Diabetes in Asia and the Pacific: Implications for the Global Epidemic

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The last three decades have witnessed an epidemic rise in the number of people with diabetes, especially type 2 diabetes, and particularly in developing countries, where more than 80% of the people with diabetes live. The rise of type 2 diabetes in South Asia is estimated to be more than 150% between 2000 and 2035. Although aging, urbanization, and associated lifestyle changes are the major determinants for the rapid increase, an adverse intrauterine environment and the resulting epigenetic changes could also contribute in many developing countries. The International Diabetes Federation estimated that there were 382 million people with diabetes in 2013, a number surpassing its earlier predictions. More than 60% of the people with diabetes live in Asia, with almost one-half in China and India combined. The Western Pacific, the world's most populous region, has more than 138.2 million people with diabetes, and the number may rise to 201.8 million by 2035. The scenario poses huge social and economic problems to most nations in the region and could impede national and, indeed, global development. More action is required to understand the drivers of the epidemic to provide a rationale for prevention strategies to address the rising global public health "tsunami." Unless drastic steps are taken through national prevention programs to curb the escalating trends in all of the countries, the social, economic, and health care challenges are likely to be insurmountable.

REVIEW

Diabetes is now a disease of major concern both globally and regionally and is a leading cause of death in most countries (1). In 2013, the International Diabetes Federation (IDF) estimated that ~382 million people had diabetes worldwide, and by 2035, this was predicted to rise to 592 million. Eighty percent live in low- and middle-income countries, and of the total, more than 60% live in Asia, with almost one-third in China (2). Major increases in the prevalence of diabetes have occurred in developing countries due to rapid and ongoing socioeconomic transition and will likely lead to further rises (2). The prevalence of both type 1 and type 2 diabetes (T2DM) has increased significantly during recent decades. T2DM, being much more common (2), has been the main driver for the increase in global diabetes prevalence and, therefore, will be the focus of this review.

It should be noted that with regard to diabetes prevalence, only broad comparisons can be made among studies on which national and global estimates by the IDF are based. This is because there are marked differences in age-groups, survey methodologies, diagnostic criteria, and other aspects of these studies in the various countries in Asia and the Pacific. Despite this, almost all developing countries in the Western Pacific region (WPR) (3) and also in South Asia (4–6) have shown escalating rates.

The WPR is the world's most populous World Health Organization (WHO) region, comprising 39 heterogeneous countries and territories, with populations

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ranging from more than 1 billion people in China to 10,000 in small Pacific Island nations like Tuvalu. The region has undergone rapid changes developmentally, socioeconomically, politically, and culturally during the last few decades (3).

The increasing prevalence of diabetes can be attributed to a multitude of interrelated factors, including rapid industrialization and urbanization and the ensuing changes in lifestyle factors (4,6). The effect of the intrauterine environment and the resulting epigenetic changes may also convey increased risk of T2DM and other chronic diseases in adult life (1,7). Epigenetic changes can be transmitted to future generations, thus becoming intergenerational. The risk factors for T2DM are summarized in Table 1 and are detailed below. Interestingly, the propensity of these risk factors to cause diabetes appears higher among the populations in South Asia and in the WPR compared with Western populations, and this is discussed in a later section.

T2DM is increasingly present in even children and adolescents (1,3–5), and the increase in gestational diabetes mellitus (GDM) poses new challenges such as higher risk of diabetes among women and long-term consequences for the offspring (2,6,8,9). Prediabetes prevalence is also higher than that of diabetes in many of the WPR countries (10). T2DM is the focus of this review, which aims to address the major ethnic, demographic, anthropometric, socioeconomic, genetic, and epigenetic factors that are likely to be responsible for the dramatic rise in T2DM. We describe the epidemiological scenario in Asia and in the Pacific. For the purpose of this review, the WPR refers to East Asia, Southeast Asia, Australia, New Zealand, and the Pacific Islands; South Asia refers to Afghanistan, Bangladesh, Bhutan, India, Maldives, Mauritius, Nepal, Pakistan, and Sri Lanka (Fig. 1). Many of the nations in these regions do not have national data, so they have not been discussed in detail in this review.

Table 1—Plausible etiological factors responsible for the increased propensity to develop T2DM

Genetic and acquired factors
Genetic factors (familial aggregations)
Ethnic susceptibility
Adverse gene–environment interaction (i.e., epigenetics, metabolic maladaptations)
Lower threshold for diabetogenic risk factors (i.e., age, BMI, central adiposity)
Low muscle mass
Increased insulin resistance
Decreased β-cell compensation disproportionate to insulin insensitivity
Presence of metabolic obesity
Increased inflammatory response
Environmental risk factors
Urbanization and modernization
Globalization and industrialization
Unhealthy behavioral habits (sedentary lifestyle, consumption of energy-dense food, smoking, tobacco chewing, and excessive alcohol consumption)
Sleep disturbances
Psychological stress
Societal factors
Cultural and religious taboos
Psychosocial factors
Lack of universal health coverage

It should be noted that much of the diabetes prevalence data discussed in this review come from IDF estimates (10). These have significant limitations, in that for countries without available local data, estimates are based on modeling using pooled estimates from countries that might be seen to be similar in geography, ethnicity, and economic development. Similarly, numerous country data are based on WHO STEPwise approach to Surveillance (STEPS) studies (11). These are not necessarily comparable with each other owing to methodological differences. These limitations must be considered when examining the data.

Impaired fasting glucose and impaired glucose tolerance (IGT) are high-risk conditions for diabetes and cardiovascular disease (12). China and most of the other countries in WPR have a high prevalence of IGT (3). This is true of many countries in Asia (13). However, many countries use only fasting plasma glucose (FPG) in epidemiological studies and therefore do not have data on IGT. The use of FPG underestimates the true level of diabetes and prediabetes compared with the oral glucose tolerance test (OGTT).

LITERATURE SEARCH STRATEGY AND SELECTION CRITERIA

We searched PubMed and Google search using key words "diabetes in Western Pacific Region," "diabetes in South Asia," diabetes in individual countries of these regions, "risk factors for T2DM in Western Pacific population," "risk factors for T2DM in South Asians," "gestational diabetes among Asian population," and "prevention of diabetes." Published reports by the IDF, the WHO, and the American Diabetes Association on the above topics were used. We selected the relevant articles and reviews from peer-reviewed journals identified by the search for preparing the review.

THE DIABETES EPIDEMIC IN THE PACIFIC REGION AND IN ASIA

WPR

Today, the nations in the WPR region are highly heterogeneous in economic profile, varying from the high per capita gross domestic product in countries such as Singapore to low gross domestic product in the poorest nations. Developed countries in WPR, such as Australia and New Zealand, have a much lower prevalence of diabetes compared with some developing countries and also the Pacific Islands (14).The IDF estimated that in the WPR in 2013, there were 138 million people with diabetes, 36% of the global total (10). The biggest contribution to this number is China, with 113.9 million adults with diabetes and 493.4 million with prediabetes (15). Some small Pacific Islands, such as Tokelau, according to the IDF estimates and the WHO STEPS studies (11), have a very high diabetes prevalence (Table 2). As mentioned earlier, these are not necessarily comparable with each other owing to methodological differences between and within countries. This point is highlighted in Cambodia by a 2005 report (16) showing that T2DM has emerged at rates similar to those in developed nations such as Australia; yet, a subsequent STEPS modeling study showed that Cambodia had the lowest prevalence in the WPR (10).

In the 2013 IDF estimates, China tops the global list of countries for the total number of people with diabetes, followed by India (2). The number of people with diabetes in Japan has increased significantly since 1997, especially among the male population. In 2013, it occupied the 10th position in the IDF list, with 7.2 million people with diabetes (17). Indonesia has not registered a significant increase since 1997 (18,19).

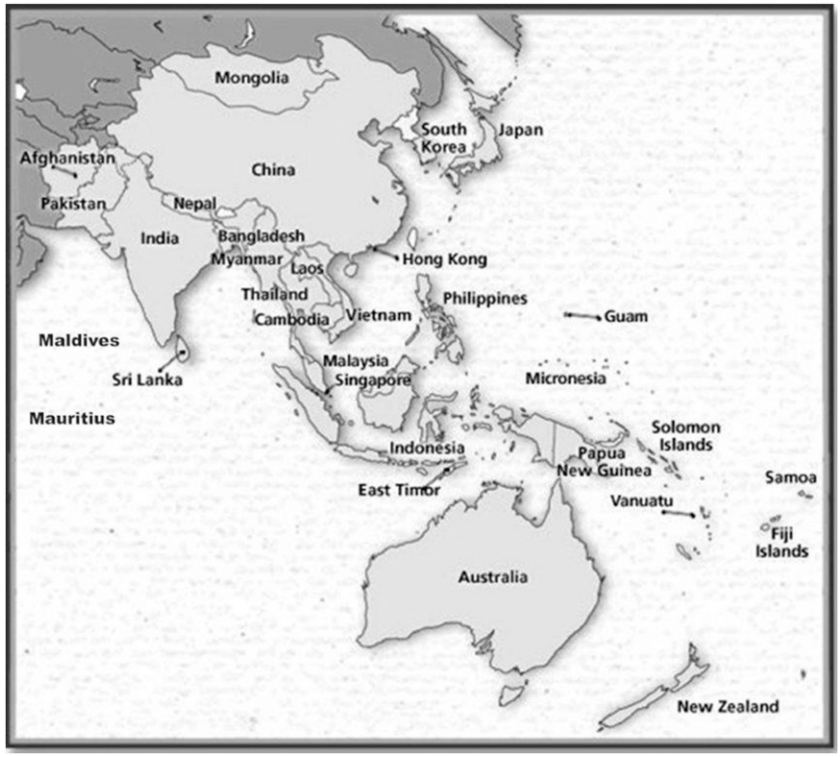

Figure 1—Map shows the Western Pacific and South Asian regions.

IDF estimates for diabetes within the Pacific vary widely, from the world's highest of 47.3% in American Samoa to a comparatively lower prevalence of 7.3% in French Polynesia (3,10). Figure 1 shows the map of the WPR, and Table 2 reports the temporal changes in the prevalence of diabetes in these countries. The rising trend in the developing countries is considerably steeper compared with the developed countries (1,12,14,15,17–34). In recent decades, apart from the WHO STEPS studies (11), there have been very few national diabetes studies for the Pacific Ocean nations (14). Nevertheless, some of the highest estimates of prevalence globally continue to be seen in this region, even though the use of FPG alone underestimates the true diabetes prevalence (35) and the laboratory methods were not standardized among the studies.

Obesity is a major driver of the T2DM epidemic, and the Pacific Island nations are among the leaders in the world obesity and diabetes charts (14). According to the latest WHO criteria for obesity (11), more than 70% of the people in American Samoa, Nauru, and Tokelau are obese. Other islands also show a high prevalence of obesity, including Kiribati (50.6%), the Marshall Islands (45%), the Federated States of Micronesia (42.6%), the Solomon Islands (32.8%), and Fiji (29.6%) (14).

Since the 1960s, the Pacific region has been recognized as a "hot spot" for diabetes, with Prior and Davidson (36) first reporting a higher diabetes prevalence in Polynesians compared with New Zealanders of European descent. In 1975, on the Central Pacific island of Nauru, the then highest ever national diabetes prevalence of 34.4% was reported (37). Income from Nauru's rich phosphate deposits had resulted in its Micronesian population becoming extremely prosperous and obese. With the phosphate deposits now exhausted, and with the consequent contraction of the national economy, a significant fall has occurred in diabetes prevalence (1). In the 1980s, Zimmet et al. (38) confirmed the higher prevalence of diabetes in other Pacific Islands using standardized protocols. However, because most of these studies were undertaken more than two decades ago, they are unlikely to reflect current diabetes rates (14).

The paucity of secular data in the Pacific presents a difficulty in monitoring trends. The age-standardized prevalence of T2DM in Western Samoa increased between 1978 and 1991 from 8.1 to 9.5% in men and from 8.2% to 13.4% in women in the urban area, and from 2.3% to 7% in men and from 4.4% to 7.5% in women in a rural community (39). In Tonga in 2002, Colagiuri et al. (40) reported a dramatic secular increase (100% in 25 years) in diabetes from 7.5% in 1973% to 15.1%, of which 80% were undiagnosed cases.

King et al. (16), in 2005, reported on diabetes in Cambodia, a relatively poor and fairly traditional country, showing prevalence of 5% (rural) and 11% (semiurban). The prevalence of IGT was 10% (rural) and 15% (semiurban). About two-thirds of all cases of diabetes were undiagnosed. These figures are much higher than those reported by a subsequent WHO STEPS study (11). Such differences, which may relate to the first study being a dedicated diabetes survey and using the OGTT and the second study being a general survey of noncommunicable diseases and relying on the fasting glucose alone, need to be kept in mind.

In Malaysia, the reported prevalence of diabetes was 11.6% in 2006 (26), 15.2% (8% undiagnosed) in the 2011 national study (41), and 22.9% in 2013 (26). The age distribution of the study groups was similar. The higher prevalence seen in the 2013 survey may partly be explained by the use of the OGTT. In Thailand, the National Health Examination Survey showed that the diabetes prevalence in people aged ≥15 increased from 2.5% in 1991 to 4.6% in 1997 and to 6.8% in 2004 (32). In 2009, their National Health Examination Survey (33) found the prevalence of impaired fasting glucose was 10.6% and diabetes was 7.5% (of which 35.4% were undiagnosed cases) in adults aged ≥20 years. These prevalences were likely to be underestimates because diagnosis relied only on a single FPG, history of physician diagnosis, and information on medications (33). The age-standardized prevalence in Singapore has remained constant at ~11% during the last two decades. In Singapore, diabetes was more common in Indians (17.2%) than in Malays (16.6%) or Chinese (9.7%) (31).

The prevalence of diabetes in Korea increased from <1% in 1960 to >10% by early 2000. The Korea National Health and Nutrition Examination Survey (KNHANES) 2010–2012 also reported a prevalence of 10.1% based on FPG (29,30), suggesting a

Table 2—Prevalence of diabetes in the WPR, with temporal changes shown wherever available*

Country	Year (Ref)	Sample size (*n*)	Characteristics	Diagnostic criteria	Diabetes (%)
American Samoa	2004 (14)	2,072	WHO STEPS; stratified cluster sampling; age: 25–64 years	Capillary FPG ≥6.1 mmol/L	47.3
Australia	2011–2012 (20)†	NR	Age: ≥18 years	HbA_{1c} ≥6.5% (≥47.5 mmol/mol)	5.4
Brunei Darussalam	2003 (21)†	NR	Population-based data from integrated health screening system from medical case records; age: NR	Capillary FPG ≥6.1 mmol/L or known diabetes	5.4
	2010 (21)†	NR	Age: ≥20 years	Capillary FPG ≥6.1 mmol/L or known diabetes	12.5
Cambodia	2004 (16)	2,246	Cross-sectional; two communities: rural and semiurban; age: ≥25 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	Rural: 5.0 Suburban: 11.0
	2011 (24)†	5,123	WHO STEPS; multistage cluster method (180 clusters); age: 25–65 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	Total: 2.9 (95% CI 2.3–3.4) Rural: 2.3 (95% CI 1.7–2.9) Urban: 5.6 (95% CI 4.0–7.2)
China	2001 (25)†	15,838	Nationally representative stratified sampling; age: 35–74 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	5.5
	2010 (15)†	98,658	Complex, multistage, probability sampling design; age: ≥18 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	11.6
China, Hong Kong SAR	1990 (22)	1,513	Participants from a public utility company and a regional hospital; age: ≥30 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	4.5
	2007–2010 (23)	3,376	Hong Kong professional driver community project; age: 18–70 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	8.1
Cook Islands	1980 (14)	1,102	Population-based study; age: ≥20 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	6.8
	2003 (14)	2,036	WHO STEPS; stratified samples; age: NR	Capillary FPG ≥6.1 mmol/L or on medication	23.6
Federated States of Micronesia	1994 (14)	2,188	Population-based study in Kosrae population; age: 20–85 years	FPG ≥7.0 mmol/L	12.0
	2002 (14)	1,638	WHO STEPS; population-based cross-sectional study; age: 25–64 years	FPG ≥7.0 mmol/L	32.1
Fiji	2002 (14)	2,277	Population-based multistage sampling in 30 clusters; age: 15–64 years	Capillary FPG ≥6.1 mmol/L or on medication; HbA_{1c} ≥6.5% (≥47.5 mmol/mol) or known to have diabetes	16.0
	2009 (14)	1,353	WHO STEPS; population-based study; age: ≥40 years		44.8
French Polynesia	2010 (14)	3,469	WHO STEPS; population-based multistage sampling; age: 18–64 years	Capillary FPG ≥6.1 mmol/L or on medication	7.3
Indonesia	1997 (18)	941	Population-based study of government and retired individuals; age: NR	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	5.4
	2009 (19)	24,417	Samples from 13 urban provinces; age: ≥15 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	5.7
Japan	1997 (17)	National	Age: ≥20 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	M:F 9.9:7.1
	2007 (17)	National	Age: ≥20 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	M:F 15.3:7.3
Kiribati	1983 (14)	2,938	Population-based survey; age: ≥20 years; South Tarawa and the four outer islands; age: 15–64 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	Urban: M:F 9.6:8.7 Rural: M:F 3.0:3.3
	2004–2006 (14)	1,146	WHO STEPS; population- based multistage sampling; age: 18–64 years	FPG ≥7.0 mmol/L	28.1

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Table 2—Continued

Country	Year (Ref)	Sample size (*n*)	Characteristics	Diagnostic criteria	Diabetes (%)
Malaysia	2006 (26)	34,539	Malaysian National Health Morbidity Survey (NHMS) III; age: ≥18 years	FPG ≥7.1 mmol/L or known to have diabetes	11.6
	2013 (26)	4,341	Two-stage stratified sampling design; age: ≥18 years	HbA_{1c} ≥6.5%, FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	22.9
Marshall Islands	2002 (14)	994	WHO STEPS; population-based; age: 15–64 years	FPG ≥7.0 mmol/L	19.6
Mongolia	2005 (27)	3,411	WHO STEPS; population-based; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or on medication	8.2
	2009 (27)	5,368	WHO STEPS; population-based; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or on medication	6.5
Nauru	1987 (1)	1,201	Population-based data; age: ≥20 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	24.0
	2004 (14)	883	Systematic random sample design; age: 15–64 years	FPG ≥7.0 mmol/L or on medication	16.2 (age 15–24 years) 22.7 (age 25–64 years)
New Zealand	2002–2003 (28)	12,929	Stratified cluster sampling; age: ≥15 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	8.1
	2008–2009 (28)	4,721	Age: ≥15 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	7.0
Niue	1980 (1)	1,128	Population-based survey; age: ≥20 years	FPG ≥7.8 mmol/L	7.2
	2012 (14)	863	WHO STEPS; population-based; age: ≥15 years	Capillary FBG ≥6.1 mmol/L or on medication	38.4
Papua New Guinea	1991 (14)	497	Population-based cluster; age: ≥25 years	Random blood glucose ≥8 mmol/L or known diabetes	Urban: 30.3 Rural: Wanigela: 11.7 Kalo: 1.6
	2008 (14)	2,944	WHO STEPS; population-based survey; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or on medication	14.4
Republic of Korea	2005 (29)	4,628	KNHANES; age: ≥30 years	FPG ≥7.0 mmol/L or/and history of diabetes	9.1
	2007–2009 (29)	13,512	Age: ≥30 years	FPG ≥7.0 mmol/L	9.9
	2011–2012 (30)†	14,330	National Health Survey; age: ≥30 years	FPG ≥7.0 mmol/L	10.1
Samoa	1991 (14)†	1,776	Population-based cluster sampling; age: 25–74 years	FPG ≥7.8 mmol/L or/and 2-h PG ≥11.1 mmol/L	Apia: M:F 9.5:13.4 Poutasi: M:F 5.3: 5.6 Tuasivi: M:F 7.0:7.5
	2002 (14)	2,817	WHO STEPS; random sample population-based study; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or venous FPG ≥7.0 mmol/L or on medication	22.1
Singapore	2004 (31)†	NR	National survey; age: 18–69 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	8.2
	2010 (31)†	NR	National survey; age: 18–69 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	11.3
Solomon Islands	1986 (14)	243	Population-based study; age ≥18 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	2.09
	2006 (14)	950	WHO STEPS; population-based; age: 25–64 years	Capillary FBG ≥6.1 mmol/L or on medication	13.5
Thailand	1991 (32)†	National	Age: ≥30 years	FPG ≥7.0 mmol/L	2.3
	2004 (32)†	National	Age: ≥15 years	FPG ≥7.0 mmol/L	6.8
	2009 (33)†	National	Age: ≥20 years	FPG ≥7.0 mmol/L	7.5
Tokelau	1976 (14)	346	Population-based study; age: 35–74 years	OGTT (100 g): 1-h PG ≥13.9 mmol/L	M:F 7.0:14.3
	2005 (14)	573	WHO STEPS; population-based national survey; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or on medication	33.6

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Table 2—Continued

Country	Year (Ref)	Sample size (*n*)	Characteristics	Diagnostic criteria	Diabetes (%)
Tonga	1991 (14)†	1,024	National sample; age: ≥15 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	15.1
	2004 (14)†	453	WHO STEPS; population-based national survey; age: 15–64 years	Capillary FBG ≥6.1 mmol/L or on medication	16.4
Vanuatu	1991 (14)	1,378	An occupation-based (civil servants) urban sample and area-based semirural and rural samples; age: NR	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	Vila: M:F 2.1:12.1 Nguna: M:F 2.1:1.1 Tanna: M:F 1.0:0.9
	2011 (14)†	4,422	WHO STEPS; population-based national survey; survey included all six provinces; age: 25–64 years	Capillary FBG ≥6.1 mmol/L or on medication	21.2
Vietnam	2001 (34)	2,932	Cross-sectional; age ≥15 years	FPG ≥7.8 mmol/L or/and 2-h PG ≥11.1 mmol/L FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	3.8
	2011 (12)	2,710	Cross-sectional; age: 40–64 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	3.7
Wallis and Futuna	1980 (14)†	549	Population-based study; age: ≥20 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	2.7
	2010 (14)†	487	WHO STEPS; population-based national survey; age: 15–64 years	FPG ≥7.0 mmol/L or on medication	17.5

F, female; FBG, fasting blood glucose; HbA_{1c}, glycated hemoglobin A_{1c}; M, male; NR, not reported; PG, plasma glucose; SAR, Special Administrative Region. *It needs to be recognized that only broad comparisons can be made from these data owing to significant differences in age-groups, survey methodologies, diagnostic criteria, etc. †National studies.

constant prevalence of diabetes during the last decade. Diabetes was more prevalent in individuals in lower socioeconomic groups, a finding similar to that in developed Western countries.

South Asia

South Asia constitutes one-fifth of the world's population and includes nine countries, all of which are undergoing lifestyle transitions that make their populations more vulnerable to develop T2DM. In the last few decades, the diabetes prevalence in South Asia has also risen considerably. Table 3 reports the secular changes that occurred in these nations (5,42–51). However, true nationally representative data, which include urban and rural prevalence, are lacking from most of these countries, including India.

South Asian populations also have a high prevalence of prediabetes and a more rapid progression to diabetes (13). This is highlighted by a recent study that reported a diabetes incidence of 22.2 per 1,000 person-years and that 59% of those with prediabetes converted to diabetes after a follow-up of 9.1 years (52).

A 2008 report from Southern India showed a marked increase in diabetes prevalence in both urban and rural areas compared with earlier studies (53). Studies from other parts of India have also shown increases in diabetes prevalence (13,46).

India is the largest country in the region and has more than 65.1 million people with diabetes, occupying the second position next to China in the IDF global list of top 10 countries for people with diabetes. Pakistan and Bangladesh are in 12th and 13th positions, respectively (10). The IDF estimates that the number of people with diabetes in South Asia will increase to 120.9 million, 10.2% of the adult population, by 2030. The highest increase in diabetes prevalence is noted in Mauritius (48) (Table 3), an Indian Ocean island with a predominantly Asian Indian population. A survey conducted in urban and rural Maldives showed that the prevalence of diabetes was 10.6% (47). However results from the STEPS survey conducted in Male, the Maldives capital city, showed the prevalence of diabetes was 4.5% in all adults (11). Again, the reason for the difference seen in the STEPS study is unclear.

Table 3—Prevalence of diabetes in South Asia, with temporal changes shown wherever available

Country	Year (Ref)	Sample size (*n*)	Characteristics	Diagnostic criteria	Diabetes (%)
Afghanistan	2013 (42)	1,169	Age: >40 years	Capillary FBG ≥6.1 mmol/L or on medication	13.3
Bangladesh	2005 (5)	6,312	Cross-sectional; age: ≥20 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	Urban: 8.3 Rural: 2.3
	2011 (43)*	8,835	Population-based national survey; age: ≥35 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	9.7
Bhutan	2008 (44)	2,474	Stratified two-stage sampling; age: 25–74 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	8.2
India	2000 (45)	11,216	Random sampling, six metropolitan cities; age: ≥20 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	12.1
	2008–10 (46)	13,055	Stratified multistage sampling (188 urban, 175 rural) in three states and one union territory; age not reported	Fasting CBG ≥7 mmol/L or/and 2-h CBG ≥12.2 mmol/L or on medication	Tamil Nadu: 10.4 Maharashtra: 8.4 Jharkhand: 5.3 Chandigarh: 13.6
Maldives	2004 (47)*	1,556	Cross-sectional; national; age: 25–64 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	4.5
Mauritius	1987 (48)	5,083	Independent population-based survey; age: 20–74 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	13.0
	2009 (48)	6,371	Age: 20–74 years	FPG ≥7.8 mmol/L or 2-h PG ≥11.1 mmol/L	21.3
Nepal	2011 (49)	14,425	Population from Eastern Nepal; age: >20–100 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	6.3
Pakistan	2000 (50)	1,042	Age: 30–64 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	6.5
	2006 (50)	5,433	Age: 30–64 years	FPG ≥7.0 mmol/L or/and 2-h PG ≥11.1 mmol/L	Urban: 10.6 Rural: 7.7
Sri Lanka	2001 (5)	6,047	Cross-sectional; stratified random samples from four provinces; age: ≥30 years	FPG ≥7.0 mmol/L or on medication	13.8
	2006 (51)*	4,532	Cross-sectional; national representative; age: ≥20 years	FPG ≥7.0 mmol/L or 2-h PG ≥11.1 mmol/L	10.3

CBG, capillary blood glucose; FBG, fasting blood glucose; PG, plasma glucose. *National study.

Several distinctive features are noted among the South Asians, such as early occurrence of diabetes at lower BMI levels (6), higher rates of insulin resistance, abdominal obesity, and familial aggregation of diabetes than in many other ethnic groups. In recent decades, an increasing diabetes prevalence has been reported in rural areas in middle-income groups and among underprivileged people (13,51). Occurrence of T2DM at a young age is commonly observed among South Asians, with the picture further complicated by the presence of maturity-onset diabetes of the young or latent autoimmune diabetes of adulthood (13).

Urban-Rural Difference

In developing countries in Asia and WPR, the urban-rural difference in diabetes prevalence is narrowing due to the increasing reach of Western lifestyles and associated behavioral changes into rural settings. In India, Nepal, Sri Lanka, the Solomon Islands, Samoa, and Thailand, more than 50% of the national population with diabetes resides in rural areas (10). Recent studies from India (53) and China (4,6,54) have shown greater rates of increase in diabetes prevalence in rural than in urban areas. Hwang et al. (55) reported that across multiple surveys, there was evidence of a fivefold rise in the prevalence of diabetes from 1985 to 2010 in rural populations of developing countries.

Diabetes in the Diaspora

Population-based studies indicate a higher prevalence of diabetes among the South Asian diaspora compared with other ethnic and the local populations in many Western nations, including the U.S. and the U.K. (13,56–60). Among South Asians, T2DM is usually diagnosed at an earlier age and is associated with increased mortality compared with the white population in these countries.

Risk Factors for Diabetes in Asians and Pacific Islanders

Similar risk factors for T2DM have been identified in Europids and in Asian populations (5,6,54). Many of these risk factors are closely linked to economic development and the increasing urbanization seen across much of Asia and the Pacific. Some risk factors for T2DM have become of great concern among developing countries in Asia and the Pacific. As discussed

later, the prevalence of GDM has also increased markedly in Asia and the Pacific in recent decades (9,10).

Much of the recent increase in diabetes prevalence is related to changes in dietary pattern, sedentary behavior, and obesity superimposed on a background of genetic/epigenetic susceptibility (61). Most Asian countries have witnessed, to different degrees, a nutritional transition, with increases in intake of refined carbohydrates, animal fats, and meat, and reduced consumption of dietary fiber and vegetables (61,62). Similar to the U.S., the consumption of sugar-sweetened beverages in China has increased dramatically during the last few decades (62).

Several dietary risk factors may be particularly relevant to Asians. The South Asian diet, characterized by high intake of carbohydrates, *trans* fats, and saturated fats (63), appears particularly conducive to the risk of T2DM. White rice constitutes up to 60% of the glycemic load among the Chinese and was found to be associated with an increased risk of diabetes in a meta-analysis (64). This association between white rice intake and risk of T2DM was also noted in India (65). Although rice has been a staple food for centuries, there has been a shift to increased intake of polished rice, which produces a greater glycemic excursion than do the more traditional types of rice. Furthermore, Asians appear to have greater glycemic excursion to white rice compared with other populations (66).

Physical inactivity is an important risk factor for T2DM in most populations (4,5). With increasing urbanization, physical activity has declined, particularly in occupational settings (67), and sedentary behavior has increased. This highlights the importance of encouraging physical activity and reducing sedentary behavior in large-scale community diabetes prevention initiatives in Asia and the Pacific.

Studies that have examined the association between adiposity and diabetes in multiethnic cohorts noted that Asians develop diabetes at a considerably lower BMI compared with Europids (54,68). This is ascribed to visceral adiposity in Asian populations (69). As a result, in Asians, lower BMI cutoffs are being used to define obesity (70) as well as lower waist circumference for defining central obesity (57,70). However, two large observational studies have shown that the incremental risk of diabetes associated with increasing adiposity does not differ between Europid and Asian populations (71,72). Thus, the ethnic difference in the adiposity-diabetes relationship is probably better characterized as an increased risk of diabetes at all levels of BMI (or waist circumference) rather than as diabetes occurring at lower levels of BMI. It is very similar to the increased diabetes risk of Asian populations seen at all ages, and both observations point to factors other than those related to obesity or age that increase diabetes susceptibility in Asian populations.

Several novel putative risk factors have recently emerged as important behavioral and environmental determinants for T2DM. These include sleep disturbances and environmental exposure to organic pollutants and other chemicals (62). Given the major problems of pollution in many developing countries, the latter has the potential to be an important contributor to the diabetes epidemic during adult life or as an in utero exposure.

Developmental Origins of T2DM: Relevance in Asia and Pacific Communities

The initial observations on the association between low birth weight and adult risk of diabetes and metabolic disturbances were made by Hales and Barker (73). It is now increasingly appreciated that the in utero environment plays an important role in modifying developmental trajectory and physiology, thereby altering the risk of obesity, T2DM, and other chronic diseases in adulthood (7).

Studies in relation to the Dutch winter (74) and Chinese (75) famines provide support for the hypothesis that nutritional deprivation in utero may predispose an individual to T2DM in adult life. In those exposed to severe famine in some parts of China during early life, there is a marked increase in the risk of diabetes as adults compared with those not exposed to the same severe nutritional restriction during in utero development. This risk of diabetes in midlife is highest among offspring exposed to in utero undernutrition and who were subsequently exposed to an affluent diet (75). This phenomenon of historical exposure to undernutrition in early life followed by exposure to a "metabolically challenging" environment characterized by an energy-dense diet may be highly relevant to the current high rates of T2DM in parts of Asia and the Pacific.

The emergence of T2DM in Cambodia at rates similar to those in developed nations (16) came decades after the political and socioeconomic upheaval caused severe food shortages in Cambodia in 1975. During World War II, the Nauruans were subjected to famine conditions on Nauru and on other Pacific Islands, such as Truk, where they had been relocated. Some three decades later, Nauru had the highest diabetes prevalence in the world (37). These historical examples show the potential of unexpected health outcomes from wars and famine when later followed by relative overnutrition. Furthermore, the study by Yajnik (76) in India strongly suggest that early development issues and epigenetics may play an important role in the contemporary burden of diabetes experienced in India.

In addition to a link between in utero undernutrition and offspring risk, epidemiological studies, particularly among the Pima Indians, have highlighted increased risk of obesity and T2DM in offspring exposed to maternal diabetes or obesity (77–79). This is also particularly relevant in Asia, where there is a higher proportion of young-onset diabetes and a higher prevalence of GDM compared with Europe and the U.S. (9). Thus, intergenerational cycles may operate in Asia to increase the risk of diabetes in future generations (76).

GDM

With the epidemiological transitions occurring in Asia, leading to a younger age of diabetes onset, the burden of pregnancy complicated by hyperglycemia is increasing (80). Hyperglycemia in pregnancy includes cases of diabetes predating pregnancy as well as GDM. On the basis of a systematic literature review of studies reporting the prevalence of GDM in different countries, the IDF estimated that 16% of pregnancies globally were affected by hyperglycemia in 2013, with a crude prevalence of 11.8% in the IDF WPR and 23.1% in the South Asian region (80). The prevalence of GDM reported in Asia has ranged from 1% to more than 20%, depending on the period, ethnicity, and population in which the study was conducted, as well as the screening

strategy and diagnostic criteria being used, which has been extensively reviewed elsewhere (9). A study from Australia comparing women of different ethnicities with a diagnosis of GDM noted that women from Southeast Asia had the lowest BMI and were more likely to be diagnosed based on elevated 2-h glucose during OGTT, whereas women from Pacific Islands and Anglo-Europeans had the highest BMI and were more likely to be diagnosed based on elevated fasting glucose (81).

A marked secular increase in prevalence of GDM has been reported in several studies; for example, universal screening of pregnant women for GDM in Tianjin, China, showed that the prevalence increased markedly from 2.4 to 6.8% from 1999 to 2008 (82). Use of the diagnostic criteria proposed by the International Association of the Diabetes and Pregnancy Study Groups (IADPSG), recently adopted by the WHO (83), is likely to lead to further increases in GDM prevalence. In a study from Vietnam, for example, applying the IADPSG criteria resulted in an increase in prevalence of GDM from 6.1 to 20.3% (84).

The offspring of mothers with GDM have increased risks of obesity, hypertension, diabetes, and other noncommunicable diseases (78,79). Given the high risk of GDM among Asian populations and the potential transgenerational effects of GDM and maternal nutrition, there is an urgent need to implement preconception interventions to optimize maternal health (85,86). Also, the high prevalence of GDM and its potential long-term effects makes a strong case for universal screening for GDM in Asian populations. This has already been adopted in some Asian countries (9).

Pattern of Diabetes Complications in Asia and Pacific Communities

There are ethnic differences in the pattern of diabetes complications (54). Early observations from the WHO Multinational Study of Vascular Disease in Diabetes (WHO MSVDD) had suggested comparatively high rates of albuminuria in Asian centers (87). In an analysis of 65,171 subjects with T2DM evaluated in primary care in New Zealand between 2000 and 2006 (including 3,166 South Asians and 1,941 East Asians), the risks of having microalbuminuria, macroalbuminuria, and advanced proteinuria were significantly increased 1.4- to 4-fold in Pacific Islanders, South Asians, and East Asians compared with Europeans (88). Moreover, recent studies in multiethnic populations that compared diabetic renal disease among individuals of different ethnicities suggest that ethnic minorities in the U.S., including South Asians and Chinese, are more likely to suffer from proteinuric diabetic renal disease than from nonproteinuric diabetic renal disease (89).

A meta-analysis of studies on the prevalence of diabetic retinopathy noted that South Asians had the lowest prevalence (90). A lower prevalence of peripheral sensory neuropathy was also reported in Asian patients in the Fremantle Diabetes Study (FDS) in Australia compared with patients of European descent (91).

The prevalence of diabetes complications in the Pacific region is higher than that reported for other regions (e.g., Asia, Africa, and the Middle East) (14). Consistent with this, Pacific Islanders in the U.S. have a comparatively high prevalence of foot complications and amputations (92).

In the WHO MSVDD, the prevalence of cardiovascular complications was high in South Asians, but in general was low in centers in China, Hong Kong, and Japan (93). More recent studies have confirmed these earlier observations. For example, other studies in multiethnic populations have noted the high prevalence of cardiovascular complications among South Asian populations, believed to be partly driven by their predisposition to visceral adiposity (6,13). In contrast, patients with T2DM in China appear to have lower rates of cardiovascular complications compared with Europeans (94), and the application to Chinese populations of risk scores developed in European populations tends to overestimate the risk of coronary heart disease (95). Studies that have compared the risk of peripheral vascular disease have noted that South Asians are at lower risk of amputations than Europeans (96).

In addition to ethnic differences in the risk of diabetes complications, the pattern of diabetes complications in Asia is also notable for the large proportion of individuals with young-onset T2DM. In the Joint Asia Diabetes Evaluation (JADE) program, among 41,029 patients recruited from across nine countries/regions in Asia, 18% had onset of T2DM below the age of 40 (97), had longer disease duration, and had higher rates of retinopathy and end-stage renal disease than those with onset of diabetes after the age of 40 (97). In the Hong Kong Diabetes Registry, patients with young-onset diabetes had higher risks of incident cardiovascular and renal complications at any age, driven by the longer disease duration (98). Given the proportion of patients with young-onset T2DM, the potential burden of diabetes-related complications is of great concern.

Prevention of Diabetes

Primary prevention of diabetes is a practical and cost-effective method of reducing incident diabetes in populations of varied ethnicity and biological characteristics (99). Systematic long-term studies conducted in Western nations, such as the U.S. (100) and Finland (101), have shown the benefits of using intensive lifestyle modification (LSM) resulting in significant weight reduction in obese and overweight persons with IGT, leading to a 58% relative risk reduction in diabetes (100). These programs in the Western countries (100) and in China have also shown the enduring effect of LSM, with the effects demonstrated to last at least 10–20 years (102,103).

Studies in the Asian populations, such as the Da Qing studies in China (102,103), the Indian Diabetes Prevention Programme (IDPP) (104) in India, and the Japanese prevention programs (105,106), have shown that LSM is effective in preventing T2DM even in nonobese populations with high levels of insulin resistance and that this is achieved without significant weight reduction. Importantly, the 23-year Da Qing IGT and Diabetes Study follow-up showed a sustained beneficial effect of LSM on diabetes incidence and on cardiovascular and all-cause mortality in the Chinese population (102). Pragmatic, cost-effective, and scalable programs are being tested in developed countries and in South Asian countries (107). A recent study in India showed that the cumulative incidence of diabetes in 2 years was significantly lower among the people with prediabetes who received frequent text messages on mobile phones on healthy lifestyle principles (18%) than among the control group on standard care (27%) (108).

Table 4—Randomized controlled prevention studies in T2DM in Asian populations using lifestyle intervention

Study (year) (Ref)	Study population characteristics	Mean duration (years)	Participants by treatment group (*n*)	Cumulative incidence of diabetes (%)	Relative risk reduction (%)
Da Qing IGT and Diabetes Study (1997) (102)	Chinese: BMI: 26.0 Age: 45.0 Cluster randomized by clinic	6	Total *n* = 577 Control: 133 Diet: 130 Exercise: 141 Diet + exercise: 126	Control: 67.7 Diet: 43.8 Exercise: 41.1 Diet + exercise: 46.0	Diet: 31.0 Exercise: 46.0 Diet + exercise: 42.0
Da Qing Diabetes Prevention Study (2008) (103)	Control BMI: 24.4 Intervention BMI: 24.5	20	Control: 138 Intervention: 439	Control: 93.0 Intervention: 80.0	43.0
Da Qing Diabetes Prevention Study (2014) (103)	Control BMI: 25.7 Intervention BMI: 26.2	23	Total *n* = 568 (by interview from medical records) Control: 138 Intervention: 430	Control: 89.9 Intervention: 72.6 CVD mortality Control: 19.6 Intervention: 11.9 All-cause mortality Control: 38.4 Intervention: 28.0	45.0 41.0 29.0
IDPP-1 (2006) (104)	BMI: 25.8 Age: 45.9 Persistent IGT, individual randomization	2.6 (median)	Total *n* = 531 Control: 136 LSM: 133 Metformin: 133 LSM + metformin: 129	Control: 55.0 LSM: 39.3 Metformin: 40.5 LSM + metformin: 39.5	LSM: 28.5 Metformin: 26.4 LSM + metformin: 28.2
Indian SMS study (2013) (108)	BMI: 25.8 Age: 45.9 Persistent IGT, men	2	Control: 266 Intervention: 271	Control: 27.4 Intervention: 18.5	36.0
Japanese prevention study (2005) (105)	Japanese men: BMI: 23.5 Age: 51.5 IGT, individual randomization	4	Control: 102 Intervention: 356	Control: 9.3 Intervention: 3.0	67.4
Zensharen Study for Prevention of Lifestyle Diseases (2011) (106)	Japanese men: BMI: 27.0 Age: 49.0 IGT, individual randomization	3	Control: 330 Intervention: 311	Control: 16.6 Intervention: 12.2	44.0

Age given as mean (years) and BMI given as mean (kg/m^2). CVD, cardiovascular disease.

Table 4 describes the major diabetes prevention studies in Asia using LSM (102–106,108).

For any program to be successful at a population level, major changes are required at relevant personal, cultural, societal, and community levels (109). An example of the principles laid out in the Western Pacific Declaration on Diabetes (110) being translated in action can be found in Singapore's diabetes prevention efforts discussed below.

Preventing Diabetes in Singapore

According to the 2010 Singapore National Health Survey, the crude diabetes prevalence increased from 8.6% in 1992 to 11.3% in 2010 (111). However, the age-standardized prevalence remained constant at ~11% during the two decades. Obesity prevalence has been rising in the last decade from 6 to 11%. The effect of rising obesity on diabetes prevalence will likely only be evident in one to two decades. It is estimated that Singapore will have half a million people with diabetes by 2020 and that this will rise to 1 million by 2050, double an earlier projection that was based on aging alone (112). The public health policy implication is clearly not just toward increasing the capability of dealing with diabetes once it has arisen (increased capacity and new models of care) but also moving upstream to primary prevention.

The traditional approach to preventing lifestyle-related diseases in Singapore is to provide public education with a strong emphasis on individual responsibility. Singapore's Healthier Hawker Program provides a case study of this approach. It is part of The Healthy Living Master Plan, a major paradigm shift recognizing the need for multisectoral and integrated approaches to intervention.

Hawker centers are a quintessential feature of the Singaporean food landscape and house a variety of cooked food stalls popular for their convenience, competitive prices, and diversity. In 2010, ~60% of Singaporeans ate at least four times per week at hawker centers, food courts, and coffee shop stalls. Improving the nutritional quality of foods sold at hawker centers provides an important opportunity for widespread dietary modification among Singaporeans (113).

The traditional model of workplace safety and health in Singapore is focused on prevention of accidents and occupational diseases. However, with the increasing incidence and earlier onset of diabetes and delay in the retirement age, there will be an increasing number of people with diabetes in the working population. It was estimated that there were 180,000 people with diabetes in Singapore's working population in 2010. The cost to the economy was $1 billion, primarily due to productivity loss. This is of major concern not only to the government but also individual employers. The Total Workplace Safety and Health (TWSH) system was launched jointly by the Ministries of Manpower and Health as a national program to provide a new model of care for the safety and health of the working population (114).

CONCLUSIONS

The scenario presented in this review poses huge social and economic problems to most nations in Asia and the Pacific and is likely to impede national and indeed regional and global development. More action, particularly research, is required to understand the drivers of the epidemic, particularly those relating to developmental origins of T2DM, to provide a rationale for prevention strategies to address this rising public health "tsunami." Primordial prevention strategies instituted in potential mothers, through prevention of malnutrition in utero and in childhood, and through healthy diets and adequate physical activity ("life course approach") are important additional elements to be included in future strategies for T2DM prevention (85). More action is also needed to effectively implement lifestyle changes on a societal level to stem the tide of the epidemic. Unless drastic steps are taken through national prevention programs in Asia and the Pacific to curb the escalating trends in all of the countries, the social, economic, and health care challenges will be insurmountable (1).

Because estimates of the diabetes burden have important implications for future public health planning, it is essential that such estimates provide reliable data. This review highlights the paucity of these data in a number of Asian and Pacific nations and the need for improving the collection of epidemiological data and its interpretation for public health planning to resource and direct urgently needed prevention activities. This applies particularly to lower- and middle-income nations in these regions. India and China already have a huge burden from diabetes, and they provide the largest diaspora communities worldwide. What is already happening in Asia and the Pacific in terms of the diabetes epidemic and the complications and socioeconomic outcomes provides a daunting lesson for what can happen globally.

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