNG) has been dominated by studies in infectious disease and nutrition, due to the evident large burden of related disease. However, since 1963 (1), it has been noted that type 2 diabetes occurs in the country and as reports of rising prevalence have accumulated, it is becoming increasingly clear that diabetes will become one of the major medical problems of the future in PNG.

The earliest reports indicated a low prevalence. Campbell in 1963 (1) reported that over three years, only 10 patients with diabetes were admitted to Port Moresby General Hospital (PMGH). All were adults, and it was notable that five subjects were relatively young, aged 16-30 years. Most subjects were underweight at diagnosis, and all required insulin. The earliest survey was by Hingston and Price in 1962 (2), using glycosuria for screaning and the glucose tolerance test for confirmation. No cases of diabetes were found in 407 adults in the Hula district of Central Province. 2 of the 1057 adult subjects tested in four suburban communities in Port Moresby had diabetes (a prevalence of 0.2%). Since the 1960s, various authors have shown that the prevalence is increasing.

Five dominant themes have emerged from the published reports of diabetes in PNG:

1. The concept of the 'thrifty genotype' predisposing Papua New Guineans and many other traditional groups to diabetes
2. Some ethnic groups in PNG are more predisposed than others
3. Prevalence of type 2 diabetes markedly rises with urbanization and adoption of a more western lifestyle
4. Morbidity and mortality associated with the disease is high
5. Type 2 diabetes is overwhelmingly the most common type, with other types rare.

The literature will be reviewed within the framework of these themes.

The thrifty genotype hypothesis

There is evidence from many populations around the world that a metabolic arrangement evolved that best coped with a usual situation of limited amount of food being available, interspersed with occasional short 'feast' periods. The genetic basis of this metabolic arrangement has been named the 'thrifty genotype'. When these communities are exposed to an unlimited food supply which is high in fat, combined with lifestyle changes that markedly reduce physical activity, they have a vulnerability to develop obesity, type 2 diabetes, and other metabolic disorders such as hypertension and hyperlipidaemia (3).

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Coastal Papua New Guineans appear to share this vulnerability with other populations around the world who have been subject to a rapid change in their lifestyle in the 20th century – eg Pima Indians and other Native American groups, Nauruans and other Pacific Islanders, Aboriginal Australians, the multiethnic groups in Mauritius and emigrant Indian populations (3-6).

The hypothesis is that there is a survival advantage for a metabolic arrangement that can take full advantage of the feast periods by efficiently converting excess energy into fat for use as a supplemental source during periods of food scarcity. This is achieved by a selective insulin resistance in which the gluco-regulatory actions of insulin are impaired, but those involving fat deposition exhibit normal or near-normal sensitivity (3).

As these communities westernize, this finely tuned metabolic system breaks down. The strong preference for survival foods with high sugar and fat is retained. Therefore profound dietary and physical exercise changes interact with the metabolic characteristics that conferred a survival advantage to produce insulin resistance and obesity. Insulin resistance worsens as obesity develops (particularly when fat is deposited centrally), and hyperinsulinism becomes more extreme in a vicious cycle as the body struggles to maintain homeostasis (normoglycaemia), soon unmasking diabetes. Later, β-cell exhaustion ensues (3).

Prevalence in different ethnic groups

Migrations to PNG

Papua New Guinea is thought to have been settled by three distinct periods of migration from South-East Asia (5). The present day Papua New Guinean highlanders are descended from the first wave – Australoid migrants arriving in New Guinea and Australia from Indonesia some 50,000 years ago. Between 10,000 and 15,000 years ago several waves of Papuan-speaking migrants reached New Guinea from the west. These Papuan-speaking peoples then spread further eastward through Melanesia to Fiji. The third wave was that of the Austronesians, who arrived 3000-5000 years ago. Consolidating their presence in coastal New Guinea, they did not penetrate the highlands, so the highlanders remain one of the few enclaves free of Austronesian admixture in the Pacific. The Austronesians spread further to the east, resulting in various degrees of Austronesian admixture in New Caledonia (20%) and Fiji (50%) (5).

The Wanigelans

The first group identified to be at particularly high risk of diabetes were the Wanigelan communities of the Papuan coast. A survey in 1977 (7,8) showed that adults from the Wanigelan Koki village in Port Moresby had a high prevalence of diabetes mellitus (DM – 2-hour glucose >11 mmol/l) and impaired glucose tolerance (IGT – 2-hour glucose 9-11 mmol/l). The prevalence was much higher than in the residents of Kalo (a non-Wanigelan rural coastal village) and in a multiethnic group of young civil servants in Port Moresby. Rates for the three groups respectively were for DM 15.6%, 1% and 0%, and for IGT 22%, 5% and 3%. The urban Wanigelans in Koki were on average 10.0 kg heavier than the rural group, despite being shorter, so they were substantially more obese (with a body mass index 3.7 units higher for males, and 5.2 units higher for females). Fasting plasma insulins were higher than for Australians (8).

Similar findings were reported in a comparison between Koki Wanigelans and their rural counterparts in the Wanigela village (9). The rural dwellers had high rates of glucose intolerance – 8.9% for diabetes and 5.7% for IGT in rural Wanigela – strongly suggesting a genetic predisposition. Again, these rates were lower than in their urban relatives.

A further study was carried out in 1991 by Dowse et al. (10). All adults >25 years old in the three previously studied villages – urban Koki and rural Kalo and Wanigela – were eligible, with enrolment rates of over 70%. The study showed that the prevalence in Koki and Wanigela had doubled since 1977, but had remained stable in Kalo. Age-standardized prevalence of diabetes in Koki Wanigelans was 37.5% in men and 33% in women, and an additional 20.5% of men and 22% of women

had IGT. Even in the youngest age group (25-34 years), 36.5% had glucose intolerance (16.1% IGT and 20.4% DM). Age-standardized rates of diabetes were the third highest in the world. The age-standardized prevalence of glucose intolerance was the second highest in the world after the Pima Indians and higher even than Micronesian Nauruans, even though the Nauruans are more obese. After adjusting for obesity, the data available suggest that the Wanigelans are more susceptible to diabetes than even the Pima Indians (6,10).

The results in the Wanigelans were similar to studies showing continuing and dramatic increases in Polynesian Western Samoans and Tokelau Islanders. It was noted that the Kalo people have an apparently similar lifestyle to the rural Wanigela people and yet do not have a high rate of diabetes, indicating the genetic susceptibility of Wanigela people. Both fasting and two-hour plasma glucose had a bimodal distribution. Bimodality has been reported in Pima Indians, Nauruans, Western Samoans and Mexican Americans (10).

The presence of low levels of antibodies to glutamic acid decarboxylase (GAD) in both subjects and controls demonstrated that autoimmunity was unlikely to be a contributing factor to this high prevalence (11).

A case-control dietary study was also done in Koki comparing newly diagnosed diabetic individuals with control subjects with normal glucose tolerance, to examine the hypothesis that saturated fat is an independent risk factor for type 2 diabetes (12). However, the study did not show any differences in mean values of total energy or energy-adjusted nutrient intakes, aside from some marginal associations when specific nutrients were categorized by tertiles.

Amini et al. (13) examined the anthropometric indices of Koki Wanigelan children aged between 7 and 9 years, comparing them to age- and sex-matched controls from two low prevalence non-Wanigelan communities also in Port Moresby. The Koki children were significantly lighter and shorter and had a lower body mass index (BMI) than the control children, but greater triceps skinfold thicknesses. The authors speculated that this may reflect subtle changes in metabolism of children destined, without intervention, to develop type 2 diabetes. Birthweights in the Koki children were also on average 0.35 kg lower, consistent with the concept (suggested from retrospective studies and now being explored in prospective studies in other countries) that impaired intrauterine growth may predispose to type 2 diabetes.

The Koki Wanigelans also have frequently elevated cholesterol and triglyceride levels, correlating with obesity (14,15).

Other coastal groups

Other communities around the country have been reported as having a high prevalence, particularly the Austronesian Tolai people of East New Britain (16-21). There are also suggestions that some coastal groups have high rates, including Hanuabada and Pari villagers in Port Moresby (22,23) and Manus Island, Sepik and Milne Bay peoples (P. Pelluru and others, personal communication). Further studies are needed to define these risks. Other groups may have a susceptibility to type 2 diabetes which will be expressed as they westernize.

Prevalence in highlanders

In 1983, King and others (19,24) studied two semi-traditional non-Austronesian highlands villages in the Asaro Valley of the Eastern Highlands. No cases of diabetes were found. This led to the concept that a more stable natural environment, greater agricultural sophistication and seclusion from Austronesian genetic admixture may have resulted in less survival advantage of the thrifty genotype. This led to a greater degree of glucose tolerance and a lower susceptibility to type 2 diabetes (20,24). This is supported by evidence from Fiji that non-Austronesian Melanesians lose their protection against glucose intolerance when exposed to a moderate proportion of Austronesian genetic admixture (5). Another non-Austronesian population, the Australian Aborigines, have high levels of glucose intolerance, which may be due to the presence of HLA-A2 (which may have been lost due to genetic drift in the

highlanders), and a more harsh environment selecting for the thrifty genotype (5).

However, a subsequent study in 1985 (20) examined a periurban highland community (near Goroka, Eastern Highlands Province). Most families were reliant on the cash economy for their needs. Nobody had diabetes but 1.7% of males and 2.2% of females had impaired glucose tolerance. Also, in both sexes the average values for two-hour plasma insulin concentrations were substantially higher than in the rural communities surveyed in 1983. They were also higher than in a rural Austronesian community in East New Britain. Glucose and insulin levels were also higher in periurban than in rural highlanders (25). A further survey in 1991 of the same rural and periurban villages showed that diabetes had appeared in both groups, at a rate of 1.2% and 1.1% respectively (15). These findings indicate that the non-Austronesian highlanders may not be as protected from diabetes as previously thought, and be in a state of 'metabolic transition' (20).

Causation

There is limited information on the genetic markers associated with these variant risks. Bhatia et al. (23) examined HLA antigens of diabetic patients at the Port Moresby General Hospital (PMGH) clinic. All subjects were Papuan, particularly from Wanigela/Rigo and Pari/Hanuabada with a few from Kerema and Samarai. There was an association of disease with BW62, a split antigen of BW15, and also, though not significantly so, with B13 and BW22.

A steadily increasing number of genes are being identified that predispose to the development of diabetes. It is very likely that future studies of these candidate genes will explain much of the variation between PNG populations.

Environmental factors remain to be studied. Cultural factors are significant in hereditability in the Tolais (21). Animal studies conducted by Boucher and colleagues suggest that betelnut may induce glucose intolerance (26,27). Moreover, the same group have found a suggestive link between betelnut chewing and glucose intolerance among Asians in east London (28). However, Dowse (29) responded that regional epidemiological data did not suggest a link with human diabetes. Further studies are warranted to determine if there is a link between betelnut chewing and diabetes.

Impact of urbanization

Price and Tulloch (22) gave the first indication of the effect of urbanization in PNG when they reported in 1966 on four communities in Port Moresby. Diabetes was present in 1.5% of the adults who had been urbanized for the longest time (the Hanuabadans), but was rarer (0.5%) in the other groups. However, the groups were not genetically homogenous.

The studies in rural Wanigelans referred to above also show the effect of urbanization, with prevalence rates higher in urban than rural Wanigelans (9); rates rose after 8-14 years in both groups, the largest rise being in the urban group, where they almost doubled (10). Likewise, highlands data suggest the effect of urbanization (see above).

Campbell et al. in 1978 (30) first noted the rapid and dramatic dietary change in urban areas. The rural people ate a largely traditional diet dominated by yams, cassava and bananas, with very little refined food. In contrast, the urban population ate a largely western diet in which bread, polished rice and tinned foods were most common (7,30). The mean total caloric intake was around 1400 Calories for rural and 2300 Calories for urban subjects (7).

King and Collins (31) developed a modernity score for individuals in Melanesian society. The score consists of eight components related to area or origin, employment, length of employment, father's employment, education, years spent in an urban centre, housing, and the spouse's score. In both males and females, the index was strongly associated with age and obesity. In males, but not in females, there was a weak association with two-hour plasma glucose concentrations after an oral glucose tolerance test (OGTT). A further study (32) using this modernity score in 6 communities – 3 in the Asaro Valley and the coastal communities of

Wanigela, Kalo and Koki – showed that the more modern subjects had a higher BMI and lower levels of physical activity. Waist-hip ratio also varied with modernity in men but not in women. Results of the dietary sub-study suggested that the lowest energy and nutrient intakes occurred in the least modern men and women. The study suggested that aspects of modernity such as more sophisticated housing and greater number of years spent in an urban centre are markers of higher income and increased adoption of western ways, including reduced physical activity and increased availability of energy-dense western food, which result in obesity.

The impact of urbanization is noticeable even in young subjects. King et al. (33) looked at 10-19 year olds in two ethnically homogenous Tolai communities in East New Britain – at Matupit (periurban to Rabaul) and Napapar (30 km from Rabaul). On oral glucose tolerance tests, the periurban group had higher average glucose (with the mode 0.5 mmol/l higher) and relative hyperinsulinaemia. The findings could not be explained by adiposity, although a variation in pubertal development was not assessed and may have contributed. The higher insulin and glucose levels suggested the development of insulin resistance and incipient glucose intolerance (33,34).

The PNG studies are thus similar to urban-rural comparisons and migration studies confirming the relationship of modernization or westernization with obesity and type 2 diabetes in developing populations of the Pacific Ocean region and in Australian Aborigines (32). Modernization of formerly traditional societies is characterized by changes in diet to a more energy-dense and more plentiful and/or consistent food supply, and reduced levels of physical activity, which result in increasing obesity (32).

The series of surveys in the Eastern Highlands reviewed in the previous section also indicate effects of urbanization and westernization. Hongo et al. (35) studied 4 non-Austronesian lowland villages depending on traditional subsistence agriculture in the Western Province. Glycosuria was present in only 0.3% of the combined population (consistent with the described low prevalence in non-Austronesian populations) with positive individuals found only in the most urbanized villages.

Morbidity and mortality

A high frequency of complications has been noted from early reports onwards. Martin (17) found that diabetic patients in Port Moresby and Rabaul were poorly controlled, with early complications, particularly significant proteinuria, neuropathy and lower limb amputations. Cataracts were common but retinopathy was recorded only rarely. Savige and Martin reported in 1982 that diabetic patients frequently had serious complications with a high case fatality rate and had a median survival time of 4-5 years (18,36). Likely contributing factors to these poor outcomes included poor compliance with diet and treatment from poor education and frequent unavailability of medications.

Patel in 1989 (37) reported a high rate of morbidity and mortality from bacterial infections in Port Moresby diabetic patients. Infections often required lengthy inpatient treatment. The usual site was the lower limb, with staphylococcus and klebsiella infections. Among the 160 patients seen, 11 had gangrene of the foot; 2 of these were less than 23 years of age. 13 patients died during the period, 9 with infections (and 3 of these were under 23 years). Tuberculosis was also common.

More recent studies have also found high complication rates. Hyperlipidaemia is common in type 2 diabetic patients in Port Moresby, with Erasmus and colleagues (38) finding that 13% of 78 patients, mostly from the Wanigelan Koki population, had hypercholesterolaemia (>5.2 mmol/l) and 8% hypertriglyceridaemia (>2.3 mmol/l). In a prospective study of PMGH clinic patients, microalbuminuria was found in 42% of patients, and hypertension in 17% (39). This is associated with generally poor control in this population – 64% of patients had a glycosylated haemoglobin (HbA1c) level of over 10% (40). Among 19 newly diagnosed patients, glycaemic control improved in only 2.

Types of diabetes

The overwhelming number of reports of

diabetes in PNG have been of type 2. Type 1 is very uncommon, with only a handful of reported cases, and a low current incidence (41).

The non-obese 'J-type' or 'tropical' diabetes has been described in Papua New Guinea (16,42). Martin and Simeanova (42) reported 9 adults who were thin and had detectable c-peptide levels. Only 2 had a history of ketosis, and in both cases this was mild. The author noted the similarity between the disease in these cases and the non-obese J-type diabetes described by others. This 'tropical diabetes' has been described in a number of countries, generally associated with malnutrition. It is not certain whether these patients have longstanding undiagnosed or inadequately treated type 2 diabetes (thus becoming thin) or whether frank obesity is lacking because obesity should be diagnosed at a lower body mass index in some ethnic groups than in caucasians (43), or whether their diabetes is truly different from type 2. This type of diabetes was excluded in the most recent disease classification (44) due to insufficient evidence; however, the topic warrants further study.

Fibrocalculous pancreatic diabetes is a disorder characterized by diabetes in association with pancreatic calcification, found in impoverished communities. It was first described in PNG from Port Moresby in 1963 (1) and then in 1988 from Goroka in the highlands (45) and from Port Moresby (46). The 9 cases in these reports ranged from 15 to 60 years at diagnosis; 3 cases had a history of recurrent abdominal pain. Most required insulin in management, and two had evidence of insulin resistance.

In conclusion, there are marked variations in the prevalence of type 2 diabetes in Papua New Guinea. Some populations have very high rates. Genetic and environmental factors are implicated. As urbanization inexorably proceeds, prevalence in all populations will rise. As has been pointed out previously (47,48), the increasing toll of complications will pose major challenges to the health system and there is an urgent need to apply effective preventive strategies.

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