Global Diabetes Landscape—Type 2 Diabetes Mellitus in South Asia: Epidemiology, Risk Factors, and Control

Rajeev Gupta, MD, PhD
Department of Medicine, Fortis Escorts Hospital, Jaipur, India

Praneet Kumar, MBBS, DHA
Department of Medical Services, Fortis Escorts Hospital, Jaipur, India

ABSTRACT

Background: Type 2 diabetes mellitus (DM) is a new epidemic in South Asia and is the result of societal influences and changing lifestyles. Epidemiologic studies suggest that the prevalence of DM has increased exponentially in urban and rural populations.

Objective: This study was conducted to determine trends in the prevalence of DM in various countries in South Asia.

Methods: We performed an extensive, systematic MEDLINE search for primary articles that reported on the epidemiology of DM in South Asia. Additional articles were obtained from personal collections and references cited in the primary articles. No formal meta-analysis was performed because of differing methodologies and diagnostic criteria.

Results: Epidemiologic studies conducted in India during the 1960s and 1970s, using random and postload blood glucose estimations, reported DM in 1% to 4% of urban populations and 1% to 2% of rural populations. More standardized epidemiologic studies in adults since the late 1980s reported DM in 5% to 15% of urban populations, 4% to 6% of semiurban populations, and 2% to 5% of rural populations. A significantly increasing trend has been observed in urban populations (exponential trend $R^2 = 0.74$), whereas the increase is slower ($R^2 = 0.29$) in rural populations. The diabetes scenario is similar in other South Asian countries. Current prevalence rates are 5% to 16% in urban areas and 2% to 8% in rural areas. Risk factors for DM in this region are increasing sedentariness, dietary excess, obesity (especially high waist-to-hip ratio), low birth weight, and genetic influences.

Conclusions: DM is a major public health problem in South Asia. The prevalence is higher in urban areas than in rural areas and is increasing. Population-based measures to control the epidemic of DM include avoidance of adiposity through enhanced physical activity and regulated calorie intake. A comprehensive national chronic care program is needed. (*Insulin*. 2008;3:78–94) © 2008 Excerpta Medica Inc.

Key words: type 2 diabetes mellitus, epidemiology, India, Pakistan, Bangladesh, Sri Lanka, Nepal, cardiovascular disease.

INTRODUCTION

Noncommunicable diseases have emerged as major health problems in South Asia.[1] The Million Death Study in India reported that noncommunicable diseases caused 41.3% of all deaths in the years 2001 to 2003.[2] The remaining deaths were attributed to communicable, maternal, perinatal, and nutritional diseases (33.4%), injuries (9.2%), and ill-defined conditions (16.1%).[2] Noncommunicable diseases and injuries caused 63.8% of deaths in urban areas and 47.7% of deaths in rural areas. Cardiovascular diseases have emerged as the leading cause of death in India; proportionate mortality due to these conditions was 17.5%, with a higher rate reported in urban areas (26.7%) than in rural areas (15.6%). Among adults aged 25 to 69 years, cardiovascular diseases led to 24.0% of all deaths (men 24.8%, women 20.6%).[2] These diseases led to a higher mortality rate in urban areas (32.1%) than in rural areas (21.9%). Other important causes of death in India include tuberculosis, chronic lung diseases, malignant neoplasms, unintentional injuries, digestive diseases, diarrhea, intentional injuries, genitourinary diseases, malaria, and type 2 diabetes mellitus (DM) (**Figure 1**).[2] Infections are more common in rural areas, whereas noncommunicable diseases such as cardiovascular diseases and DM are more common in urban areas. Accurate mortality statistics are lacking in other South Asian countries but likely are similar, and cardiovascular diseases and DM are important health issues in this region.

According to the second Global Burden of Disease study[3] and World Health Report 2004,[4] the annual disability-adjusted life years (DALYs) lost due to DM in 2002 was

Accepted for publication November 12, 2007.

1557-0843/$32.00
© 2008 Excerpta Medica Inc. All rights reserved.

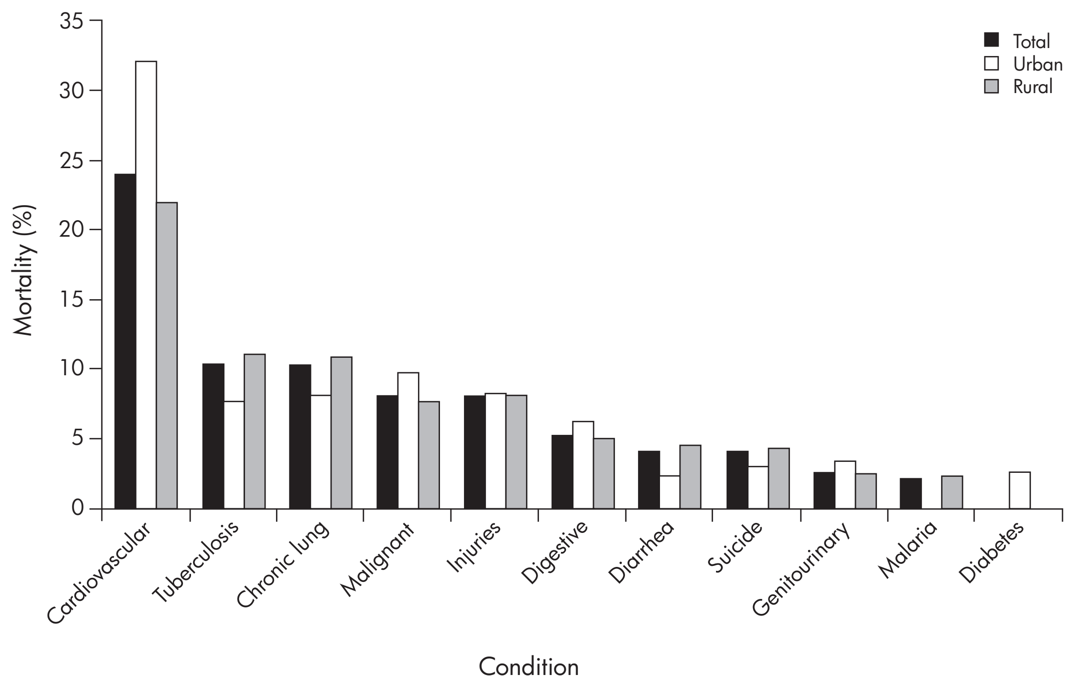


Figure 1. Major causes of death among adults 25 to 69 years of age in India from 2001 to 2003.[2] The bars represent proportionate mortality from various conditions. Diabetes mellitus is an important cause of death, especially among urban populations.

16.2 million (men 7.6 million, women 8.6 million), which was 1.1% of the total disease burden and 2.3% of the noncommunicable disease burden worldwide. The burden of DM varied in different World Health Organization (WHO) regions; DALYs lost were 0.5 to 0.6 million in Africa, 0.2 to 1.8 million in the Americas, 0.5 to 1.1 million in Europe, and 0.4 to 0.8 million in the Eastern Mediterranean region. The burden is very high in Southeast Asia, which includes India (1.1–3.6 million) and Bangladesh, and in the Western Pacific region, which includes China (0.2–1.3 million).[3]

DM caused 988,000 deaths worldwide in the year 2002, amounting to 1.7% of all deaths.[4] The mortality burden from diabetes is low, possibly due to forgotten importance of diabetes as a risk factor for infections and cardiovascular disease in routine national mortality statistics. It has been reported that among adults aged >50 years, men with DM lived 7.5 years less and women with DM lived 8.2 years less than their nondiabetic peers.[5]

Cardiovascular disease is a major cause of death in patients with DM. The Framingham study reported that diabetic subjects faced mortality similar to that of nondiabetic subjects with acute myocardial infarction, and when subjects with diabetes developed coronary heart disease, the risk of death almost doubled.[6]

Changing societal structures and lifestyles are accelerating the epidemic of DM in South Asian countries.[7] Proximate causes for this epidemic are excessive consumption of calories and declining physical activity, which lead to increasing obesity, especially truncal obesity (high waist-to-hip ratio). The interaction of genetic predisposition, environmental influences, and multiple risk factors initiates a pathophysiologic cascade that culminates in DM.[5]

DM has been present in South Asia for centuries.[8] Epidemiologic studies reveal that the prevalence of this condition has increased exponentially in urban populations and that even the underprivileged are not exempt.[9–11] The region of South Asia that includes India, Pakistan, Bangladesh, Sri Lanka, and Nepal is home to 1.5 billion people, and recent estimates show that this area houses the largest number of people with DM in the world.[10] This article summarizes studies that have been conducted on the epidemiology of DM in India and other countries of South Asia, discusses these findings in the context of worldwide data, and suggests population-based interventions for control of this epidemic. A novel national chronic care program is suggested.

METHODS

The studies reported in this review are based on an extensive literature search and participation in expert meetings, along with many years of research in the area. We conducted a systematic MEDLINE search for articles in English using the key words *diabetes*, *epidemiology*, *prevalence*, *burden*, *India*, *Pakistan*, *Bangladesh*, *Sri Lanka*, *Ceylon*, and *Nepal*. We also obtained articles that were referenced from the primary articles and published in regional journals. A manual search

of articles in Indian journals that were not available in MEDLINE was also performed.

Because the sample selection criteria and methodologies differed between studies, no attempt was made to conduct a formal meta-analysis. Results from a large number of studies from India and studies that used similar age-specific selection criteria were plotted using Microsoft® PowerPoint software (2003) (Microsoft Corporation, Redmond, Washington), and trends were determined after plotting the exponential trendline within this program.

DIABETES MELLITUS IN SOUTH ASIA

The Past

The epidemiology of DM in this region has a long history. *Charaka Samhita*, an ancient South Asian medical treatise, described this condition succinctly and noted that obesity was a major risk factor.[8] Initial data on the epidemiology of DM in India were available as hospital- and clinic-based case series reported in the early and mid-20th century.[12] This was followed by epidemiologic studies that initially involved opportunistic screening and later population-based surveys.[13] Ramaiya et al[14] reviewed all these studies extensively in 1990 (**Table I**). Hospital records in Kolkata during the 1930s and in Mumbai and Delhi during the 1940s revealed that DM, diagnosed on the basis of glycosuria, was not uncommon (0.7%–1% of all patients). Similar observations were reported by subsequent hospital-based and opportunistic-screening studies from Kolkata, Mumbai, Lucknow, and Vellore in the 1950s.[12,14]

The first concerted effort on epidemiology was started by Indian investigators after the WHO provided some guidelines for diagnosis of cardiovascular disease risk factors. The initial systematic study of the prevalence of DM in India emanated from medical institutes in Delhi, Chandigarh, Hyderabad, and Chennai, and organized sectors such as the armed forces and railways.[12] These groups used different diagnostic criteria regarding the presence of glycosuria and random or fasting blood glucose measurements, and they reported results inconsistently. Epidemiologic studies from other regions of South Asia at that time also reported low prevalence rates of DM using nonstandardized approaches. A low prevalence of DM was reported in Pakistan, Bangladesh, and other parts of South Asia in the 1970s.[15]

The first systematic investigation in India was performed by the Indian Council of Medical Research Task Force on DM.[16] This study used uniform methodology and sampling techniques and was performed at 6 centers in India. Population sampling was based on a stratified, random design in urban areas and on cluster sampling in rural areas. The population aged >14 years was screened using a post–50-g glucose load, and capillary blood glucose >170 mg/dL was

Table I. Compilation of early epidemiologic studies of diabetes mellitus in India.[13,14]

First Author	Year of Publication	Location	Age	Diagnostic Criteria	Sample Size	Prevalence, %
Urban populations						
Patel JC	1963	Mumbai	20+	Urine	18,243	1.5
Rao PS	1966	Hyderabad	20+	Urine	21,396	4.1
Berry JN	1966	Chandigarh	30+	Urine	3846	2.9
Vishwanathan M	1966	Chennai	20+	Urine	5030	5.6
Gour KN	1966	Varanasi	10+	Urine	2572	2.7
Patel JC	1966	Mumbai	20+	RBG	3200	2.1
Das SP	1966	Pondicherry	10+	RBG	2694	0.9
Data SN	1973	Lucknow	20+	RBG	2190	1.1
Parameswara A	1973	Bangalore	10+	RBG	25,273	2.3
Ahuja MMS	1974	Delhi	15+	RBG	2783	2.3
Varma RN	1974	Delhi	20+	RBG	2291	2.7
Chhetri MK	1975	Kolkata	20+	RBG	4000	2.3
Gupta OP	1978	Ahmedabad	15+	RBG	3516	3.0
Rural populations						
Tripathy BB	1971	Orissa	10+	RBG	2447	1.2
Vigg BL	1972	Andhra	10+	RBG	847	2.5
Rao KSJ	1972	Andhra	20+	RBG	2006	2.4
Murthy PD	1984	Andhra	15+	RBG	848	4.7
Patel JC	1986	Maharashtra	10+	RBG	3374	3.8
Iyer SR	1987	Maharashtra	10+	RBG	1348	4.4
Tiwari AK	1988	Madhya Pradesh	15+	RBG	15,000	1.9

RBG = random blood glucose.

considered DM. In all, 34,194 subjects were screened; the prevalence of DM was 2.1% in urban populations and 1.5% in rural populations. Additional studies that were performed in India in the 1970s and 1980s are shown in **Table I**.[14]

There has been a veritable explosion in research on the epidemiology of DM in India in the past 20 years. Pioneered by investigators from Delhi and Chennai and contributions from all parts of the country, the knowledge base has expanded significantly (**Table II**).[9,11–13,17–36] However, the studies still suffer from major lacunae, and there is significant variability in methodologies such as sample size, sample selection, case detection, responder–nonresponder status, age standardization, diagnostic criteria, biochemical estimations, regression–dilution effects and reporting methods, and other inherent limitations of cross-sectional epidemiologic studies.[11] Therefore, most of these studies cannot be considered nationally representative. More than a billion people live in India, and to extrapolate results from nonrepresentative studies to the whole country is not appropriate scientifically. However, despite these caveats, it is worthwhile to examine these studies.

Current Diabetes Mellitus Scenario in India

The current era of DM epidemiology in India began with studies in urban areas of Delhi that reported on subjects with known DM and compared this information with the prevalence of DM in Southall, London.[17] DM was significantly more prevalent among Indians living in Delhi and Southall than among whites living in the United Kingdom. Other studies on subjects from urban and semiurban areas as well as subjects from various parts of India have confirmed the high prevalence of DM among these populations, although the prevalence rates vary widely (**Table II**).[11] Studies conducted in large cities in north and south India (Chennai,[18–22] Trivandrum,[23] Mumbai,[25] Delhi,[26,27] Jaipur,[28–30] and Guwahati[31]) as well as in large metropolises[32] have reported DM in 8% to 15% of adults >20 years of age. A study from Srinagar, Kashmir, confined to adults >40 years of age, reported a low prevalence of 4.25%.[33] A national study that involved >21,000 subjects from large and small cities in India also reported an overall lower prevalence of DM (age-adjusted prevalence, 4.6%) than did studies from large cities (10.3%–20.1%).[34]

A study of Indian industrial noncommunicable disease surveillance reported a high prevalence of DM (9%–11%) with significant regional variations.[35] Within urban populations, there is a large heterogeneity of DM prevalence, depending on the socioeconomic stratum studied and sampling response rates. For example, Ramachandran et al[18,19] and Mohan et al[21,22] reported a high prevalence of DM (11%–12%) in Chennai,

Table II. Recent studies on the prevalence of diabetes mellitus in India: Urban populations.[9,11,12]

Reference	Year of Publication	Location	Age	Diagnostic Criteria	Sample Size (n)			Prevalence, %		
					Male	Female	Total	Male	Female	Total*
Verma[17]	1986	Delhi	20+	K	3643	3235	6878	3.8	2.3	3.1
Ahuja[13]	1991	Delhi	20+	K+PG	2572	–	2572	4.1	–	4.1
Ramachandran et al[18]	1992	Chennai	20+	K+F+PG	457	443	900	8.3	7.6	8.3 (8.3)
Ramachandran et al[19]	1997	Chennai	20+	K+F+PG	1081	1102	2183	10.4	12.7	11.6 (11.6)
Shah et al[31]	1998	Guwahati	20+	K+PG	595	421	1016	8.7	7.8	8.2 (8.2)
Bai et al[20]	1999	Chennai	20+	K+F+PG	743	455	1198	8.7	5.7	7.6
Zargar et al[33]	2000	Srinagar	40+	K+F+PG	1038	500	538	5.4	5.0	5.2
Kutty et al[24]	2000	Kerala	20+	K+PG	225	293	518	16.4	9.2	12.4
Joseph et al[23]	2000	Trivandrum	20+	K+F	76	130	206	16.3	16.3	16.3
Asha Bai et al[36]	2000	Chennai	20+	K	13,366	12,700	26,066	2.9	3.1	2.9 (4.9)
Iyer et al[25]	2001	Mumbai	20+	K+F+PG	–	–	520	–	–	7.5
Misra et al[26]	2001	Delhi	18+	K+F	170	362	532	11.2	9.9	10.3
Mohan et al[21]	2003	Chennai	20+	K+F+PG	518	657	1175	–	–	12.3
Ramachandran et al[32]	2001	National	20+	K+F+PG	5288	5928	11,216	13.8	14.0	13.9 (12.1)
Gupta et al[28]	2003	Jaipur	20+	K+F	532	559	1091	13.2	11.5	12.3 (8.6)
Sadikot et al[34]	2004	National	20+	K+F+PG	10,865	10,651	21,516	4.7	4.8	4.8 (4.6)
Gupta et al[29]	2004	Jaipur	20+	K+F	226	232	458	17.7	14.2	16.8 (12.1)
Mohan et al[22]	2005	Chennai	20+	K+F+PG	–	–	2350	18.0	13.4	15.5
Prabhakaran et al[27]	2005	Delhi	20–59	K+F+PG	2122	–	2122	15.0	–	15.0
Reddy et al[35]	2006	National	20–59	K+F	6536	3890	10,442	11.2	8.2	10.1 (8.3/9.0)
Gupta et al[30]	2007	Jaipur	20+	K+F	556	571	1127	26.4	16.7	20.1

K = known; PG = postglucose load; F = fasting.
*Age adjusted.

whereas Asha Bai et al[20,36] reported a lower prevalence of known DM (4.9%) as well as overall DM (7.6%) in the same city. Variations in prevalence rates in different urban populations in India are expected because of the large variation in the prevalence of cardiovascular risk factors in different Indian regions and states.[37,38]

Few studies have been conducted recently on the prevalence of DM in semiurban[24,39,40] and rural populations[13,18,33,34,41–46] in India (**Tables I** and **III**). The prevalence of DM is very low in rural populations, but the rate increases considerably from rural to semiurban to urban to cosmopolitan areas. A secular trend in the prevalence of DM in India shows a slower increase in prevalence in rural subjects than in urban subjects (**Figure 2**). Although the prevalence of DM is low in rural populations, some evidence suggests a high burden of impaired glucose tolerance.[18,47] Two recent studies, one in rural Maharashtra[44] and the other in rural Andhra Pradesh,[45] reported the prevalence of DM to be almost as high as that in urban areas. These rates suggest the overwhelming influence of societal and lifestyle changes on the prevalence of DM in India.

Few serial, cross-sectional epidemiologic studies on DM have been conducted to demonstrate secular changes in India. From Chennai in South India, an increase in the prevalence of DM was reported among adults.[48] Using similar diagnostic criteria (known DM and/or fasting and postglucose-load hyperglycemia), the age-adjusted prevalence of DM among adults in urban Chennai increased from 8.3% (1988–1989) to 11.6% (1994–1995), 13.5% (2000), and 14.3% (2003–2004) (P for trend <0.05). Similar increases were observed in the prevalence of impaired glucose tolerance (from 8.3% to 9.1%, 16.8%, and 10.2%, respectively). An increase in the prevalence of DM has also been reported from rural Tamilnadu.[47] Serial studies from Jaipur using slightly different criteria (known DM and fasting hyperglycemia) have also reported an increasing prevalence of DM among urban subjects.[30] Larger, multicenter cohort studies are needed to accurately evaluate trends in DM in India and to identify risk factors.

The prevalence of DM in India is very low in rural populations, but the rate increases considerably from rural to semiurban to urban to cosmopolitan areas.

Diabetes Mellitus in Pakistan and Bangladesh

Surveys of risk factors for cardiovascular and chronic diseases in Pakistan as well as population surveys from Bangladesh have reported DM prevalence rates similar to

Table III. Recent studies of the prevalence of diabetes mellitus in India: Semiurban and rural populations.

Reference	Year of Publication	Location	Age	Diagnostic Criteria	Sample Size (n)			Prevalence, %		
					Male	Female	Total	Male	Female	Total*
Semiurban populations										
Ramachandran et al[39]	1988	Karnataka	20+	K+F+PG	346	332	678	5.8	4.2	5.0 (5.0)
Kutty et al[24]	2000	Kerala	20+	K+F+PG	2388	2600	4988	7.2	6.2	6.7 (8.2)
Singh et al[40]	2001	Manipur	15+	K+F+PG	884	780	1664	5.1	2.8	4.0
Rural populations										
Ahuja[13]	1991	Bengal	20+	K+PG	–	–	2375	–	–	0.8
		Delhi	20+	K+PG	–	–	992	–	–	1.5
		Kerala	20+	K+PG	–	–	1488	–	–	1.3
		Gujarat	20+	K+PG	–	–	1294	–	–	3.9
		Himachal	20+	K+PG	–	–	999	–	–	0.4
Ramachandran et al[18]	1992	Tamilnadu	20+	K+PG	520	518	1038	2.6	1.6	2.4
Wander et al[41]	1994	Punjab	20+	K+PG	–	–	809	–	–	4.6
Patandin et al[42]	1994	Tamilnadu	40+	K+PG	–	–	467	–	–	4.9
Zargar et al[33]	2000	Kashmir	40+	K+F+PG	1996	2049	4045	3.5	4.5	4.0
Agrawal et al[43]	2004	Rajasthan	20+	K+F+PG	–	–	882	–	–	1.8
Sadikot et al[34]	2004	National	20+	K+F+PG	9669	10,085	19,754	1.8	1.9	1.9 (1.9)
Deo et al[44]	2006	Maharashtra	20+	K+F+PG	449	553	1022	9.2	9.9	9.3
Chow et al[45]	2006	Andhra	30+	K+F	–	–	4535	14.3	12.0	13.2
Agrawal et al[46]	2007	Rajasthan	20+	K+F+PG	1222	877	2099	–	–	1.7

K = known; F = fasting; PG = postglucose load.
*Age adjusted.

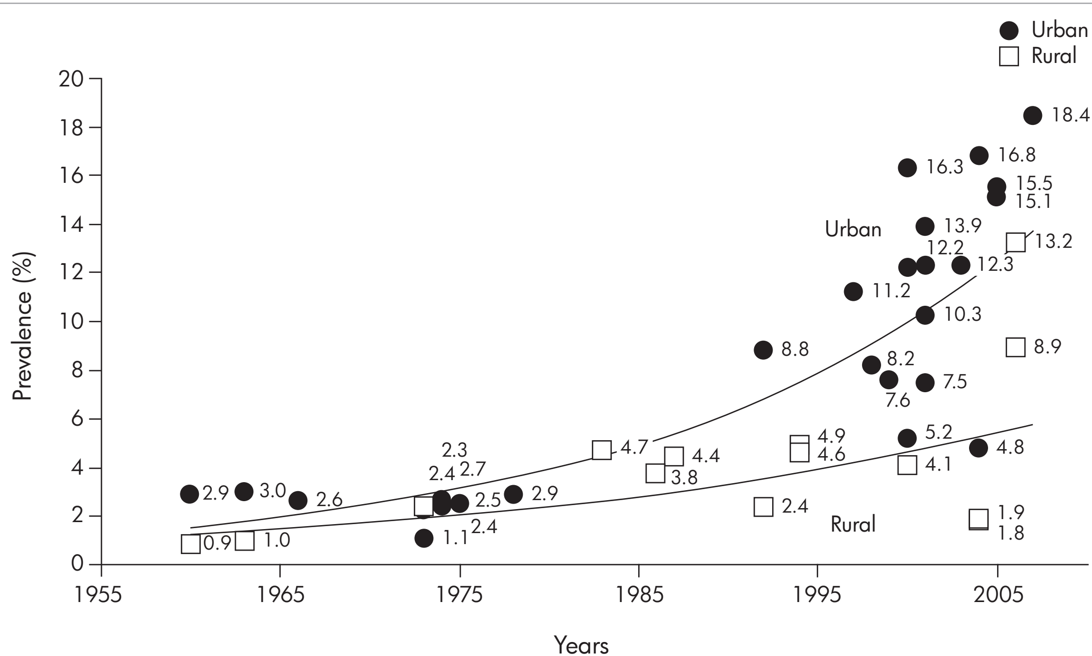


Figure 2. Trends in the prevalence of diabetes mellitus in Indian urban and rural populations. A significantly increasing trend is apparent in urban populations (exponential trend R^2 = 0.76). Among rural populations, the prevalence is increasing at a slower rate (R^2 = 0.43) but has accelerated recently.

those in Indian populations, with significant rural-urban gradients. In Pakistan, national DM surveys have been conducted in various regions since the mid-1990s (**Table IV**).[15,49–55] These studies used standardized diagnostic criteria and reported variable prevalence rates in different provinces of Pakistan.[15] A high prevalence of DM was observed in southern Sindh Province.[49,50] Urban areas of Pakistan also reported a high prevalence rate.[15,51–53] The prevalence of DM in rural areas of Pakistan[15,54,55] is higher than that in India,[11] which may be related to differences in dietary patterns and obesity levels. Overall, these studies in the Pakistan National Diabetes Survey[15] and National Health Survey of Pakistan[56] reported age-adjusted diabetes prevalence rates of 8% to 10% in urban populations and 2% to 10% in rural populations.

In Bangladesh, DM prevalence rates were 1% to 2% in rural populations in the mid-1990s but have escalated rapidly (**Table V**).[57–61] Few studies were conducted in urban areas, and those studies reported DM in 7% to 9% of the subjects.[62] Large, area-based differences similar to those in India have been observed. Risk factors also are similar to those in India. Multiethnic studies among emigrant South Asians have reported that in the United Kingdom, the prevalence of DM is the highest among Bangladeshis, followed by Pakistanis and Indians.[63] Changing lifestyles are considered to be important factors, and the fastest increases in obesity levels have occurred among Bangladeshis.

Changing lifestyles are considered to be important factors in the epidemiology of DM, and the fastest increases in obesity levels have occurred among Bangladeshis.

Diabetes Mellitus in Other South Asian Countries

A high prevalence of DM has also been reported in other South Asian countries. In Sri Lanka, successive studies in rural and urban regions reported escalating DM prevalence rates. Temporal trends in the prevalence of DM have been reported in rural regions of Sri Lanka. In contrast to the prevalence of 2.5% reported in 1990, a study conducted in 2004 by the same investigators reported a prevalence of 8.5%.[64] A prevalence of 5.8% in men aged 35 to 59 years was reported in a rural region of central Sri Lanka in 1994,[65] whereas another study in suburban Sri Lanka reported a prevalence of 5.0% in adults.[66] Recent studies in urban locations reported DM in 14.2% of men and 13.5% of women 30 to 65 years of age.[67,68] The gap between the prevalence rates of diabetes in urban and rural areas seems to be decreasing as differences in lifestyle between the 2 areas diminish.[69]

A few studies have been conducted on the prevalence of DM in Nepal.[70–72] A recent study in 1012 subjects >40 years of age in urban Nepal reported DM in 19.0%, impaired glucose tolerance in 10.6%, and impaired fasting glucose in 9.9%, with 30.5% of subjects showing evidence of any dysglycemia.[70] These data are similar to the results of studies from other South Asian nations. Community-based studies in rural subjects revealed an increasing trend in DM, and one study reported DM in 1.4% of subjects >20 years of age

Table IV. Recent population-based epidemiologic studies of diabetes mellitus in Pakistan.[74]

Reference	Year of Publication	Location	Age	Diagnostic Criteria	Sample Size	Prevalence, %
Urban populations						
Hameed et al[49]	1995	Karachi	20+	K	4232	3.1
Shera et al[50]	1999	Sindh	25+	K+F+PG	967	16.2
Shera et al[51]	1995	Baluchistan	25+	K+F+PG	834	10.8
Dodani et al[52]	2004	Karachi	18+	K	1400	9.1
Dennis et al[53]	2006	Karachi	20+	K	NA	8.0
Shera et al[15]	2007	Pakistan	25+	K+F+PG	1982	10.6
Semiurban and rural populations						
Shera et al[51]	1995	Baluchistan	25+	K+F+PG	570	6.5
Shera et al[54]	1999	NWFP	25+	K+F+PG	1035	11.1
Basit et al[55]	2002	Baluchistan	20+	K+F	2032	6.3
Shera et al[15]	2007	Pakistan	25+	K+F+PG	3451	7.7

K = known; F = fasting; PG = postglucose load; NA = not available; NWFP = North-West Frontier Province.

Table V. Recent studies on the prevalence of diabetes mellitus in Bangladesh.

Reference	Year of Publication	Location	Age	Diagnostic Criteria	Sample Size	Prevalence, %
Urban populations						
Rahim et al[62]	2004	Dhaka	20+	K+F+PG	476/1522	8.1
Semiurban and rural populations						
Sayeed et al[57]	1995	Dhaka	20+	K+F+PG	NA	NA
Hussain et al[58]	2005*	Dhaka	20+	K+F+PG	1046/4757	2.3
Sayeed et al[59]	2003	Dhaka	20+	K+F	4923	4.3
Sayeed et al[60]	2004	Dhaka	20+	K+F	4144	5.9
		Khagrachari	20–70	K+F	1287	6.6
Hussain et al[58]	2005	Dhaka	20+	K+F+PG	147/2205	6.8
Rahim et al[61]	2007	Dhaka	20+	K+F+PG	3981	6.8

K = known; F = fasting; PG = postglucose load; NA = not available.
*Study conducted in 1999.

in the early 1990s, which almost doubled (to 2.5%) by 2003.[72] Again, it seems that societal and lifestyle changes are accelerating the DM epidemic in South Asia and that urban-rural differences are disappearing.

WORLDWIDE DIABETES MELLITUS SCENARIO

In 1985, the WHO Study Group[73] on DM reported that, using standard diagnostic criteria (blood glucose fasting >140 mg/dL, postglucose load >200 mg/dL), the prevalence of DM varied from almost 0% in Papua New Guinea to 25% in populations of Pima Indians and Pacific Islanders. The prevalence was very low in Indonesia (1.7%), high in Fiji Indians (13.5%), Israelis (15.9%), and Mexican Americans (17.0%), and intermediate in the United States (6.9%). The WHO group also reported that, within the same ethnic group, the prevalence of DM was lower in rural residents than in urban residents and migrants to urban areas. It was concluded that DM was the result of changing age-structure and control of infections in these populations associated with changing lifestyles and obesity. Genetic factors were believed to be important considerations in the high prevalence of DM among certain subgroups.

The prevalence of DM in various regions of the world has recently been reported, with substantial variations (**Table IV**).[74]

The lowest prevalence rates (almost zero) were reported in rural Third World countries, whereas the highest rates (37%–50%) were reported among the Nauru Islanders of the Pacific, Pima Indians in Arizona, and urban Wanigela in Papua New Guinea (**Table VI**).[74] Most of the world's broad geographic locations include people with very low and very high prevalence rates of DM (eg, Mapuche Indians vs Pima Indians in the United States, rural Australian aborigines vs urban aborigines, and tribal South Indians vs urban Chennai residents). Populations experiencing increases in the incidence of DM include not only Asians, Indians, and Chinese, but also Japanese, aboriginal Australians, Hispanic Americans, and African Americans.

DM is one of the fastest-growing chronic diseases in the world, and India, the "diabetes capital of the world," is home to an estimated 46 million people with DM.[75] By the year 2030, the number is expected to climb to 80 million.[75] The global prevalence of DM was estimated to be 4.0% in 1995 and projected to rise to 5.4% by the year 2025. It is estimated that the number of adults with DM throughout the world will increase from 135 million in 1995 to 300 million in the year 2025. A major part of this increase is expected to occur in developing countries. It has been projected that the numbers will increase by 42% (from 51 to 72 million) in developed countries and by 170% (from 84 to 228 million) in developing countries. However, the accelerating obesity epidemic in both developed and developing countries has resulted in multiple revisions of these numbers, and the adjusted estimate is 350 to 400 million.[76] Most of the subjects with DM are expected to be 45 to 64 years of age in developing countries and >65 years of age in developed countries. This pattern may change considerably by the year 2025, given the recent evidence of increasing DM among obese children and adolescents.[77]

India, the "diabetes capital of the world," is home to an estimated 46 million people with DM.

Table VI. Age-standardized prevalence of diabetes mellitus in various parts of the world in 2003.[74]

Population	Region	Prevalence, %
Western Europeans (white)	United Kingdom	2
	Germany	2
	Australia (1981)	2
	Australia (2002)	8
	United States (US)	8
Native Americans	Chile Mapuche	1
	US Hispanic	17
	US Pima Indians	50
Pacific Islanders	Nauru (1952)	0
	Nauru (2002)	41
New Guineans	Rural	0
	Urban	23
Aboriginal Australians	Traditional	0
	Westernized	23
Middle East	Yemen, traditional	1
	Lebanon, westernized	14
Black Africans	Rural Tanzania	1
	Urban South Africa	8
	United States	13
Chinese	Rural China	0
	Urban Singapore	9
	Urban Taiwan	12
	Urban Mauritius	13
Asian Indians	Rural India	0
	Urban India	12
	Urban Singapore	17
	Urban Fiji	22

WHY THE INCREASE IN SOUTH ASIANS?

Prospective studies that have examined risk-factor determinants of DM are still in progress in various parts of South Asia. However, risk-association studies demonstrate that lifestyle (eg, sedentary habits, excessive calorie consumption) and physiology (eg, generalized and central obesity) are important predisposing factors (**Table VII**). The important conclusion from various studies appears to be that such risk factors tend to develop early in the life cycle in South Asians and, consequently, DM occurs at least 10 to 15 years earlier in residents of this region than in residents of developed countries.[78] We focus here on a few of these risk factors.

Lifestyle and Environmental Factors

Rapid urbanization and globalization in South Asian countries promote mechanization, which leads to sedentariness. This factor, coupled with recently found affluence, is

Table VII. Risk factors for diabetes mellitus.

Lifestyle	Socioeconomic status
	Sedentary lifestyle
	Excessive calorie consumption
	Specific dietary factors (eg, glycemic index, omega-3 fatty acids)
	Stress
Physiology	Age
	Family history
	Obesity
	Truncal obesity
	Metabolic syndrome
	Genetic and epigenetic factors

Risk factors (eg, sedentary lifestyle, excessive calorie consumption, generalized and central obesity) tend to develop early in South Asians; consequently, DM occurs at least 10 to 15 years earlier in residents of this region than in residents of developed countries.

increasing the use of tobacco and intake of calories and fat, which lead to increases in weight, glucose, blood pressure, and unfavorable lipid profiles.[1] These changes are associated with increasing obesity, although no national data are available from this region. The Jaipur Heart Watch (JHW) studies reported significantly escalating trends in obesity and truncal obesity in an Indian urban population. These studies were performed in 1992–1993 (JHW-1),[79] 1999–2001 (JHW-2),[80] 2002–2003 (JHW-3),[29] and 2005–2006 (JHW-4).[30] The prevalence of DM was determined in the latter 3 studies, and a significant 2-line correlation was noted between increasing DM and levels of obesity and truncal obesity (**Figure 3**).

Age-adjusted prevalence rates of obesity in subjects 20 to 59 years of age showed that obesity (body mass index [BMI] >25 kg/m^2) and high waist-to-hip ratio (>0.95) have increased significantly ($P < 0.05$) (**Figure 3**). A strong correlation was found between increasing socioeconomic status (literacy levels) and increasing levels of obesity and truncal obesity. These studies demonstrate that in low-income countries of South Asia, increasing socioeconomic status is associated with increasing obesity. This is in contrast to high- and middle-income countries, where poverty is associated with a higher prevalence of obesity.[81]

Obesity, particularly truncal obesity, is a major risk factor for DM. It has also been observed that, for similar body weights, South Asians have more adiposity than white populations and develop dyslipidemia, hypertension, and DM at lower levels.[78,82] Studies have reported that the levels of generalized and central obesity at which DM occurs are also lower in Indian subjects than in white subjects.[82] A waist size of >90 cm in men and >80 cm in women is now accepted as a major risk factor for DM and the metabolic syndrome in South Asians.[83]

A waist size of >90 cm in men and >80 cm in women is now accepted as a major risk factor for DM and the metabolic syndrome in South Asians.

Low Birth Weight and Maternal Undernutrition

Barker's hypothesis,[84] which focuses on the influences of maternal and fetal undernutrition and low birth weight on DM, has been proposed as an important pathophysiologic factor. Studies have reported that low-birth-weight neonates have higher insulin levels and greater insulin resistance than normal-weight neonates.[85] This trend persists into early and mid-childhood.[86–88] In the United Kingdom, it has been observed that South Asian children have lower birth weights and greater insulin resistance than white children.[89] The long-term prognostic impact of this finding was studied in the Delhi Birth Cohort Study, which showed that rapidly increasing weight resulted in greater insulin resistance and higher rates of DM at 30 years of age.[90] The Pune Maternal Nutrition Study[91] reported that a deficiency of vitamin B_{12} in mothers was an important determinant of low birth weight and insulin resistance in their offspring. More studies are needed to evaluate the long-term consequences of this finding because, if true, this hypothesis portends a major DM epidemic in South Asia.

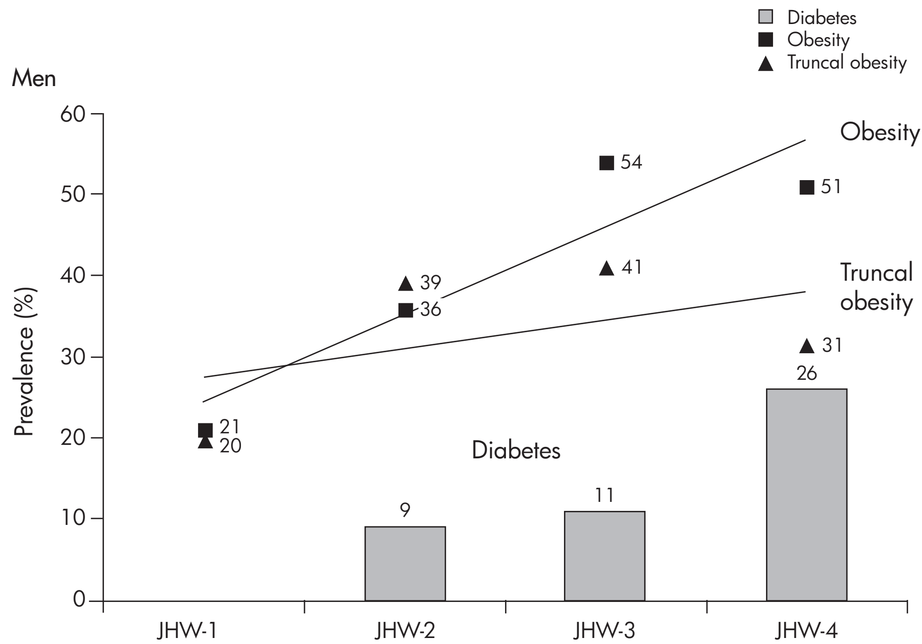
Genetic Factors

Over the years, it has been considered that DM has a large genetic component, as suggested by familial inheritance patterns.[92] There is a concordance in diagnosis of almost 100% for monozygotic twins but only 20% for dizygotic twins. However, no particular pattern of inheritance has been observed in various studies, and the patterns vary from female-pedigree inheritance to mixed patterns, suggesting involvement of multiple genes linked to chromosomal DNA and mitochondria. It is now clear that DM is a heterogeneous disorder and that multiple genes in insulin pathways regulating insulin secretion and action, intracellular fat metabolism pathways, and pancreatic β-cell function could be involved.[93,94] Recent studies that have performed genome-wide sequencing indicate that such genes could be present at chromosome regions 1q, 3q, 8p, 10q, 12q, and 20q.[92] Hundreds of single nucleotide polymorphisms (SNPs) are being evaluated, but most of the studies have failed to identify significant markers due to small sample size and technologic issues.

Large gene-association studies have been performed recently. The Wellcome Trust Case Control Consortium[95] in white subjects in the United Kingdom evaluated almost 500,000 SNPs and reported that 3 SNPs were important. Another case–control study in French subjects[96] involving 392,935 SNPs reported important mutations in TCF7L2, SLC30A8, IDE-KIF11-HHEX, and EXT2-ALX4 genes. The functional significance of these findings awaits further evaluation.[97]

Gene-Environment Interaction

Diamond[74] initially commented on a high prevalence of DM in all ethnic groups worldwide and observed that the surprise is not the high prevalence in native communities in South Asia, the Americas, and Pacific Islands, but the low prevalence in white populations. He opined that white subjects are somehow protected from the epidemic of DM. Gerstein and Waltman[98] took this observation further by suggesting that gene-environment interactions are crucial in the epidemiology of DM. Populations that have not suffered from malnutrition and periodic famines over the past 15 to 20 generations (white Western Europeans) have genetically adapted



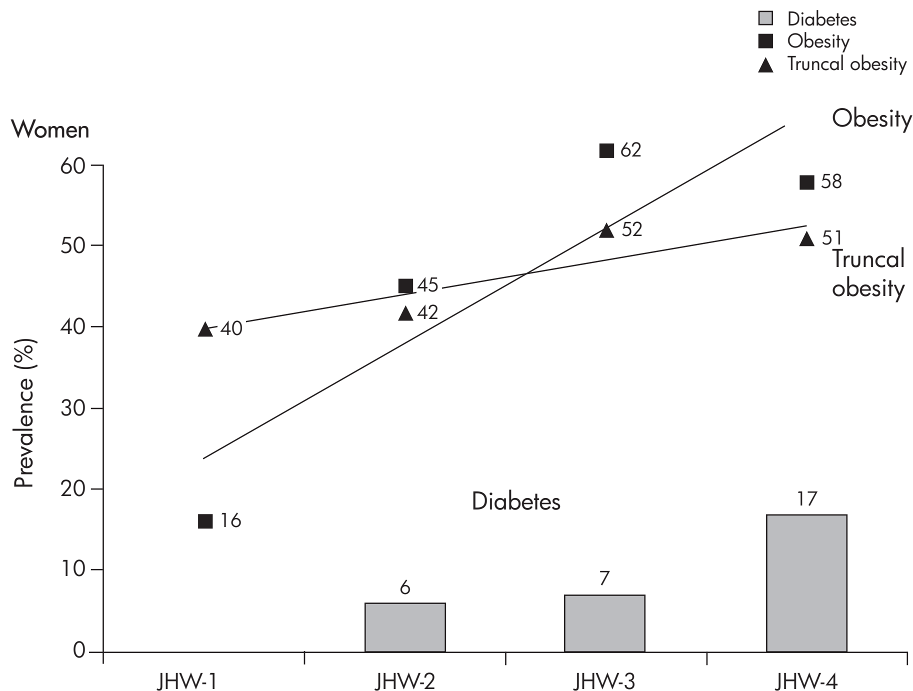


Figure 3. Increasing prevalence rates of obesity (body mass index >25 kg/m^2) and truncal obesity (waist-to-hip ratio >0.95) in Indian urban populations and escalating diabetes mellitus. Age-adjusted prevalence of risk factors in adults 20 to 59 years of age in the Jaipur Heart Watch (JHW) studies.[29,30,79,80] A significant 2-line correlation (unadjusted r^2) was noted between increasing prevalence of diabetes mellitus and levels of obesity (men 0.84, women 0.93) and truncal obesity (men 0.75, women 0.33) ($P < 0.05$).

themselves to high calorie intakes and have low insulin resistance. In contrast, populations that are exposed to periodic famines (eg, South Asians) have high insulin resistance and develop DM when exposed to obesogenic environments. Indeed, among the world populations, the gradient in DM prevalence escalates as one moves from affluent and acclimatized old-world populations (whites, 2%–3%) to evolving urban populations (East Asia, 5%–10%; Middle East, 10%–12%; South Asia, 10%–15%; Australia, 20%–25%; North and South America, 30%–35%; Pacific Islands, 40%–50%).[74] The current epidemic of DM in South Asia and other developing countries may have developed because populations in these countries have not yet had time to genetically adapt to the new diabetogenic environment. This hypothesis needs to be tested in areas of South Asia where there are existing pure genetic lineages with ancient wealth and affluence as well as newly acquired wealth.

Populations that are exposed to periodic famines (eg, South Asians) have high insulin resistance and develop DM when exposed to obesogenic environments.

INTERVENTIONS

Rose[99] stressed the importance of population-wide shifts in risk factors for the prevention of cardiovascular disease. A similar approach would be useful in the prevention of DM. The influence of societal affluence on the incidence of diabetes in India suggests that development of a global solution that will slow or stop the DM epidemic rests not with individuals but with policy makers and governments.[1] The economic and environmental structure of westernizing societies in urban areas of the country should be changed in ways that would promote physical activity and healthy dietary choices. Indeed, population-wide deleterious shifts in physical activity, calorie intake, BMI, waist size, and waist-to-hip ratio should be stopped.[100]

Categories of Interventions

Cost-effective interventions for the management of DM in developing countries of South Asia include preventive approaches, screening for DM, and treatment of DM and its complications.[7] Cost-efficacy analyses have been performed and interventions classified accordingly[7]: level 1, which are cost saving and feasible (eg, glycemic control, blood pressure control, foot care); level 2, which are cost sensitive but feasible (eg, preconception care for women of reproductive age, lifestyle interventions, detection and management of eye disease, use of angiotensin-converting enzyme inhibitors, smoking cessation); and level 3, which involve significant costs and pose major feasibility challenges (eg, metformin therapy for prevention of DM, intensive glycemic control, lipid control, screenings for microalbuminuria and DM, polypharmacy). Diabetes education is an essential background intervention and has been recommended for the entire population.

Lifestyle Changes

Lifestyle management is crucial for control of obesity, the major precursor of DM. Weight reduction and maintenance of a lower body weight are best achieved by a combination of reduced calorie intake and increased physical activity, as well as behavioral changes. Achievement of target weight to decrease BMI to <25 kg/m^2 and waist size to <90 cm in Indian men and <80 cm in Indian women through lifestyle modifications will reduce the prevalence rates of DM and the metabolic syndrome. Both the Finnish Diabetes Prevention Study[101] and the Diabetes Prevention Program[102] showed that diet and exercise had a significant effect on reducing disease progression from impaired glucose tolerance to DM. The Indian Diabetes Prevention Programme[103] evaluated increased physical activity and use of metformin for the prevention of DM in subjects with impaired glucose tolerance. At a median follow-up of 30 months, lifestyle modification reduced progression to DM by 28.5%, which was essentially the same as with metformin (26.4%) and the combination of metformin and lifestyle changes (28.2%). Yoga-based comprehensive lifestyle change has been evaluated in the prevention of DM, and preliminary results are encouraging. These studies support the use of multidimensional lifestyle modifications for prevention of DM in susceptible individuals. A major limitation of these studies is lack of data on specific cardiovascular end points and mortality outcomes. Larger and longer prospective studies are required.

A comprehensive approach consisting of weight reduction, regular physical exercise, and yoga is suggested for control of the insulin-resistance state that characterizes early phases of DM.[104] This can also prevent DM in high-risk individuals. More epidemiologic studies that evaluate influences of gene-environment interactions and interventional studies that evaluate uses of diet, lifestyle changes, and pharmacological approaches for primary prevention of DM are required. Population-based measures for prevention and control of the DM epidemic in South Asia are urgently needed. A novel public health education campaign focusing on lifestyle changes (increased physical activity, prudent diet, tobacco cessation) has been launched in Chennai, and preliminary results are encouraging.[105] Epidemiologic studies have provided important information about the increasing prevalence of DM in South Asian countries.[9–11] Studies in developed countries have indicated ways in which the epidemic can be slowed, stopped, or reversed.[1] The important next step is to integrate this information into everyday clinical awareness and practice.[7] It is crucial at the same time to increase public knowledge about self-protection and prevention of DM by maintaining a sensible and healthy lifestyle.

Polypharmacy

Pharmacological approaches are not currently recommended for primary prevention of diabetes, although some

evidence suggests that obesity-reducing drugs (sibutramine, orlistat) and endocannabinoid-receptor blockers (rimonabant) control insulin resistance and the metabolic syndrome and may prevent DM.[106] Prospective studies that include outcome measures are needed. Use of polypharmacy to prevent vascular complications of DM needs to be tested in prospective studies.[107] A provocative Canadian study recently suggested that, instead of using the population-based risk-reduction strategy suggested by Rose,[99] a baseline, high-risk treatment strategy, as suggested by New Zealand cardiovascular prevention guidelines, would be a more appropriate approach to initiating polypharmacy for the prevention of vascular disease in the general population.[108]

Macrolevel Initiatives

More than 10% of the adult population in South Asia suffers from DM. In Pakistan, a national action plan to prevent and control noncommunicable diseases and promote health has been developed.[109] This incorporates prevention and control of DM as part of a comprehensive and integrated national noncommunicable disease prevention effort. Building on existing data, the DM surveillance process has been integrated with a comprehensive, population-based, noncommunicable disease surveillance system, using waist circumference as a proxy indicator for the risk of DM in the short-term. However, the surveillance strategy makes a case for future efforts to upgrade surveillance, to allow a more comprehensive assessment incorporating biochemical assessments. The program focuses on prevention of DM by maximizing risk-factor control as a common theme across the range of noncommunicable diseases and emphasizes integration of DM prevention and intensified case finding in high-risk groups into health services as part of a comprehensive and sustainable, scientifically valid, culturally appropriate, and resource-sensitive continuing medical education program for all categories of health care providers. The program also focuses on ensuring the availability of antidiabetic agents (insulin, sulfonylureas, metformin) at all levels of health care. Increasing the capacity of the health system and coalitions in support of DM prevention has also been regarded as a critical factor.[109]

India is the country with the highest number of deaths related to chronic diseases given its risk profile with high tobacco consumption, increased obesity, abnormal lipid profiles, and DM.[1] Less than 1% of India's gross domestic product is spent on health care and, proportionately, very little is spent on chronic diseases.[110] Current health challenges urgently require capacity building for health research, policy development and analysis, program development and evaluation, health systems organization, models of health care financing, and operational systems research.[110,111] The Indian Council of Medical Research has developed a chronic diseases risk-factor surveillance program for India.[112] Pilot surveys have been conducted in various locations in the country using the WHO STEPwise approach to Surveillance (STEPS), which outlines sequential measurement of behavioral, physical, and biochemical risk factors through its core, expanded, and optional modules.[113] Preliminary results of the risk-factor data for subjects 15 to 64 years of age indicate a high rate of multiple cardiovascular risk factors, with higher frequencies of risk factors noted among respondents residing in urban areas than among those residing in poor/periurban and rural areas.[114] The successful adaptation and implementation of the STEPS approach for noncommunicable disease risk-factor surveillance has paved the way for development of a module for risk-factor surveillance in the national Integrated Disease Surveillance Program launched by the government of India.[115]

Microlevel Initiatives

To succeed, a DM intervention program has to focus on the individual first and then gradually envelop the family, society, region, and nation. On the other hand, public health dictum is to have a top-down approach for the prevention and control of the disease.[110,116] A balanced approach is the best solution to the problem of DM and other chronic lifestyle diseases that are epidemic in South Asia. A strong public–private partnership model is needed. A model for chronic surveillance and health care in India and other countries in this region is proposed (**Figure 4**).[115,116] A continuous surveillance mechanism that focuses on nurse practitioners and general practitioners outside the government system is proposed. The subject and family records would be stored using electronic data capture, and these records could be transmitted to local health authorities as well as medical care units in primary, secondary, or tertiary health care settings.[117] Two-way communication between the primary health care provider, tertiary levels, and the government would be facilitated. Extensive field testing of this model is required before it is implemented. Lessons learned from other countries should be translated into practice.[118]

CONCLUSIONS

DM is a major health problem in South Asian countries, and this region is home to more people with diabetes than any other region in the world. Epidemiologic studies reveal a high burden in both urban and rural populations, with a large proportion of subjects remaining undiagnosed. It has been estimated that developing countries spend 2.5% to 15% of their annual health budgets on this condition. A major public health challenge is the prevention of DM and its complications through continuing education. Interventions are urgently needed to improve the overall suboptimal quality of care, with a focus on providing important drugs at affordable prices and creating opportunities for operational and health systems research to develop better management strategies. The Indian National Diabetes Control Program, which is part of the Integrated Disease Surveillance Program, and the National Action Plan for Prevention and Control of Noncommunicable Diseases and Health Promotion in Pakistan are useful models. Important lessons can be learned from the developed world.

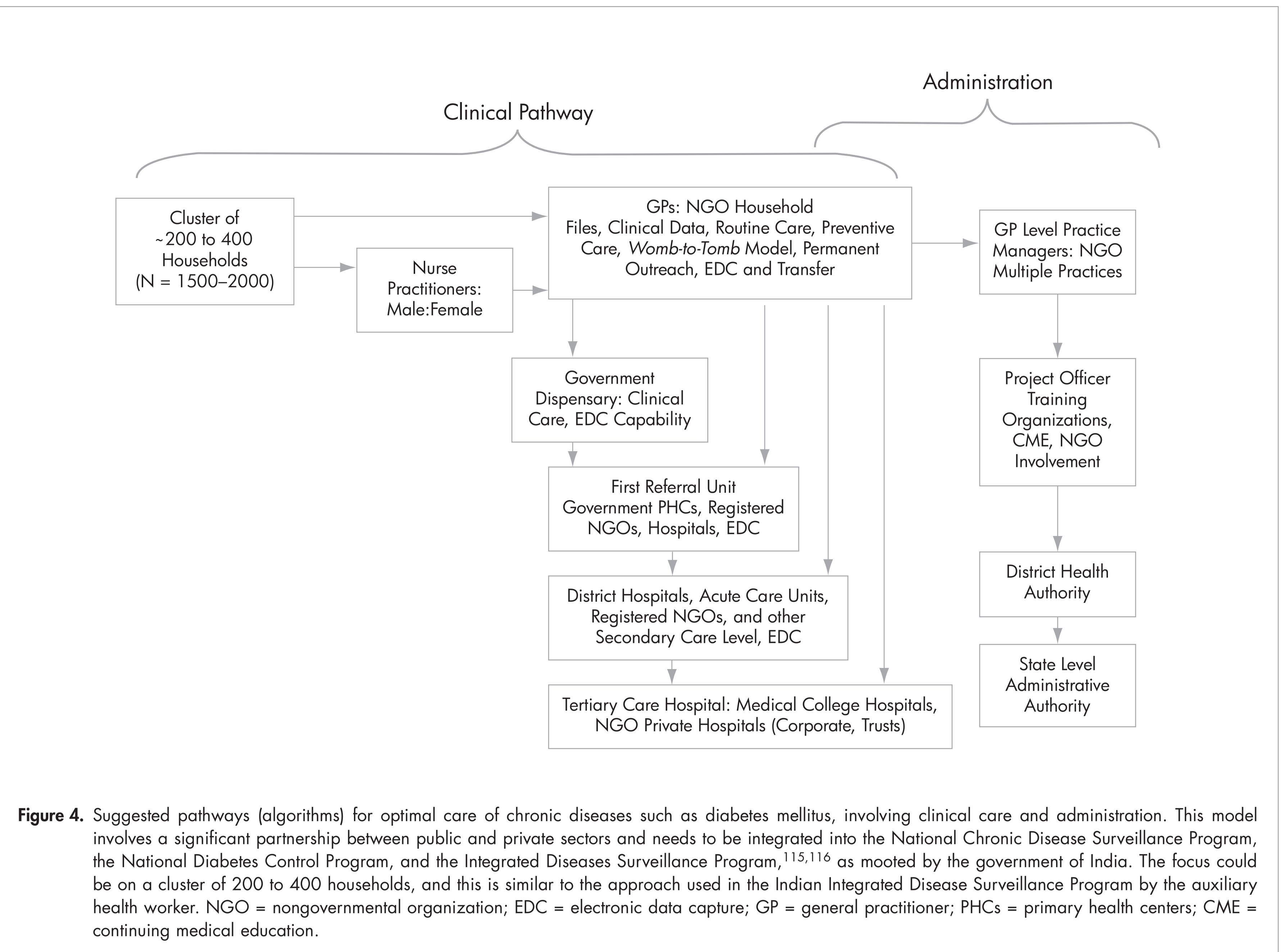


Figure 4. Suggested pathways (algorithms) for optimal care of chronic diseases such as diabetes mellitus, involving clinical care and administration. This model involves a significant partnership between public and private sectors and needs to be integrated into the National Chronic Disease Surveillance Program, the National Diabetes Control Program, and the Integrated Diseases Surveillance Program,[115,116] as mooted by the government of India. The focus could be on a cluster of 200 to 400 households, and this is similar to the approach used in the Indian Integrated Disease Surveillance Program by the auxiliary health worker. NGO = nongovernmental organization; EDC = electronic data capture; GP = general practitioner; PHCs = primary health centers; CME = continuing medical education.

REFERENCES

1. Srinath Reddy K, Shah B, Varghese C, Ramadoss A. Responding to the threat of chronic diseases in India. *Lancet*. 2005;366: 1744–1749.
2. Sample Registration System. Million Death Study: Preliminary Report on Causes of Death in India 2001–2003. New Delhi: Registrar General of India; 2007.
3. Murray CJ, Lopez AD. *Global Burden of Disease*: *A Comprehensive Assessment of Mortality and Disability from Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020*. Boston, Mass: Harvard University Press; 1996:398–975.
4. World Health Organization. *World Health Report 2004: Changing History*. Geneva, Switzerland: World Health Organization; 2004.
5. Howard BV, Rodriguez BL, Bennett PH, et al. Prevention Conference VI: Diabetes and cardiovascular disease: Writing Group I: Epidemiology. *Circulation*. 2002;105:e132–e137.
6. Haffner SM, Lehto S, Rönnemaa T, et al. Mortality from coronary heart disease in subjects with type 2 diabetes and in nondiabetic subjects with and without prior myocardial infarction. *N Engl J Med*. 1998;339:229–234.
7. Venkat Narayan KM, Zhang P, Kanaya AM, et al. Diabetes: The pandemic and potential solutions. In: Jamison DT, Breman JG, Measham AR, et al, eds. *Disease Control Priorities in Developing Countries*, 2nd ed. Washington, DC: The World Bank Group; 2006:591–603.
8. Valiathan MS. *The Legacy of Caraka*. Hyderabad, India: Orient Longman; 2003:88–91.
9. Ramachandran A. Epidemiology of diabetes in India—three decades of research. *J Assoc Physicians India*. 2005;53:34–38.
10. Mohan V, Sandeep S, Deepa R, et al. Epidemiology of type 2 diabetes: Indian scenario. *Indian J Med Res*. 2007;125:217–230.
11. Gupta R, Misra A. Type 2 diabetes in India: Regional disparities. *Br J Diab Vasc Dis*. 2007:7:12–16.
12. Ahuja MM, Kumar V. Diabetes mellitus in the Indian scene. In: Ahuja MM, ed. *Progress in Clinical Medicine in India*. New Delhi, India: Arnold-Heinemann; 1976:538–560.
13. Ahuja MM. Recent contributions to the epidemiology of diabetes mellitus in India. *Int J Diab Dev Countries*. 1991;11:5–9.
14. Ramaiya KL, Kodali VR, Alberti KG. Epidemiology of diabetes in Asians of the Indian subcontinent. *Diabetes Metab Rev*. 1990;6:125–146.
15. Shera AS, Jawad F, Maqsood A. Prevalence of diabetes in Pakistan. *Diabetes Res Clin Pract*. 2007;76:219–222.
16. Sridhar GR, Rao PV, Ahuja MM. Epidemiology of diabetes and its complications. In: Ahuja MM, Tripathy BB, Moses SG, et al, eds. *RSSDI Textbook of Diabetes Mellitus*. Hyderabad, India: Research Society for the Study of Diabetes in India; 2002: 95–112.
17. Verma NP, Mehta SP, Madhu S, et al. Prevalence of known diabetes in an urban Indian environment: The Darya Ganj diabetes survey. *Br Med J (Clin Res Ed)*. 1986;293:423–424.
18. Ramachandran A, Snehalatha C, Dharmaraj D, Viswanathan M. Prevalence of glucose intolerance in Asian Indians. Urban-rural difference and significance of upper body adiposity. *Diabetes Care*. 1992;15:1348–1355.
19. Ramachandran A, Snehalatha C, Latha E, et al. Rising prevalence of NIDDM in urban population in India. *Diabetologia*. 1997;40:232–237.
20. Bai PV, Krishnaswami CV, Chellamariappan M. Prevalence and incidence of type-2 diabetes and impaired glucose tolerance in a selected Indian urban population. *J Assoc Physicians India*. 1999;47:1060–1064.
21. Mohan V, Shanthirani CS, Deepa R. Glucose intolerance (diabetes and IGT) in a selected South Indian population with special reference to family history, obesity and lifestyle factors—the Chennai Urban Population Study (CUPS 14). *J Assoc Physicians India*. 2003;51:771–777.
22. Mohan V, Deepa R, Deepa M, et al. A simplified Indian Diabetes Risk Score for screening for undiagnosed diabetes subjects. *J Assoc Physicians Ind*. 2005;53:759–763.
23. Joseph A, Kutty VR, Soman CR. High risk for coronary heart disease in Thiruvananthapuram City: A study of serum lipids and other risk factors. *Indian Heart J*. 2000;52:29–35.
24. Kutty VR, Soman CR, Joseph A, et al. Type 2 diabetes in southern Kerala: Variation in prevalence among geographic divisions within a region. *Natl Med J India*. 2000;13:287–292.
25. Iyer SR, Iyer RR, Upasani SV, Baitule MN. Diabetes mellitus in Dombivli—an urban population study. *J Assoc Physicians India*. 2001;49:713–716.
26. Misra A, Pandey RM, Devi JR, et al. High prevalence of diabetes, obesity and dyslipidaemia in urban slum population in northern India [published correction appears in *Int J Obes Relat Metab Disord*. 2002;26:1281]. *Int J Obes Relat Metab Disord*. 2001;25:1722–1729.
27. Prabhakaran D, Shah P, Chaturvedi V, et al. Cardiovascular risk factor prevalence among men in a large industry of northern India. *Natl Med J India*. 2005;18:59–65.
28. Gupta A, Gupta R, Sarna M, et al. Prevalence of diabetes, impaired fasting glucose and insulin resistance syndrome in an urban Indian population. *Diabetes Res Clin Pract*. 2003;61: 69–76.
29. Gupta R, Sarna M, Thanvi J, et al. High prevalence of multiple coronary risk factors in Punjabi Bhatia community: Jaipur Heart Watch-3. *Indian Heart J*. 2004;56:646–652.
30. Gupta R, Bhagat N, Misra A, et al. Trends in prevalence of coronary risk factors in an urban Indian population: Jaipur Heart Watch-4. *Indian Heart J*. 2007;59:346–353.
31. Shah SK, Saikia M, Barman NN, et al. High prevalence of type 2 diabetes in urban population in north-eastern India. *Int J Diab Dev Countries*. 1998:18:97–101.
32. Ramachandran A, Snehalatha C, Kapur A, et al, for the Diabetes Epidemiology Study Group in India (DESI). High prevalence of diabetes and impaired glucose tolerance in India: National Urban Diabetes Survey. *Diabetologia*. 2001; 44:1094–1101.
33. Zargar AH, Khan AK, Masoodi SR, et al. Prevalence of type 2 diabetes mellitus and impaired glucose tolerance in the Kashmir Valley of the Indian subcontinent. *Diabetes Res Clin Pract*. 2000;47:135–146.

34. Sadikot SM, Nigam A, Das S, et al, for Diabetes India. The burden of diabetes and impaired glucose tolerance in India using the WHO 1999 criteria: Prevalence of Diabetes in India Study (PODIS). *Diabetes Res Clin Pract*. 2004;66:301–307.
35. Reddy KS, Prabhakaran D, Chaturvedi V, et al. Methods for establishing a surveillance system for cardiovascular diseases in Indian industrial populations. *Bull WHO*. 2006;84:461–469.
36. Asha Bai PV, Murthy BN, Chellamariappan M, et al. Prevalence of known diabetes in Chennai City. *J Assoc Phys India*. 2000; 49:974–981.
37. Gupta R. Burden of coronary heart disease in India. *Indian Heart J*. 2005;57:632–638.
38. Gupta R, Misra A, Pais P, et al. Correlation of regional cardiovascular disease mortality in India with lifestyle and nutritional factors. *Int J Cardiol*. 2006;108:291–300.
39. Ramachandran A, Jali MV, Mohan V, et al. High prevalence of diabetes in an urban population in south India. *BMJ*. 1988; 297:587–590.
40. Singh TP, Singh AD, Singh TB. Prevalence of diabetes mellitus in Manipur. In: Shah SK, ed. *Diabetes Update*. Guwahati, India: North Eastern Diabetes Society; 2001:13–19.
41. Wander GS, Khurana SB, Gulati R, et al. Epidemiology of coronary heart disease in a rural Punjab population—prevalence and correlation with various risk factors. *Indian Heart J*. 1994;46:319–323.
42. Patandin S, Bots ML, Abel R, Valkenburg HA. Impaired glucose tolerance and diabetes mellitus in a rural population in south India. *Diabetes Res Clin Pract*. 1994;24:47–53.
43. Agrawal RP, Singh G, Nayak KC, et al. Prevalence of diabetes in camel-milk consuming 'RAICA' rural community of north-west Rajasthan. *Int J Diab Dev Countries*. 2004;24:109–114.
44. Deo SS, Zantye A, Mokal R, et al. To identify the risk factors for high prevalence of diabetes and impaired glucose tolerance in Indian rural population. *Int J Diab Dev Countries*. 2006;26: 19–23.
45. Chow CK, Raju PK, Raju R, et al. The prevalence and management of diabetes in rural India. *Diabetes Care*. 2006;29: 1717–1718.
46. Agrawal RP, Budania S, Sharma P, et al. Zero prevalence of diabetes in camel milk consuming Raica community of north-west Rajasthan, India. *Diabetes Res Clin Pract*. 2007;76:290–296.
47. Ramachandran A, Snehalatha C, Baskar AD, et al. Temporal changes in prevalence of diabetes and impaired glucose tolerance associated with lifestyle transition occurring in the rural population in India. *Diabetologia*. 2004;47:860–865.
48. Mohan V, Deepa M, Deepa R, et al. Secular trends in the prevalence of diabetes and impaired glucose tolerance in urban South India—the Chennai Urban Rural Epidemiology Study (CURES-17). *Diabetologia*. 2006;49:1175–1178.
49. Hameed K, Kadir M, Gibson T, et al. The frequency of known diabetes, hypertension and ischaemic heart disease in affluent and poor urban populations of Karachi, Pakistan. *Diabet Med*. 1995;12:500–503.
50. Shera AS, Rafique G, Khawaja IA, et al. Pakistan National Diabetes Survey: Prevalence of glucose intolerance and associated factors in Baluchistan province. *Diabetes Res Clin Pract*. 1999;44:49–58.
51. Shera AS, Rafique G, Khwaja IA, et al. Pakistan National Diabetes Survey: Prevalence of glucose intolerance and associated factors in Shikarpur, Sindh Province. *Diabet Med*. 1995; 12:1116–1121.
52. Dodani S, Mistry R, Khwaja A, et al. Prevalence and awareness of risk factors and behaviors of coronary heart disease in an urban population of Karachi, the largest city of Pakistan: A community survey. *J Public Health (Oxf)*. 2004;27:245–249.
53. Dennis B, Aziz K, She L, et al. High rates of obesity and cardiovascular disease risk factors in lower middle class community in Pakistan: The Metroville Health Study. *J Pak Med Assoc*. 2006;56:267–272.
54. Shera AS, Rafique G, Khwaja IA, et al. Pakistan National Diabetes Survey prevalence of glucose intolerance and associated factors in North West at Frontier Province (NWFP) of Pakistan [published correction appears in *J Pak Med Assoc*. 1999;49:317]. *J Pak Med Assoc*. 1999;49:206–211.
55. Basit A, Hydrie MZ, Ahmed K, Hakeem R. Prevalence of diabetes, impaired fasting glucose and associated risk factors in rural area of Baluchistan province according to new ADA criteria. *J Pak Med Assoc*. 2002;52:357–360.
56. Pappas G, Akhtar T, Gergen PJ, et al. Health status of the Pakistani population: A health profile and comparison with the United States. *Am J Public Health*. 2001;91:93–98.
57. Sayeed MA, Banu A, Khan AR, Hussain MZ. Prevalence of diabetes and hypertension in a rural population of Bangladesh. *Diabetes Care*. 1995;18:555–558.
58. Hussain A, Rahim MA, Azad Khan AK, et al. Type 2 diabetes in rural and urban population: Diverse prevalence and associated risk factors in Bangladesh. *Diabet Med*. 2005;22:931–936.
59. Sayeed MA, Mahtab H, Akter Khanam P, et al. Diabetes and impaired fasting glycemia in a rural population of Bangladesh. *Diabetes Care*. 2003;26:1034–1039.
60. Sayeed MA, Mahtab H, Akter Khanam P, et al. Diabetes and impaired fasting glycemia in the tribes of Khagrachari hill tracts of Bangladesh. *Diabetes Care*. 2004;27:1054–1059.
61. Rahim MA, Hussain A, Azad Khan AK, et al. Rising prevalence of type 2 diabetes in rural Bangladesh: A population based study. *Diabetes Res Clin Pract*. 2007;77:300–305.
62. Rahim MA, Vaaler S, Keramat Ali SM, et al. Prevalence of type 2 diabetes in urban slums of Dhaka, Bangladesh. *Bangladesh Med Res Counc Bull*. 2004;30:60–70.
63. Bhopal R, Unwin N, White M, et al. Heterogeneity of coronary heart disease risk factors in Indian, Pakistani, Bangladeshi, and European origin populations: Cross sectional study. *BMJ*. 1999;319:215–220.
64. Illangasekera U, Rambodagalla S, Tennakoon S. Temporal trends in the prevalence of diabetes mellitus in a rural community in Sri Lanka. *J R Soc Health*. 2004;124:92–94.
65. Mendis S, Ekanayake EM. Prevalence of coronary heart disease and cardiovascular risk factors in middle aged males in a defined population in central Sri Lanka. *Int J Cardiol*. 1994; 46:135–142.

66. Fernando DJ, Siribaddana S, de Silva D. Impaired glucose tolerance and diabetes mellitus in a suburban Sri Lankan community. *Postgrad Med J.* 1994;70:347–349.
67. Malavige GN, de Alwis NM, Weersooriya N, et al. Increasing diabetes and vascular risk factors in a sub-urban Sri Lankan population. *Diabetes Res Clin Pract.* 2002;57:143–145.
68. Wijewardene K, Mohideen MR, Mendis S, et al. Prevalence of hypertension, diabetes and obesity: Baseline findings of a population based survey in four provinces in Sri Lanka. *Ceylon Med J.* 2005;50:62–70.
69. Katulanda P, Sheriff MH, Matthews DR. The diabetes epidemic in Sri Lanka—a growing problem. *Ceylon Med J.* 2006;51: 26–28.
70. Singh DL, Bhattarai MD. High prevalence of diabetes and impaired fasting glycaemia in urban Nepal. *Diabet Med.* 2003;20:170–171.
71. Shrestha UK, Singh DL, Bhattarai MD. The prevalence of hypertension and diabetes defined by fasting and 2-h plasma glucose criteria in urban Nepal. *Diabet Med.* 2006;23:1130–1135.
72. Sasaki H, Kawasaki T, Ogaki T, et al. The prevalence of diabetes mellitus and impaired fasting glucose/glycaemia (IFG) in suburban and rural Nepal—the communities-based cross-sectional study during the democratic movements in 1990. *Diabetes Res Clin Pract.* 2005;67:167–174.
73. WHO Study Group. Prevention of diabetes mellitus. Technical Report Series 727. Geneva, Switzerland: World Health Organization; 1985.
74. Diamond J. The double puzzle of diabetes. *Nature.* 2003; 423:599–602.
75. Wild S, Roglic G, Green A, et al. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. *Diabetes Care.* 2004;27:1047–1053.
76. Zimmet P, Alberti KG, Shaw J. Global and societal implications of the diabetes epidemic. *Nature.* 2001;414:782–787.
77. Smyth S, Heron A. Diabetes and obesity: The twin epidemics. *Nature Med.* 2005;12:75–80.
78. Pradeepa R, Deepa R, Mohan V. Epidemiology of diabetes in India—current perspective and future projections. *J Indian Med Assoc.* 2002;100:144–148.
79. Gupta R, Prakash H, Majumdar S, et al. Prevalence of coronary heart disease and coronary risk factors in an urban population of Rajasthan. *Indian Heart J.* 1995;47:331–338.
80. Gupta R, Gupta VP, Sarna M, et al. Prevalence of coronary heart disease and risk factors in an urban Indian population: Jaipur Heart Watch-2. *Indian Heart J.* 2002;54:59–66.
81. Ezzati M, Vander Hoorn S, Lawes CM, et al. Rethinking the "disease of affluence" paradigm: Global patterns of nutritional risks in relation to economic development. *PLoS Med.* 2005; 2:e133.
82. Misra A, Vikram NK, Gupta R, et al. Waist circumference cutoff points and action levels for Asian Indians for identification of abdominal obesity. *Int J Obes (Lond).* 2006;30:106–111.
83. Alberti KG, Zimmet P, Shaw J, for the IDF Epidemiology Task Force Consensus Group. The metabolic syndrome—a new worldwide definition. *Lancet.* 2005;366:1059–1062.
84. Barker DJ. *Mothers, Babies and Health in Later Life.* 2nd ed. Edinburgh, UK: Churchill Livingstone; 1998:1–150.
85. Yada KK, Gupta R, Gupta A, Gupta M. Insulin levels in low birth weight neonates. *Indian J Med Res.* 2003;118:197–203.
86. Yajnik CS, Fall CH, Vaidya U, et al. Fetal growth and glucose and insulin metabolism in four-year-old Indian children. *Diabet Med.* 1995;12:330–336.
87. Bavdekar A, Yajnik CS, Fall CH, et al. Insulin resistance syndrome in 8-year-old Indian children: Small at birth, big at 8 years, or both? *Diabetes.* 1999;48:2422–2429.
88. Gupta M, Gupta R, Bhatia R, et al. Low birth weight and insulin resistance in mid and late childhood. *Indian Pediatrics.* 2007;44:177–184.
89. Whincup PH, Gilg JA, Papacosta D, et al. Early evidence of ethnic differences in cardiovascular risk: Cross sectional comparison of British South Asian and white children. *BMJ.* 2002; 324:635.
90. Bhargava SK, Sachdev HS, Fall CH, et al. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *N Engl J Med.* 2004;350:865–875.
91. Rao S, Yajnik CS, Kanade A, et al. Intake of micronutrient-rich foods in rural Indian mothers is associated with the size of their babies at birth: Pune Maternal Nutrition Study. *J Nutr.* 2001; 131:1217–1224.
92. Stumvoll M, Goldstein BJ, van Haeften TW. Type 2 diabetes: Principles of pathogenesis and therapy. *Lancet.* 2005;365: 1333–1346.
93. Ehm MG, Karnoub MC, Sakul H, et al, for the American Diabetes Association GENNID Study Group. Genetics of NIDDM. Genomewide search for type 2 diabetes susceptibility genes in four American populations [published correction appears in *Am J Hum Genet.* 2002;70:284]. *Am J Hum Genet.* 2000;66:1871–1881.
94. Permutt MA, Wasson J, Cox N. Genetic epidemiology of diabetes. *J Clin Invest.* 2005;115:1431–1439.
95. Genome-wide association study of 14,000 cases of seven common diseases and 3,000 shared controls. *Nature.* 2007;447: 661–678.
96. Sladek R, Rocheleau G, Rung J, et al. A genome-wide scan association study identifies novel risk loci for type 2 diabetes. *Nature.* 2007;445:881–885.
97. Rosenzweig A. Scanning the genome for coronary risk. *N Engl J Med.* 2007;357:497–499.
98. Gerstein H, Waltman L. Why don't pigs get diabetes? Explanations for variations in diabetes susceptibility in human populations living in a diabetogenic environment. *CMAJ.* 2006;174: 25–26.
99. Rose G. *The Strategy of Preventive Medicine.* Oxford, UK: Oxford University Press; 1992.
100. Deedwania PC, Gupta R. East Asians and South Asians, and Asian and Pacific Islander Americans. In: Wong ND, Black HR, Gardin JM, eds. *Preventive Cardiology: A Practical Approach.* 2nd ed. New York, NY: McGraw Hill; 2004:456–472.

101. Tuomilehto J, Lindström J, Eriksson JG, et al, for the Finnish Diabetes Prevention Study Group. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344: 1343–1350.
102. Knowler WC, Barrett-Connor E, Fowler SE, et al, for the Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346:393–403.
103. Ramachandran A, Snehalatha C, Mary S, et al, for the Indian Diabetes Prevention Programme (IDPP). The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia*. 2006;49: 289–297.
104. Grundy SM, Benjamin IJ, Burke GL, et al. Diabetes and cardiovascular disease: A statement for healthcare professionals from the American Heart Association [published correction appears in *Circulation*. 2000;101:1629–1631]. *Circulation*. 1999;100: 1134–1146.
105. Mohan V, Shanthirani CS, Deepa M, et al. Community empowerment—a successful model for prevention of non-communicable diseases in India—the Chennai Urban Population Study (CUPS-17). *J Assoc Physicians India*. 2006;54:858–865.
106. Deedwania PC, Gupta R. Management issues in the metabolic syndrome. *J Assoc Physicians India*. 2006;54:797–810.
107. Combination Pharmacotherapy and Public Health Research Working Group. Combination pharmacotherapy for cardiovascular disease. *Ann Intern Med*. 2005;143:593–599.
108. Manuel DG, Lim J, Tanuseputro P, et al. Revisiting Rose: Strategies for reducing coronary heart disease. *BMJ*. 2006; 332:659–662.
109. Nishtar S. National Action Plan for Prevention and Control of Non-communicable Diseases and Health Promotion in Pakistan. Islamabad, Pakistan: Ministry of Health, Government of Pakistan; 2005:43–50.
110. Jacob KS. Public health in India and the developing world: Beyond medicine and primary healthcare. *J Epidemiol Community Health*. 2007;61:562–563.
111. Rao M, Nayar KR. Public health in private hands? A note on the Public Health Foundation of India. *Natl Med J India*. 2006;19:221–224.
112. Shah B, Menon G. Burden of non-communicable disease in India. New Delhi, India: Indian Council of Medical Research; 2005.
113. Bonita R, de Courten M, Dwyer T, et al. Surveillance of risk factors for non-communicable disease: The WHO STEPS Approach. Geneva, Switzerland: World Health Organization; 2001.
114. Anand K, Shah B, Yadav K, et al. Are the urban poor vulnerable to non-communicable diseases? A survey of risk factors for non-communicable diseases in urban slums of Faridabad. *Natl Med J India*. 2007;20:115–120.
115. Integrated Disease Surveillance Program. Ministry of Health, Government of India. http://www.inclentrust.org/pdf/inclennews/July%202003/Partners%20Development%20Disease%20Surveillance%20Program.pdf. Accessed August 28, 2007.
116. Shah B, Gupta R, Mathur P, et al. An action plan for non-communicable disease prevention, surveillance, management and control in economically deprived states: Lessons from Rajasthan. *S Asian J Prev Cardiol*. 2006;10:5–45.
117. Gupta R, Saxena M, Bhambhani A, Chandra B. Telesurveillance: Use of wireless communication systems for noncommunicable disease surveillance in India. *S Asian J Prev Cardiol*. 2006;10: 46–51.
118. Smith SC, Jackson R, Pearson TA, et al. Principles for national and regional guidelines on cardiovascular disease prevention: A scientific statement from the World Heart and Stroke Forum. *Circulation*. 2004;109:3112–3121.

Address correspondence to: Rajeev Gupta, MD, PhD, Department of Medicine, Room 5033, Fortis Escorts Hospital, JLN Marg, Malviya Nagar, Jaipur 302017, India. E-mail: rajeevg@satyam.net.in