Diabetes in Asia
Epidemiology, Risk Factors, and Pathophysiology

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Once considered a disease of the West, type 2 diabetes is now a global health priority. The International Diabetes Federation has predicted that the number of individuals with diabetes will increase from 240 million in 2007 to 380 million in 2025, with 80% of the disease burden in low- and middle-income countries. More than 60% of the world’s population with diabetes will come from Asia, because it remains the world’s most populous region. The number of individuals with diabetes and impaired glucose tolerance (IGT) in each Asian country will increase substantially in coming decades (Table 1). Unlike in the West, where older populations are most affected, the burden of diabetes in Asian countries is disproportionately high in young to middle-aged adults (Figure).

Asia has undergone marked economic and epidemiologic transition in recent decades. Increasing globalization and East-West exchanges have been accompanied by increasing population movements, changes in food supply and dietary patterns, technology transfer, and cultural admixtures. In the recent World Economics Forum Report, the increasing burden of chronic diseases including diabetes was highlighted as a major global risk predicted to cause substantial financial loss resulting from increased health care expenditure and lost productivity. However, there is considerable heterogeneity in ethnicity, cultures, and stages of socioeconomic development within Asia, all of which affect clinical presentation, management, and prevention of diabetes. In this article, we review epidemiologic trends and complications of type 2 diabetes in Asian populations and discuss risk factors implicated in this epidemic.

EVIDENCE ACQUISITION
We searched MEDLINE using the term diabetes and other relevant keywords (diabetes mellitus, metabolic syndrome, type 2 diabetes). The prevalence of diabetes in Asian populations has increased rapidly in recent decades. In 2007, more than 110 million individuals in Asia were living with diabetes, with a disproportionate burden among the young and middle aged. Similarly, rates of overweight and obesity are increasing sharply, driven by economic development, nutrition transition, and increasingly sedentary lifestyles. The “metabolically obese” phenotype (ie, normal body weight with increased abdominal adiposity) is common in Asian populations. The increased risk of gestational diabetes, combined with exposure to poor nutrition in utero and overnutrition in later life in some populations, may contribute to the increasing diabetes epidemic through “diabetes begetting diabetes” in Asia. While young age of onset and long disease duration place Asian patients with diabetes at high risk for cardio renal complications, cancer is emerging as an important cause of morbidity and mortality.

Conclusions Type 2 diabetes is an increasing epidemic in Asia, characterized by rapid rates of increase over short periods and onset at a relatively young age and low body mass index. Prevention and control of diabetes should be a top public health priority in Asian populations.

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diabetic complications, clinical studies, registry, prospective cohorts, cross-sectional cohorts, case-control, cohorts, epidemiology, prevalence, incidence, causes, causation, diagnosis, prognosis, socioeconomic status, ethnicity, depression, psychosocial stress, smoking, hemoglobinopathy, thalassaemia, visceral fat, hepatitis, C reactive proteins, infections, tobacco, alcohol, dietary factors, persistent organic pollutants, environmental toxins, pollutants, urbanization, acculturation, iron, iron overload, birthweight, body mass index, waist circumference, central obesity, waist hip ratio, exercise, physical activity, risk score, risk equation, risk prediction, adolescent obesity, gestational diabetes, inflammation, nutritional transition, sleep, television watching).

Separate searches were performed for specific Asian countries. We limited the searches to English-language articles published between January 1980 and March 2009; non–English-language studies were excluded, because the quality of these studies is difficult to evaluate. Publications on type 1 diabetes were excluded. High-priority articles included meta-analyses, systematic reviews, large surveys, and cohort studies.

### Table 1. Top 10 Countries in Asia With the Highest Number of Persons With Type 2 Diabetes and Impaired Glucose Tolerance in the Age Group 20 to 79 Years in 2007 and Projected Data in 2025

<table>
<thead>
<tr>
<th>Country</th>
<th>2007</th>
<th>2025</th>
<th>2007</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>40 850</td>
<td>69 882</td>
<td>35 906</td>
<td>56 228</td>
</tr>
<tr>
<td>China</td>
<td>39 809</td>
<td>59 270</td>
<td>64 323</td>
<td>79 058</td>
</tr>
<tr>
<td>Japan</td>
<td>6978</td>
<td>7171</td>
<td>12 891</td>
<td>12 704</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>3848</td>
<td>7416</td>
<td>6819</td>
<td>10 647</td>
</tr>
<tr>
<td>Korea</td>
<td>3074</td>
<td>4163</td>
<td>3224</td>
<td>4240</td>
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<tr>
<td>Thailand</td>
<td>3162</td>
<td>4660</td>
<td>1896</td>
<td>2399</td>
</tr>
<tr>
<td>Philippines</td>
<td>3055</td>
<td>5129</td>
<td>14 144</td>
<td>20 597</td>
</tr>
<tr>
<td>Indonesia</td>
<td>2887</td>
<td>5129</td>
<td>14 144</td>
<td>20 597</td>
</tr>
<tr>
<td>Malaysia</td>
<td>1530</td>
<td>2743</td>
<td>2915</td>
<td>4442</td>
</tr>
<tr>
<td>Vietnam</td>
<td>1294</td>
<td>2500</td>
<td>1175</td>
<td>1902</td>
</tr>
</tbody>
</table>

Subtotal:
- Western Pacific: 66 993 to 99 401
- Southeast Asia: 46 543 to 80 341
- Grand total Asia: 113 536 to 179 742

Source: International Diabetes Federation. All values are in thousands. Includes numbers from Asian countries not shown here.

### Figure. Number of Persons With Diabetes in Different Age Groups and Number of Deaths Attributable to Diabetes in Different Regions of the World in 2007

Source: International Diabetes Federation. EMME indicates Eastern Mediterranean/Middle East; SACA, South America/Central America; SEA, Southeast Asia (comprises Bangladesh, Bhutan, India, Maldives, Mauritius, Nepal, and Sri Lanka [total population, 770 350 000; estimated prevalence of diabetes in the region, 6.3%]). Western Pacific comprises Australia, Brunei Darussalam, Cambodia, China, Hong Kong, Macau, Cook Islands, Fiji, French Polynesia, Guam, Indonesia, Japan, Kiribati, Korea (Democratic People’s Republic of), Korea (Republic of), Lao People’s Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federal States of), Mongolia, Myanmar, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Taiwan, Thailand, Timor-Leste, Tokelau, Tonga, Tuvalu, Vanuatu, and Vietnam (total population, 146 859 000; estimated prevalence of diabetes in the region, 7.6%).

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## Table 2. Trend of Prevalence of Type 2 Diabetes in Asia in Comparison With That in the United States During the Last 2 to 3 Decades

<table>
<thead>
<tr>
<th>Country</th>
<th>Sample</th>
<th>Age, y</th>
<th>Women, %</th>
<th>Mean BMI in Survey Population</th>
<th>Diagnosis Method</th>
<th>Criteria&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Prevalence, %</th>
<th>Age Adjusted</th>
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<tbody>
<tr>
<td><strong>United States</strong></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>1976-1980</td>
<td>National</td>
<td>20-74</td>
<td>51.9</td>
<td>25.3</td>
<td>FPG</td>
<td>ADA 1997</td>
<td>5.3</td>
<td>Yes</td>
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<td>1999-2000</td>
<td>National</td>
<td>20-74</td>
<td>50.4</td>
<td>28.0</td>
<td>FPG</td>
<td>ADA 1997</td>
<td>8.2</td>
<td>Yes</td>
</tr>
<tr>
<td>2005-2006</td>
<td>National</td>
<td>20-74</td>
<td>51.07</td>
<td>28.7</td>
<td>FPG/OGTT</td>
<td>ADA 1997</td>
<td>12.6</td>
<td>Yes</td>
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<tr>
<td><strong>Mainland China</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>14 provinces</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>FPG/OGTT</td>
<td>&gt;130/&lt;200 mg/dL</td>
<td>~ 1</td>
<td>Yes</td>
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<tr>
<td>1994-1995</td>
<td>19 provinces</td>
<td>25-64</td>
<td>44.8</td>
<td>23.8 (NGT)</td>
<td>FPG/OGTT</td>
<td>WHO 1985</td>
<td>2.5</td>
<td>Yes</td>
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<td>2000-2001</td>
<td>31 provinces</td>
<td>35-74</td>
<td>51.4</td>
<td>24.3 (urban, 23.3 (rural) 24.8 (North) 22.8 (South))</td>
<td>FPG</td>
<td>ADA 1997</td>
<td>5.5</td>
<td>No</td>
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<td></td>
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<tr>
<td>1993</td>
<td>Employees</td>
<td>30-64</td>
<td>39.8</td>
<td>NA</td>
<td>FPG/OGTT</td>
<td>WHO 1985</td>
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<td>1995-1996</td>
<td>Entire region</td>
<td>25-74</td>
<td>Men:Women</td>
<td>23.5 (NGT) 26.6 (impaired fasting glucose [ADA criteria])</td>
<td>FPG/OGTT</td>
<td>WHO 1999</td>
<td>9.8</td>
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<td>1987-1988</td>
<td>Pu-Li</td>
<td>≥30</td>
<td>52.1</td>
<td>23.0 (NGT) 23.7 (diabetes; 23.0 (previous, 24.6 (new))</td>
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<td>WHO 1985 (modified)</td>
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<td>Tainan city</td>
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<td>48.7</td>
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<td>OGTT</td>
<td>WHO 1985</td>
<td>9.2</td>
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<td>1981-1982</td>
<td>Tokyo</td>
<td>≥30</td>
<td>21.6</td>
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<td>WHO 1980</td>
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<td>WHO 1985</td>
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<td>WHO 1985</td>
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<td>1991</td>
<td>Yonchon County, South Korea</td>
<td>30-64</td>
<td>56.3</td>
<td>Not reported</td>
<td>OGTT</td>
<td>WHO 1985</td>
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<td>≥30</td>
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<td>ADA 1997</td>
<td>6.9</td>
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<td>Nationwide</td>
<td>≥20</td>
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<td>FPG</td>
<td>ADA 1997</td>
<td>7.6</td>
<td>Yes</td>
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<td>≥30</td>
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<td>OGTT</td>
<td>ADA 1997</td>
<td>11.7</td>
<td>Yes</td>
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<td><strong>India</strong></td>
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<td>1979</td>
<td>Multicenter</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
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<td>3 (urban) 1.3 (rural)</td>
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<td>≥25</td>
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<td>OGTT</td>
<td>WHO 1999</td>
<td>4.3 5.6 (urban) 2.7 (rural)</td>
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<td>2003-2005</td>
<td>Nationwide</td>
<td>15-64</td>
<td>51</td>
<td>23.1 (urban males) 24 (urban females) 20.3 (rural males) 20.8 (rural females)</td>
<td>Self-report</td>
<td>NA</td>
<td>4.5 7.3 (urban) 3.1 (rural)</td>
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<td><strong>Pakistan</strong></td>
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<tr>
<td>1994-1999</td>
<td>Nationwide</td>
<td>≥25</td>
<td>66.2</td>
<td>22.4 (urban men) 24.5 (urban women) 22.6 (rural men) 25 (rural women)</td>
<td>OGTT</td>
<td>WHO 1985</td>
<td>6 (urban men) 3.5 (urban women) 3.3 (rural men) 2.5 (rural women)</td>
<td>No</td>
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</table>

Table 2. Trend of Prevalence of Type 2 Diabetes in Asia in Comparison With That in the United States During the Last 2 to 3 Decades (continued)

<table>
<thead>
<tr>
<th>Country</th>
<th>Sample</th>
<th>Age, y</th>
<th>Women, %</th>
<th>Mean BMI in Survey Population</th>
<th>Diagnosis Method</th>
<th>Criteria</th>
<th>Prevalence, %</th>
<th>Age Adjusted</th>
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<tbody>
<tr>
<td>Bangladesh</td>
<td>Dhaka city-suburban</td>
<td>30-64</td>
<td>35.2</td>
<td>20.17 (NGT, men) 19.7 (NGT, women)</td>
<td>FPG/OGTT</td>
<td>WHO 1985</td>
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<td>1999</td>
<td>Chandra region-rural</td>
<td>≥20</td>
<td>57.2</td>
<td>20.2</td>
<td>FPG/OGTT</td>
<td>WHO 1999</td>
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<td>59.8</td>
<td>20.7</td>
<td>FPG/OGTT</td>
<td>WHO 1999</td>
<td>6.8</td>
<td>No</td>
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<td>2005</td>
<td>Dhaka city-urban</td>
<td>≥20</td>
<td>52.9</td>
<td>19.4</td>
<td>FPG/OGTT</td>
<td>WHO 1999</td>
<td>8.1</td>
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<td>Nepal</td>
<td>Kathmandu/Kabre</td>
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<td>52</td>
<td>19.5 (suburban men) 19.6 (suburban women)</td>
<td>FPG</td>
<td>ADA 1997</td>
<td>1.4 (suburban) 0.3 (rural)</td>
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<td>1999-2001</td>
<td>Urban/rural</td>
<td>≥20</td>
<td>53.7</td>
<td>Not reported</td>
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<td>ADA 1997</td>
<td>14.6 (urban) 2.5 (rural)</td>
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<td>2007</td>
<td>Semi-urban</td>
<td>21-94</td>
<td>60</td>
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<td>NA</td>
<td>NA</td>
<td>9.5</td>
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<td>Sri Lanka</td>
<td>Suburban</td>
<td>30-64</td>
<td>50.7</td>
<td>Not reported</td>
<td>OGTT</td>
<td>WHO 1985</td>
<td>5.0</td>
<td>Yes</td>
</tr>
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<td>2005-2006</td>
<td>National</td>
<td>&gt;20</td>
<td>60</td>
<td>21.2 (NGT) 23.8 (diabetes)</td>
<td>FPG/OGTT</td>
<td>ADA 1997</td>
<td>10.3</td>
<td>Yes</td>
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<tr>
<td>Indonesia</td>
<td>Jakarta-urban</td>
<td>≥15</td>
<td>52.8</td>
<td>NA</td>
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<td>NA</td>
<td>10.5</td>
<td>NA</td>
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<td>1995</td>
<td>Jakarta-urban</td>
<td>NA</td>
<td>Male/Female</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2.1</td>
<td>NA</td>
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<td>Kelantan-Malay/rural</td>
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<td>Men/Women</td>
<td>NA</td>
<td>FPG/OGTT</td>
<td>WHO 1980</td>
<td>10.5</td>
<td>NA</td>
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<td>2005-2006</td>
<td>National</td>
<td>25-64</td>
<td>Men/Women</td>
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<td>11</td>
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<td>Thailand</td>
<td>National</td>
<td>≥30</td>
<td>56.5</td>
<td>22 (men) 23.5 (women)</td>
<td>FPG ≥7.8 mmol/L</td>
<td>2.4 (men) 3.7 (women)</td>
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<tr>
<td>2000</td>
<td>National</td>
<td>≥35</td>
<td>Men/Women</td>
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<td>FPG ≥7 mmol/L</td>
<td>9.6</td>
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<tr>
<td>2004</td>
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<td>≥15</td>
<td>Male/Female</td>
<td>22.3 (NGT) 28.3 (diagnosed diabetes)</td>
<td>FPG ≥7 mmol/L</td>
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<td>Vietnam</td>
<td>Hanoi</td>
<td>30-64</td>
<td>53.5</td>
<td>19.3 (men) 20.1 (women) (subset of 116 with new diabetes)</td>
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<td>WHO 1985</td>
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<td>Ho Chi Minh</td>
<td>≥15</td>
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<td>ADA</td>
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<td>Cambodia</td>
<td>Rural/suburban</td>
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<td>Philippines</td>
<td>Luzon-urban</td>
<td>Adults</td>
<td>Men/Women</td>
<td>NA</td>
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<td>20-65</td>
<td>63.5</td>
<td>22.9 (men) 23.3 (women)</td>
<td>OGTT</td>
<td>WHO 1999</td>
<td>4.8</td>
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(continued)
In urban Indian adults, diabetes prevalence increased from 3% in the early 1970s to 12% in 2000, with a narrowing rural-urban gradient. In 2006, the rate of type 2 diabetes in rural South India was 9.2%, compared with an increase in urban South India from 13.9% in 2000 to 18.6% in 2006.

In rural Bangladesh, prevalence of diabetes increased from 2.3% to 6.8% between 1999 and 2004. In a national survey in 2001, 8% of Korean adults had diabetes, with little difference between urban and rural areas. In a nationwide survey in Singapore in 1998, Indians had the highest prevalence of diabetes (12.8%), followed by Malays (11.3%) and Chinese (8.4%). Similarly, 11% of Malays living in Malaysia have diabetes. Other Asian countries including Japan, Sri Lanka, Indonesia, Thailand, and Vietnam have also experienced a marked increase in prevalence of diabetes (Table 2). While some Asian countries like China and India have a very large number of patients with diabetes, the prevalence of diabetes can be as high as 40% in some Pacific Island populations.

### Risk Factors for the Diabetes Epidemic in Asia

#### Increasing Overall and Abdominal Obesity

Asians have lower rates of overweight and obesity than their Western counterparts, using conventional definitions (body mass index [BMI] ≥25 for overweight and ≥30 for obesity, calculated as weight in kilograms divided by height in meters squared). Despite lower BMI, some Asian countries have similar or even higher prevalence of diabetes than Western countries. These data confirm that the risk of type 2 diabetes starts at a lower BMI for Asians than for Europeans.

In China, the prevalence of overweight (BMI ≥25) in adults increased from 14.6% to 21.8% between 1992 and 2002. In a cross-sectional survey of 15,540 Chinese adults aged 35 to 74 years in 2000-2001, the age-standardized prevalence of overweight was 26.9% in men and 31.1% in women, with higher rates in northern than in southern China as well as higher rates in urban than in rural residents. In India, between 2003 and 2005, the prevalence of overweight ranged from 9.4% in rural men to 38.8% in urban women. Using the same BMI cutpoint, 28.6% of adults living in urban Pakistan were overweight. In developing countries, obesity in adults is not necessarily a disease of the socioeconomic elite, as is commonly believed.

In fact, the burden of obesity and diabetes tends to shift toward lower socioeconomic status groups as a country’s gross national product increases. The increasing trend of childhood obesity in Asia places many young individuals at high risk for type 2 diabetes in early adulthood. In China, based on the 2000 reference values from the US Centers for Disease Control and Prevention, 22.9% of boys and 10.4% of girls attending urban schools were overweight. Among schoolchildren in urban South India, 17.8% of boys and 15.8% of girls were overweight. Similar rates have been reported in Malaysia, Korea, and Thailand. In Hong Kong, 2.3% of adolescents have the metabolic syndrome, with family history of diabetes, BMI, and low academic performance as independent predictors.

Asian populations, especially those of South Asian descent, are more prone to abdominal obesity and low muscle mass with increased insulin resistance.
compared with their Western counterparts.20,67-77 Thus, waist circumference reflecting central obesity is a useful measure of obesity-related risk of type 2 diabetes, especially in individuals with normal BMI values.87,74 In Singapore, for the same age, sex, and BMI, Indians had the highest body fat percentage, followed by Malays and Chinese. All 3 groups had a higher body fat percentage than whites.70

Using imaging technology (such as computed tomography scan) to measure total body fat and specific depots of fat, healthy Chinese and South Asian individuals were found to have a greater amount of visceral adipose tissue than Europeans with the same BMI or waist circumference.73 These data suggest that the increased risk of type 2 diabetes in Asian populations may be attributed to increased abdominal and visceral adiposity for a given BMI. Despite having a lower body weight, Indian infants have higher subcutaneous fat, leptin, and insulin levels than white infants.76 This “metabolically obese” phenotype (eg, normal weight by conventional BMI standards but increased abdominal adiposity) has been associated with increased risk of insulin resistance and diabetes.77 In Asian populations, the amount of visceral fat (including mesenteric fat) and fatty liver was significantly associated with subclinical atherosclerosis.78 In addition, increased waist circumference has been associated with substantially increased risk of developing diabetes.67,79,80 as well as increased risk of cardiovascular and all-cause mortality, independent of BMI.81-84

Nutrition Transition and Changes in Diet and Lifestyle. In many Asian countries, rapid socioeconomic development has led to a concurrent shift in infrastructure, technology, and food supply that promotes overnutrition and sedentary lifestyles. Traditional dietary patterns are disappearing as Asians adapt to increasingly industrial and urban conditions resulting from globalization. Rapid nutrition transition has left many countries facing coexisting problems of overnutrition and undernutrition.60,83

In China between 1992 and 2002, the proportion of energy intake from animal foods increased from 9.3% to 13.7% and that from fats from 22% to 29.8%.88 In India the change was more pronounced among urban residents, who consumed 32% of energy from fat compared with 17% in rural residents.86 Substantial increases in animal fat intake also have been reported in Vietnam,40 Japan,86 Korea,64,88 and Thailand.89 Vegetable ghee, such as Dalda—a clarified butter commonly used in cooking in India and other southeastern Asian countries—contains trans fatty acid levels as high as 50%.90 Higher intake of trans fatty acids has been associated with weight gain, increased cardiometabolic risk, and insulin resistance.91-93 Polished rice and refined wheat form the basis of most Asian diets with high glycemic index and glycemic load values.94 The glycemic index of Vietnamese rice ranges from 86 to 109.72 In a prospective cohort study of middle-aged Chinese women, a high intake of foods with a high glycemic index or glycemic load, especially rice, is associated with a 2-fold increased risk of type 2 diabetes,95 especially in overweight and obese individuals. Similar findings have been reported in Japan.96 Consumption of sugar-sweetened beverages, an important contributor of dietary glycemic load and excess calories, has increased rapidly worldwide, particularly in Asia.97 Increased urbanization and universal use of automobiles has caused many Asians to shift from a physically active, agrarian lifestyle marked by energy scarcity to a sedentary lifestyle marked by energy surplus. In developing countries, a rapid uptake of technologies has been accompanied by increasing shifts from agriculture and increasing employment in manufacturing and services.90 In Asia, automobiles are rapidly replacing bicycles as the primary mode of transportation. In China, an average of 1 in 10 Beijing permanent residents owns a car.98 In the past decade, the annual rate of increase in motor vehicle ownership in India was approximately 11%.99

Psychosocial stress, depression, and short sleeping hours, which have become increasingly common in developing countries undergoing rapid economic developments, have been associated with higher risk of the metabolic syndrome and diabetes in Asian populations.98-101 In a meta-analysis, depression was associated with a 60% increased risk of type 2 diabetes, while the latter was associated with a 15% increased risk of depression.102 The coexistence of diabetes and depression was associated with a 50% to 100% increased risk of all-cause mortality.103

Cigarette Smoking. In a recent meta-analysis, current smoking was associated with 44% increased risk of developing diabetes.104 A similar positive association has been reported in Korea,105 Taiwan,106 and China.107 Smoking is known to induce insulin resistance and inadequate compensatory insulin secretion responses. Among individuals with normal BMI, smokers were more likely to have abdominal obesity than nonsmokers.108 In many Asian countries, between 50% and 60% of adult men are regular smokers.105-107 China, followed by India, is the greatest producer and consumer of cigarettes in the world. Almost 1 of 3 cigarettes produced worldwide is consumed in China.108 Most Indians use smokeless tobacco products, such as betel quid, and 40% smoke bidi—small, often flavored, nontaxable cigarettes—the production of which provides employment for many urban poor.109

Pancreatic Beta Cell Function. In the 1980s, Japanese researchers first unraveled that reduced early insulin response was an independent predictor for diabetes.110 Fukushima et al111 found that at all stages of glucose intolerance, Japanese individuals had reduced early and late phases of insulin responses. In Japanese men with normal glucose tolerance, even a small increase in BMI produced a decrease in beta cell function disproportionate to that in insulin sensitivity.112 In a sample of Chinese patients with type 2 diabetes, 50% were of normal weight, with
low BMI correlating with low levels of fasting plasma C-peptide (a marker of decreased insulin secretion) and high glycated hemoglobin levels. In a prospective survey of Japanese Americans, visceral fat area and reduced incremental insulin response were independent predictors for diabetes. Taken together, in some Asian populations, inadequate beta cell response to increasing insulin resistance results in loss of glycemic control and increased risk of diabetes, even with relatively little weight gain.

**Developmental Origins of Diabetes.**
Many Asian adults who experienced great hardship during wartime or civil unrest in early life are now experiencing marked changes in lifestyle. In addition, low birth weight and exposure to undernutrition in utero are common in some Asian populations, especially in India, where 30% of infants are underweight. Insults or stresses during the intrauterine period can lead to permanent changes in structure, metabolism, and physiology through altered expression of the genome without changes in the DNA code, a process called epigenetics. These early life events may influence later susceptibility to diabetes, the metabolic syndrome, and cardiorenal diseases. Prospective studies from India have shown the impact of fetal undernutrition (often manifested as low birth weight) as well as overnutrition (eg, the infant of a mother with diabetes) on future risk of diabetes. In India, thinness in infancy and overweight at age 12 years was associated with increased risk of developing IGT or diabetes in young adulthood.

A recent meta-analysis of 30 studies found a significant graded association between low birth weight and increased risk of type 2 diabetes. Low birth weight has also been found to predict diabetes and the metabolic syndrome in Asian adults and children, thus lending support to the notion that fetal programming with exposure to poor nutrition in utero or during early childhood can promote a fat-preserving or thrifty phenotype. These metabolic changes predispose individuals to insulin resistance and reduced beta cell function. Positive energy balance in later life, caused by rapid westernization of diet and lifestyle, may then exacerbate accumulation of adiposity, particularly in the central depots.

The 2- to 3-fold higher risk of gestational diabetes in Asian women than in their white counterparts also may contribute to the increasing epidemic of young-onset diabetes in Asia. Asian women with a history of gestational diabetes have a substantially increased risk of diabetes, while their offspring exhibit early features of the metabolic syndrome, thus setting up a vicious cycle of “diabetes begetting diabetes.” This combination of gestational diabetes, in utero nutritional imbalance, childhood obesity, and overnutrition in adulthood will continue to fuel the epidemic in Asian countries undergoing rapid nutritional transitions.

**Genetic Susceptibility.** Among lean, healthy individuals matched for age, BMI, waist circumference, birth weight, and current diet, Asians (especially those of Southeast Asian descent) had higher levels of postprandial glycaemia and lower insulin sensitivity than whites in response to a 75-g carbohydrate load. These findings raise the possibility that Asians are more genetically susceptible to insulin resistance and diabetes than whites.

Several diabetes genes recently discovered through genome-wide association studies in white populations have been confirmed in Asians as well. However, there were significant inter-ethnic differences in risk allele frequency and location. Using the transcription factor 7-like 2 gene TCF7L2 (rs7901349) as an example, the minor allele frequency was 0.28 to 0.41 and 0.05 to 0.07 in Asian and European populations, respectively. The potassium voltage-gated channel, subfamily Q, member 1 gene KCNQ1, the minor allele frequency of rs2237892 was 0.28 to 0.41 and 0.05 to 0.07 in East Asian and European populations, respectively. Most diabetes genetic variants identified so far, including those in TCF7L2 and KCNQ1, appear to be associated with decreased insulin secretion in whites as well as Asians. In addition, among Asian adults diagnosed with diabetes before age 40 years, approximately 40% had a lean, nonautoimmune phenotype with rapid oral drug failure. Approximately 10% of these patients carried genetic variants encoding pancreatic beta cell pathways, including transcription factors and amylin, or mitochondrial polymorphisms. These findings provide further evidence that beta cell dysfunction plays a critical role in the development of diabetes in Asians.

**Other Risk Factors.** Emerging evidence suggests that exposure to environmental irritants, such as persistent organic pollutants, is associated with increased insulin resistance, the metabolic syndrome, and diabetes. Studies from Taiwan and Bangladesh have found a strong association between chronic arsenic exposure and risk of diabetes. Consistent with studies in whites, found that moderate iron overload predicted diabetes in Chinese individuals. Hemoglobinopathies, such as α and β thalassemia traits and hemoglobin H disease, which are associated with increased iron turnover, are present in 8% to 10% of Chinese individuals. Asian individuals with thalassemia traits were reported to have a several-fold increased risk of gestational diabetes, insulin resistance, and glucose intolerance.

Approximately 8% to 10% of Asian populations, including Chinese individuals, are chronic hepatitis B viral carriers. Compared with noncarriers, Chinese women who were hepatitis B carriers had a 30% increased risk of gestational diabetes, independent of other well-known diabetes risk factors. Chronic hepatitis B carriers affected by type 2 diabetes also had an earlier age of diagnosis and 4-fold higher risk of end stage renal disease (ESRD) than noncarriers. Similar risk associations with diabetes and diabetic kidney disease have been reported in chronic hepatitis C carriers. Other infections endemic in Asia, such as tuberculosis, have also been linked with increased risk of diabetes. The 2- to 3-fold higher risk of gestational diabetes in Asian women than in their white counterparts also may contribute to the increasing epidemic of young-onset diabetes in Asia. Asian women with a history of gestational diabetes have a substantially increased risk of diabetes, while their offspring exhibit early features of the metabolic syndrome, thus setting up a vicious cycle of “diabetes begetting diabetes.” This combination of gestational diabetes, in utero nutritional imbalance, childhood obesity, and overnutrition in adulthood will continue to fuel the epidemic in Asian countries undergoing rapid nutritional transitions.

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Complications and Comorbid Conditions of Diabetes in Asia

In the World Health Organization Multinational Study of Vascular Diseases in Diabetes, conducted in the early 1970s, stroke and kidney failure were leading causes of death in Chinese, Japanese, and Pima Indian patients with diabetes, compared with coronary heart disease (CHD) in white patients. In the Asia-Pacific Collaborative Study, among patients with diabetes, the leading cardiovascular cause of death was stroke (42%) in Asia and CHD (59%) in Australia and New Zealand. However, within Asia, there were marked differences in these complications, with China and Japan having higher rates of stroke than CHD, while in Hong Kong and Singapore, the rate of stroke was similar to or even lower than that of CHD.

Asian patients with diabetes continue to exhibit high risk for renal complications, even after accounting for socioeconomic status. In an international survey, 55% of Asian and 40% of white patients with type 2 diabetes had increased albuminuria. Chinese individuals with IGT were found to have a high prevalence of albuminuria, with 2-hour plasma glucose level as an independent predictor. In observational studies as well as clinical trials, Asian patients with diabetes were more likely to develop ESRD than their white counterparts. However, only a small fraction of these patients can afford renal replacement therapy in developing countries such as China. Importantly, albuminuria and renal function are powerful predictors of CHD in Asian as well as white populations, with or without diabetes.

In a 25-year prospective survey, 60% of young Japanese patients with type 2 diabetes diagnosed before age 35 years became blind or had developed ESRD at a mean age of 50 years. In a multiflcanic study in Singapore, Indians had the highest risk of diabetes. Among the individuals with diabetes, Indians had the highest risk for CHD, while Malays had the highest risk for ESRD and mortality due to heart failure. In a Malaysian dialysis registry, diabetic nephropathy contributed 55% of all new cases of dialysis, with a mean age of 50 years and a preponderance of women. In this multiethnic registry, Malays had the highest incidence of ESRD, followed by Indians and Chinese.

In Chinese patients with diabetes, risk factors for chronic kidney disease included smoking, long disease duration; high calcium phosphate product; albuminuria; increased blood pressure, waist circumference, and levels of triglycerides, low-density lipoprotein cholesterol, and glycated hemoglobin; and decreased glomerular filtration rate and levels of high-density lipoprotein cholesterol. Genetic factors, including aldose reductase and angiotensin-converting enzyme deletion/insertion polymorphisms, were associated with risk of chronic kidney disease in patients with diabetes. In addition, low hematocrit values were found to be an independent predictor of ESRD and cardiovascular complications in Chinese individuals. Furthermore, low blood hemoglobin level was associated with decreased levels of insulin growth factor 1 and testosterone in Asian and white men with diabetes, the metabolic syndrome, or diabetic kidney disease. Given the possible epigenetic regulation of the hypothalamic-pituitary-adrenal axis and the growth hormone–insulin growth factor 1 axis, neurohormonal dysregulation is likely to be implicated in diabetic kidney disease.

Several meta-analyses have shown that except for prostate cancer, diabetes was associated with a 30% to 40% increased risk of breast, endometrial, pancreatic, liver, and colorectal cancers. Patients with cancer as well as diabetes also had a 40% to 80% higher risk of death than those without diabetes. Community-based prospective surveys, including those conducted in Asia, reported independent associations of fasting and 2-hour plasma glucose levels with cancer risk. Given the high rates of IGT, which predicts all-cause mortality in Asian populations, there is a need to understand the potential role of glucose metabolism and insulin resistance in carcinogenesis.

Changing patterns of disease and medical care are accompanied by secular changes in causes of death in Asian patients with diabetes. In Hong Kong, for example, the majority of Chinese patients with type 2 diabetes died from stroke and ESRD until the early 1990s. In the mid-1990s, heart disease emerged as the leading cause of death. In 1995, a prospective diabetes registry was established in Hong Kong. It recruited 7000 patients with type 2 diabetes, half of whom were middle-aged at diagnosis. Ten years after diagnosis, 30% had died or had sustained a major clinical event, with cancer (20%), CHD (20%), ESRD (10%), and stroke (10%) as major causes of death.

COMMENT

The diabetes epidemic in Asia is characterized by rapid rates of increase over short periods and onset at a relatively young age and low BMI. The epidemic is heterogeneous, varying according to different ethnic and cultural subgroups, degree of urbanization, and socioeconomic conditions in different Asian populations. In parallel with economic development and nutrition transition, the rates of overweight and obesity have been increasing rapidly in Asian countries. Abdominal or central adiposity, particularly detrimental to type 2 diabetes and other metabolic diseases, is highly prevalent in Asians. The high rates of gestational diabetes, in combination with in utero exposure to poor nutrition, childhood obesity, and overnutrition in later life, may contribute substantially to the increasing diabetes epidemic in Asia.

While further research is needed to systematically monitor secular trends of diabetes in Asian populations, characterize risk factors, and understand interactions between genetic and envi...
ronmental risk factors, ample evidence from Asia has shown that diabetes and its complications is preventable and highly treatable. In the early 1990s, a randomized trial in China demonstrated that dietary and exercise intervention reduced diabetes risk by 31% to 46% in individuals with IGT. These results have since been confirmed in Europe, the United States, India, and Japan. In observational studies and randomized trials conducted in Asia and Europe, control of multiple risk factors reduced cardiorenal complications and all-cause death by 50% to 70% in individuals with type 2 diabetes.

Type 2 diabetes mellitus has become an epidemic in Asia. To curb this epidemic, an integrated strategy combining population-wide preventive policies (eg, changing food and the built environment), early detection, and multidisciplinary care programs may reduce the risk of diabetes and associated complications in the general population and in high-risk individuals.

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Drafting of the manuscript: Chan, Malik, Hu.

Critical revision of the manuscript for important intellectual content: Chan, Malik, Jia, Kadowaki, Yajnik, Yoon, Hu.

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