



Challenges in Diabetes Care in India : Sheer Numbers, Lack of Awareness and Inadequate Control

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Abstract

With an estimated 40 million people suffering from the condition, the largest in any country in the world, diabetes has become a major health care problem in India. Recent epidemiological studies from India point to the great burden due to diabetes and its micro and macrovascular complications. This is primarily because the status of diabetes control in India is far from ideal. Based on the available data, the mean glycated hemoglobin levels are around 9% which is at least 2% higher than the goal currently suggested by international bodies. The IMPROVE study has helped identify the barriers to good control of diabetes both among patients as well as physicians in today's practice. However the recent ACCORD study points to the dangers of overaggressive treatment, especially in high risk in elderly patients. A balanced approach to improve awareness about diabetes and its control both among patients and the medical fraternity is urgent need of the hour in India. The associated risks of tight control in high risk groups should also be kept in mind. ©

DIABETES BURDEN IN INDIA : MEDICAL, SOCIAL AND ECONOMIC

Diabetes has emerged as a major health care problem in India. According to the Diabetes Atlas published by the International Diabetes Federation (IDF), there are an estimated 40 million persons with diabetes in India in 2007 and this number is predicted to rise to almost 70 million people by 2025 by which time every fifth diabetic subject in the world would be an Indian.¹ Genetic predisposition combined with life style changes, associated with urbanization and globalization, contribute to this rapid rise of diabetes in India.² Moreover, type 2 diabetes in the Indian population appears to occur at least a decade earlier compared to Europeans.³ This means that, in the next 10 – 20 years, productivity of the youth of our country could be seriously affected.^{1,4} Due to these sheer numbers, the economic burden due to diabetes in India is among the highest in the world.⁵ The real burden of the disease is however due to its micro and macrovascular complications which lead to increased morbidity and mortality.^{6,7} It is also known that almost 50% of people

with diabetes remain undetected and hence some may even present with microvascular and macrovascular complications at the time of diagnosis.^{8,9}

Although sporadic studies on prevalence of diabetes have been available for several decades, reliable epidemiological data became available in India since the 1970's. Published studies vary in methodologies adopted and sampling frames and hence comparison of prevalence rates is, strictly speaking, not meaningful. However as Table 1 shows, despite all methodological issues, there is little doubt that the prevalence rates are rising in India.¹⁰⁻³⁹ The Indian Council of Medical Research (ICMR) study done in the 1970's reported a prevalence of 2.3% in urban areas^{11,12} which has risen to 12-19 % in 2000's. Correspondingly, in rural areas, prevalence rates have increased from around 1%^{11,12} to 4-10%, and even 13.2% in one study.³⁶ Thus it is clear that both in urban and rural India, prevalence rates of diabetes are rising rapidly with a rough urban-rural divide of 2:1 or 3:1 being maintained through the last 2-3 decades with the exception of Kerala where rural prevalence rates have caught up with or even overtaken urban prevalence rates.³⁸ The probable explanation for this phenomenon is that in Kerala, there is indeed no clear urban/rural demarcation and the whole of Kerala can now be considered to be urbanized.

Data on various complications of diabetes have also been published by several authors (Table 2).⁴⁰⁻⁵⁸ However, till recently, most such data were hospital or clinic based and therefore subject to referral bias.

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Table 1 : Prevalence of diabetes in urban and rural India

Year	Author (Reference)	Place	Prevalence (%)	
			Urban	Rural
1971	Tripathy <i>et al</i> ¹⁰	Cuttack	1.2	-
1972	Ahuja <i>et al</i> ¹¹	Multicentre (ICMR)	2.3	1.5
1978	Gupta <i>et al</i> ¹²	Multicentre	3.0	1.3
1984	Murthy <i>et al</i> ¹³	Tenali	4.7	-
1986	Patel ¹⁴	Bhadran	3.8	-
1988	Ramachandran <i>et al</i> ¹⁵	Kudremukh	5.0	-
1989	Kodali <i>et al</i> ¹⁶	Gangavathi	-	2.2
1989	Rao <i>et al</i> ¹⁷	Eluru	1.6	-
1991	Ahuja <i>et al</i> ¹⁸	New Delhi	6.7	-
1994	Wander <i>et al</i> ¹⁹	Punjab	-	4.6
1997	Ramachandran <i>et al</i> ²⁰	Chennai	11.6	-
2000	Ramankutty <i>et al</i> ²¹	Kerala	12.4	2.5
2000	Zargar <i>et al</i> ²²	Kashmir	-	4.0
2001	Ramachandran <i>et al</i> ²³	National Urban Diabetes Study (NUDS)	12.1	-
2001	Misra <i>et al</i> ²⁴	New Delhi	10.3	-
2001	Mohan <i>et al</i> ²⁵	Chennai (CUPS)	12.1	-
2001	Sadikot <i>et al</i> ²⁶	Prevalence of Diabetes in India Study (PODIS)	5.6	2.7
2003	Gupta <i>et al</i> ²⁷	Jaipur	8.6	-
2004	Agarwal <i>et al</i> ²⁸	Rajasthan	-	1.8
2004	Ramachandran <i>et al</i> ²⁹	Chennai	-	6.4
2004	Mohan <i>et al</i> ³⁰	Chennai (CURES)	14.3	-
2005	Basavanagowdappa <i>et al</i> ³¹	Mysore	-	3.8
2005	Prabhakaran <i>et al</i> ³²	Delhi	15.0	-
2006	Reddy <i>et al</i> ³³	National	10.1	-
2006	Deo <i>et al</i> ³⁴	Maharashtra	-	9.3
2006	Menon <i>et al</i> ³⁵	Ernakulam	19.5	-
2006	Chow <i>et al</i> ³⁶	Andhra	-	13.2
2007	Raghupathy <i>et al</i> ³⁷	Vellore	3.7	2.1
2008	Mohan <i>et al</i> ³⁸	Multicentre (WHO – ICMR) Self reported	7.3	3.1
2008	Ramachandran ³⁹	Tamil Nadu	18.6	9.2

Moreover they had often not used standardized technologies (e.g. retinal photography to document diabetic retinopathy).

The Chennai Urban Rural Epidemiology Study (CURES) and the Chennai Urban Population Study (CUPS) provide the first population based data from India on virtually all complications of diabetes.

CURES was a population-based study involving 26,001 participants aged 20 years or above based on a representative population of Chennai. The overall prevalence of diabetic retinopathy based on four-field stereo colour retinal photography was 17.6%.⁴⁴ The prevalence of overt nephropathy was 2.2% while that of microalbuminuria was 26.9%.⁵¹ Peripheral neuropathy based on biothesiometry was seen in 26.1%.⁵⁷

In the CUPS study, coronary artery disease was seen in 21.4% of diabetic subjects, 14.9% of subjects with impaired glucose tolerance and in 9.1% of people with normal glucose tolerance.⁵⁴ In the same study, peripheral vascular disease was present in 6.3% of diabetic subjects compared to 2.7% among non-diabetic subjects.⁵⁵ Diabetic subjects also had increased subclinical atherosclerosis as measured by intimal medial thickness at every age point, compared to their

non-diabetic counterparts.⁵⁸ Assuming that 40 million people in India have diabetes, this translates to at least 7 million with retinopathy, 0.8 million with nephropathy, 10.4 million with neuropathy, 8.5 million with CAD and 2.5 million with PVD. Thus, the burden due to diabetic complications is very high in India due to the sheer number of people with diabetes. These figures are in fact very conservative and it is possible that in rural areas, the prevalence of complications is much higher because of poorer control of diabetes and lack of access to health care.

AWARENESS OF DIABETES IN INDIA

Not only is there a huge number of people with diabetes in India but awareness levels are also low. CURES reported that nearly 25% of the population was unaware of a condition called diabetes.⁵⁹ Only around 40% of the participants felt that the prevalence of diabetes was increasing and only 22.2% of the population and 41% of known diabetic subjects felt that diabetes could be prevented.⁵⁹ Though the awareness levels increased with education, only 42.6% of postgraduates and professionals, which group included doctors and lawyers, knew that diabetes was

Table 2 : Population and clinical based studies on prevalence of diabetes complications in India

Author (Reference)	Type of the study	City	Prevalence
RETINOPATHY			
Rema <i>et al</i> , 1996 ⁴⁰	Clinical based	Chennai	34.1%
Dandona <i>et al</i> , 1999 ⁴¹	Population based	Hyderabad	22.6%
Ramachandran <i>et al</i> , 1999 (42)	Clinical based	Chennai	23.7%
Rema <i>et al</i> , 2000 (8)	Clinic based	Chennai	7.3%
Narendran <i>et al</i> , 2002 (43)	Population based	Palakkad	26.8
Rema <i>et al</i> , 2005 (44)	Population based	Chennai	17.6%
NEPHROPATHY			
John <i>et al</i> , 1991 (45)	Clinic based	Vellore	Microalbuminuria: 19.7% Diabetic nephropathy: 8.9%
Gupta <i>et al</i> , 1991 (46)	Clinical based	New Delhi	Microalbuminuria: 26.6%
Yajnik <i>et al</i> , 1992 (47)	Clinic based	Pune	Microalbuminuria: 23.0%
Vijay <i>et al</i> , 1994 (48)	Clinical based	Chennai	Proteinuria: 18.7%
Mohan <i>et al</i> , 2000 (49)	Clinical based	Chennai	Macroproteinuria with retinopathy: 6.9%
Varghese <i>et al</i> , 2001 (50)	Clinical based	Chennai	Microalbuminuria: 36.3%
Unnikrishnan <i>et al</i> , 2006 (51)	Population based	Chennai	Microalbuminuria : 26.9% Overt nephropathy with diabetic retinopathy : 2.2%
CORONARY ARTERY DISEASE			
Mohan <i>et al</i> , 1995 (52)	Clinical based	Chennai	17.8%
Ramachandran <i>et al</i> , 1999 (53)	Clinical based	Chennai	11.4%
Mohan <i>et al</i> , 2001 (54)	Population based	Chennai	21.4%
PERIPHERAL VASCULAR DISEASE			
Premalatha <i>et al</i> , 2000 (55)	Population based	Chennai	6.3%
PERIPHERAL NEUROPATHY			
Ramachandran <i>et al</i> , 1999 (42)	Clinical based	Chennai	27.5%
Ashok <i>et al</i> , 2002 (56)	Clinical based	Chennai	19.1%
Pradeepa <i>et al</i> (57)	Population based	Chennai	26.10%
CAROTID ATHEROSCLEROSIS			
Mohan <i>et al</i> , 2001 (58)	Population based	Chennai	20%

preventable. The knowledge of risk factors of diabetes was even lower with only 11.9% of the study subjects reporting obesity and physical inactivity as risk factors for diabetes. More alarming was the fact that even among known diabetic subjects, only 40.6% were aware that diabetes could lead to some organ damage.⁵⁹ There is another population based study which was done to find out the levels of awareness on diabetes in urban adult Indian population aged ≥ 20 years details regarding awareness about diabetes.⁶⁰ Knowledge regarding causes of diabetes, its prevention and the methods to improve health was significantly low among the general population. In the total study group, 41% were unaware of health being affected by diabetes and only less than 30% knew about complications related to kidneys, eyes and nerves. Many persons with diabetes (46%) felt it was a temporary phenomenon. Among the diabetic subjects 92.3% had sought the help of a general practitioner to take treatment. Only a small proportion went to a specialist.

CURRENT STATUS OF DIABETES CONTROL IN INDIA

The next challenge in India is that the quality of diabetes care varies considerably depending upon the awareness levels, expertise available, attitudes and perceptions amongst diabetes care providers. An

estimate based on sales of anti-diabetic pharmaceutical agents shows that on an average only 10-12% of people with diabetes receive modern pharmacological treatment in India.⁶¹ In 1998, the Diabcare-Asia study was carried out to investigate the relationship between diabetes control, management and late complications in a subset of urban Indian diabetes population treated at 26 tertiary diabetes care centres.⁶² A total of 2,269 patients participated in this study and it was observed that approximately half the patients had poor control ($\text{HbA1c} > 2\%$ points above upper limit of normal) and mean HbA1c was significantly higher ($8.9 \pm 2.1\%$) than the levels recommended by the American Diabetes Association⁶³ and the ICMR guidelines in India.⁶⁴ Over 54% patients had diabetes related complications. The mean HbA1c levels and frequency of complications were higher in patients with longer diabetes duration. This study also showed that 4% of patients were on diet therapy, 53.9% were receiving oral anti-diabetic agents (OHA's), 22% were receiving insulin and 19.8% a combination of insulin and OHA's. This study concluded that with increasing duration of diabetes, glycemic control deteriorates leading to late complications. It also confirmed that diabetes care in India leaves much to be desired and suggested the need for efforts to increase awareness amongst health professionals to improve diabetes care in India.⁶⁵

THE IMPROVE™ CONTROL INDIA (ICI) STUDY

The IMPROVE Control India (ICI) study involved 451 clinicians and was carried out in the 8 metropolitan cities of India. Face to face interviewing using a mix of both qualitative and quantitative techniques was used in the study. The main objectives of the study were to shed light on the doctors and patients' knowledge, expectations and attitudes with regards to glucose control, and to understand the barriers to achieving good glucose control among patients and health professionals.

This study showed that though insulin therapy is accepted as one of the most effective and dependable treatment option in management of diabetes, there are several barriers to its usage among type 2 diabetic cases particularly the acceptance of insulin therapy. There were many other barriers identified in terms of regular monitoring of diabetes status and lack of standardization in laboratory techniques. Surprisingly, the majority of these barriers involved the treating doctors as well.

From the doctor's perspective, the ICI study observed no consensus on targets and guidelines amongst the

treating doctors, e.g., lack of consensus on parameters to be measured [fasting or post prandial plasma glucose (PPG) or glycated haemoglobin (HbA1c)] or on the ideal target values of HbA1c. Various studies from India⁶⁵ have confirmed the association of HbA1c with prevalent diabetic complications^{44,51,57} as well as with cardiovascular disease.⁶⁵ In accordance with current guidelines in the management of diabetes in the ICI study also, most doctors agreed that HbA1c testing is crucial. However, as shown in Figure 1 the advice for HbA1c testing was given in only in 79% as against that of FPG & PPG in 97% & 96% of patients respectively. Although HbA1c was considered as an important parameter in diabetes management, the emphasis on this test while making the patient understand the importance of various tests was relatively very low (Fig. 1). When it came to patient's perception, in 19% of cases HbA1c was felt to be a routinely advised test (Fig. 2). Moreover only 1/3rd of the patients were aware of the HbA1c test (Fig. 2). Many doctors felt that standardization of HbA1c in laboratories is not reliable and therefore preferred only FPG and PPG measurements. Even when HbA1c tests were requested, they were done only once or twice a year.

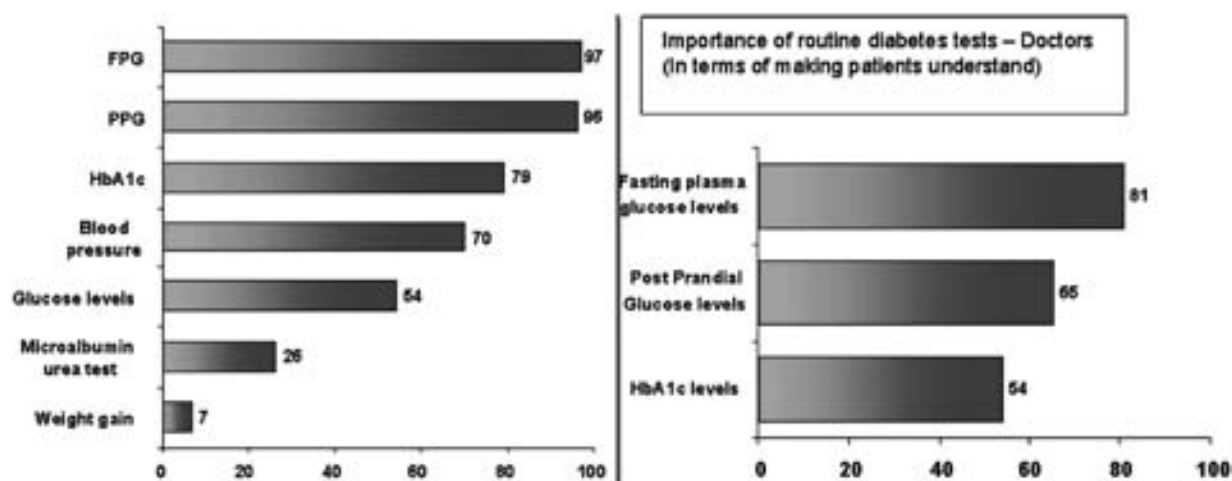


Fig. 1 : Routine tests advised - Doctors (IMPROVE™ Control India Study)

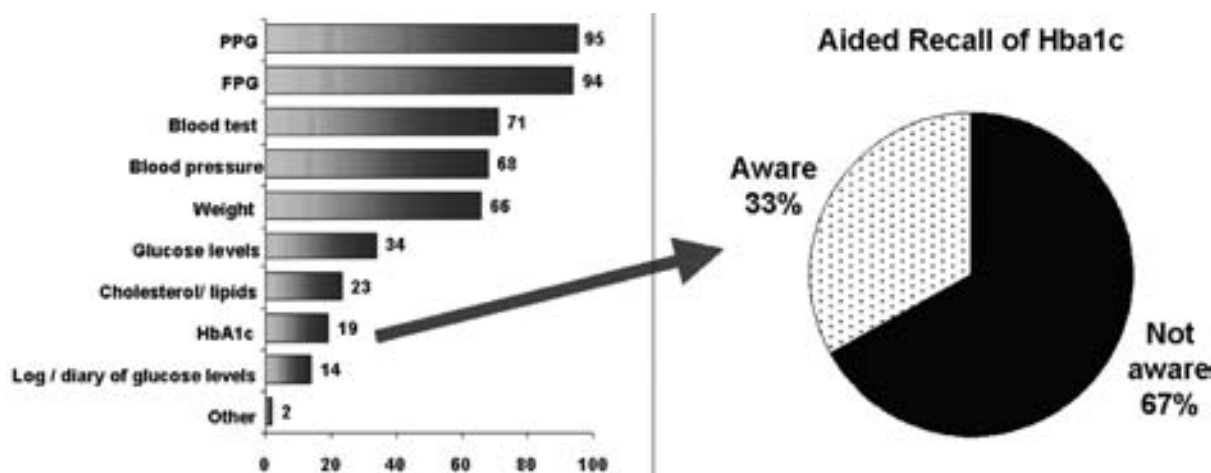


Fig. 2 : Routine tests advised – patient's perspective (IMPROVE™ Control India Study)

Moreover, even among patients whose HbA1c values were measured, most (53%) were not given glycemic targets as the study also reported relaxation of targets as duration of diabetes increased. Difficulty in long-term maintenance of HbA1c targets were recognized by majority of doctors. This might be one of the contributing factors towards lack of motivation to achieve good glycemic control by the patients.

“CLINICAL INERTIA” IN DIABETES – FAILURE TO ACHIEVE TIGHT CONTROL

Failure of initiation of or intensification of therapy, when indicated, is termed “clinical inertia”. Though we have well-defined management goals, effective therapies and practice guidelines, there is often a failure to take appropriate action despite recognition of the problem. This is a common problem in management of patients with asymptomatic chronic illnesses. Use of “soft” reasons to avoid intensification of therapy and lack of education, training and practice organization aimed at achieving therapeutic goals are the common reasons for clinical inertia. Data from the United States suggest that of the 65% of the patients diagnosed with diabetes, only 73% are prescribed pharmacologic therapy and only 33% of those thus treated achieve a hemoglobin A1C value of less than 7% by the ADA goal.⁶⁶

Clinical inertia in achieving glycemic targets in Indian diabetic subjects could be expected to be even more due to the low rates of awareness of diabetes and its complications in India resulting in poor glycemic control seen in Indians with diabetes. Moreover other factors like poverty, lack of accessibility to health services and inadequate follow-up are additional factors in developing countries like India.

Consequently insulin is delayed until it is absolutely necessary. Most patients are initiated on insulin after a course of multiple oral anti-diabetic drugs. Insulin therapy is initiated only when the HbA1c levels had deteriorated further to around 9%. Doctors often delay insulin therapy worrying that the daily injections, modification of lifestyle due to insulin and dependence on insulin for life and that patients may feel that insulin therapy indicates the last stage of diabetes. However, patients who had moved on to insulin seemed to have a more positive approach towards his/her treatment due to improve in quality of life and better control despite the issues outlined above.

The ICI study also tried to evaluate the patient's attitudes towards glucose control. Most patients were under the impression that they were in control of their diabetes despite lack of knowledge of their blood sugar levels. The average patient's perception of being in good control of diabetes was the fact that he/she complied with medication, diet, exercise plan and that they did not feel any untoward symptoms. Too few of them

stated or knew target blood glucose or HbA1c values as a measure of control of their diabetes.

THE ACCORD TRIAL – THE OTHER SIDE OF TIGHT CONTROL OF DIABETES

One of the primary objectives of the randomized multicentric trial Action to Control Cardiovascular Risk in Diabetes (ACCORD), was to determine whether intensive lowering of blood sugar levels would reduce the risk of fatal and non-fatal cardiovascular events, specifically in type 2 diabetic subjects, who are at a high risk of developing a cardiovascular event. It was conducted in the USA and in Canada and included adults in the 40-82 years age group who had, in addition to diabetes, two or more other risk factors for heart disease or had been diagnosed with heart disease prior to the study. The participants had been having diabetes for 10 years on an average, at the time of enrollment. Of the 10,251 participants in the study, 5,128 were randomized to the intensive glycemic control group (target HbA1c < 6.0%) and 5123 to the standard glycemic control group (target HbA1c between 7.0 and 7.9%).⁶⁷ Unfortunately, this study showed that out of the total deaths reported from among the study participants after having been followed up for nearly 4 years, 257 were in the intensively treated group and 203 in the standard treatment group.⁶⁸ Following this, the intensive treatment given to participants randomized to that group was stopped 18 months ahead of the protocol time and the patients randomized to the intensive glycemic control group also started receiving the same treatment as the standard glycemic control group.⁶⁷ However, the deaths were due to different causes like surgical complications, sepsis and strokes, many were heart attacks and no specific cause for the increase in deaths in the intensive treatment group was identifiable and no medication was deemed responsible. A hypothesis proposed was that though atherosclerosis was more in diabetic subjects than in others, the extra sugar in the plaques stabilized them. Hence, when diabetes was over aggressively controlled (target HbA1c < 7.0%), the plaques are believed to lose their stability with increased likelihood of their rupture. The little or no relationship established between HbA1c and cardiovascular problems in type 2 diabetes in studies including the 20-year United Kingdom Prospective Diabetes Study (UKPDS), was quoted as support for this hypothesis. Another hypothesis was that hypoglycemic episodes associated with insulin treatment could cause tachycardia and have untoward effects on the cardiovascular system.⁶⁸

The ACCORD trial is a warning to clinicians of the consequences of overaggressive treatment of type 2 diabetes especially in high risk groups such as the elderly. It highlights that the treatment goals should be individualized according to the patient's health profile

and not all diabetic subjects should be aggressively treated. Further, it establishes the need of achieving a balance between the benefits of intensive glycemic control and the disadvantages of standard glycemic control.

CONCLUSIONS

Considering the enormous burden due to diabetes in India, it is important to realize the cost-effective measures of diabetes care like early screening, tight metabolic control, monitoring of risk factors and assessing of organ damage. The study done for economic analysis in diabetes care in India has also shown that the cost of providing routine care is only a fraction of the overall cost and is perhaps still manageable. However, when this is not available or its quality is poor, the overall direct and indirect costs escalate with disastrous health and economic consequences to the individual, his family and society particularly due to the onset of the micro and macrovascular complications of diabetes.⁶⁹ Published data from several epidemiological, experimental human and animal studies as well as the data from several mega trials like DCCT, Kumamoto study and UKPDS have convincingly proved the importance of tight metabolic control in arresting and preventing the progression of target organ damage. In the last two decades there is better understanding of pathophysiology of type 2 diabetes and availability of newer oral drugs for diabetes, newer insulin and improved delivery systems should translate to improve diabetes control. However the survey described above indicates the gaps between the guidelines and real life practice.^{36,70-72} In view of this, appreciation and understanding of both patient and physician barriers regarding proper monitoring and judicious use of therapeutic options including insulin therapy for optimizing diabetes management should be encouraged in order to improve control of diabetes in India. Result oriented organized programmes involving patient education, updating medical fraternity on various developments in the management of diabetes and providing them the opportunity to use and analyze these newer treatment options in the form of observational studies is required to combat the diabetes epidemic currently threatening to affect the lives of millions of people in India.

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REFERENCES

1. Sicree R, Shaw J, Zimmet P. Diabetes and impaired glucose tolerance in India. Diabetes Atlas. Gan D Ed. International Diabetes Federation, Belgium. pp 15-103, 2006.
2. Mohan V, Sandeep S, Deepa R, Shah B, Varghese C. Epidemiology of type 2 diabetes: Indian Scenario. *Indian Journal of Medical Research* 2007;125:217-30.
3. Mohan V, Alberti KGMM. Diabetes in the tropics. In: International Text Book of Diabetes Mellitus (Second Edition). Alberti KGMM, Zimmet P, Defronzo RA, Keen H. (eds.), John Wiley and Sons Ltd, Chichester. U.K., 1997;171-87.
4. Nakagami T, Qiao Q, Carstensen B, Nhr-Hansen C, Hu G, Tuomilehto J, Balkau B, Borch-Johnsen K; The DECODE-DECODA Study Group. Age, body mass index and Type 2 diabetes-associations modified by ethnicity. *Diabetologia* 2003;46:1063-70.
5. <http://www.globalforumhealth.org/filesupld/forum9/CD%20Forum%209/papers/Bjork%20S.pdf>.
6. Zargar AH, Wani AI, Masoodi SR, Laway BA, Bashir MI. Mortality in diabetes mellitus—data from a developing region of the world. *Diabetes Res Clin Pract* 1999;43:67-74.
7. Mohan V, Shanthirani CS, Deepa M, Deepa R, Unnikrishnan RI, Datta M. Mortality rates due to diabetes in a selected urban south Indian population – The Chennai Urban Population Study (CUPS-16). *Journal of Association of Physicians of India*. 2006;54: 113-117.
8. Rema M, Deepa R, Mohan V. Prevalence of retinopathy at diagnosis among Type 2 diabetic patients attending a diabetic centre in South India. *British Journal of Ophthalmology* 2000;84:1058-60.
9. Ramachandran A, Snehalatha C, Satyavani K, Latha E, Sasikala R, Vijay V. Prevalence of vascular complications and their risk factors in type 2 diabetes. *J Assoc Physicians India* 1999;47:1152-6.
10. Tripathy BB, Panda NC, Tej SC, Sahoo GN and Kar BK. Survey for detection of glycosuria, hyperglycaemia and diabetes mellitus in urban and rural areas of Cuttack district. *J Assoc Physicians India* 1971;19:681.
11. Ahuja MMS, Sivaji L, Garg VK and Mitroo P. Prevalence of diabetes in northern India (Delhi area). *Horn Metab Res* 1974;4:321.
12. Gupta OP, Joshi MH, Dave SK. Prevalence of diabetes in India. *Adv Metabolic Disorders* 1978;9:147-65.
13. Murthy PD, Pullaiah B and Rao KV. Survey for detection of hyperglycaemia and diabetes mellitus in Tenali. In *Diabetes Mellitus in Developing Countries*. Bajaj JS Ed. Interprint, New Delhi, 1984, 55.
14. Patel JC. Prevalence of hypertension and diabetes mellitus in a rural village. *J Diabetic Assoc India* 1986;26:68.
15. Ramachandran A, Jali MV, Mohan V, Snehalatha C, Viswanathan M. High prevalence of diabetes in an urban population in south India. *Br Med J* 1988;297:587-90.
16. Kodali VRR, Alberti KGMM. Diabetes mellitus and hypertension among rural-rural migrants in South India. *Hum Biol* 1989.
17. Rao PV, Ushabala P, Seshiah V, Ahuja MM, Mather HM. The Eluru survey: prevalence of known diabetes in a rural Indian population. *Diabetes Res Clin Pract* 1989;7:29-31.
18. Ahuja MMS. Diabetes mellitus in India in the context of social change. Bombay, India: Health Care Communications 1996.
19. Wander GS, Khurana SB, Gulati R, Sachar RK, Gupta RK, Khurana S, Anand IS. Epidemiology of coronary heart disease and risk factors in a rural Punjab population: prevalence and correlation with various risk factors. *Ind Heart J* 1994;46:319-23.

20. 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.
21. Ramankutty V, Joseph A, Soman CR. High prevalence of type 2 diabetes in an urban settlement in Kerala, India. *Ethn Health Med* 1999;4:231-9.
22. Zargar AH, Khan AK, Masoodi SR, Laway BA, Wani AI, Bashir MI, Dar FA. 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.
23. Ramachandran A, Snehalatha C, Kapur A, et al. 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.
24. Misra A, Pandey RM, Devi JR, Sharma R, Vikram NK, Khanna N. High prevalence of diabetes, obesity and dyslipidaemia in urban slum population in northern India. *Int J Obes* 2001;25:1722-9.
25. 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.
26. Sadikot SM, Nigam A, Das S, et al. 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.
27. Gupta A, Gupta R, Sarna M, Rastogi S, Gupta VP, Kothari K. Prevalence of diabetes, impaired fasting glucose and insulin resistance syndrome in an urban Indian population. *Diabetes Res Clin Pract* 2003; 61:69.
28. Agrawal RP, Singh G, Nayak KC, Kochar DK, Sharma RC, Beniwal R, et al. Prevalence of diabetes in camel milk consuming 'RAICA' Rural Community of North West Rajasthan. *Int J Diab Dev Countries* 2004;24:109-14.
29. Ramachandran A, Snehalatha C, Baskar AD, Mary S, Kumar CK, Selvam S, Catherine S, Vijay V. Temporal changes in prevalence of diabetes and impaired glucose tolerance associated with lifestyle transition occurring in the rural population in India. *Diabetologia* 2004;47:860-5.
30. Mohan V, Deepa M, Deepa R, et al. Secular trends in the prevalence of diabetes and glucose tolerance in urban South India-the Chennai Urban Rural Epidemiology Study (CURES-17). *Diabetologia* 2006;49:1175.
31. Basavanagowdappa H, Prabhakar AK, Prasannaraj P, Gurudev KC, Virupaksha, Suma. Study of prevalence of diabetes mellitus and impaired fasting glucose in a rural population. *Int J Diab Dev Ctries* 2005;25:98-101.
32. Prabhakaran D, Shah P, Chaturvedi V, Ramakrishnan L, Manhapra A, Reddy KS. Cardiovascular risk factor prevalence among men in a large industry of northern India. *Natl Med J India* 2005;18:59-65.
33. Reddy KS, Prabhakaran D, Chaturvedi V, et al, on behalf of the Sentinel Surveillance System for Indian Industrial Populations Study Group. Methods for establishing a surveillance system for cardiovascular diseases in Indian industrial populations. *Bull WHO* 2006;84:461-9.
34. Deo SS, Zantye A, Mokul R, Mithbawkar S, Rane S, Thakur K. 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.
35. Menon VU, Kumar KV, Gilchrist A, Sugathan TN, Sundaram KR, Nair V, Kumar H. Prevalence of known and undetected diabetes and associated risk factors in central Kerala - ADEPS. *Diabetes Res Clin Pract* 2006;74:289.
36. Chow CK, Raju PK, Raju R, et al. The prevalence and management of diabetes in rural India. *Diabetes Care* 2006;29:1717-18.
37. Raghupathy P, Antonisamy B, Fall CH, Geethanjali FS, Leary SD, Saperia J, Priya G, Rajaratnam A, Richard. High prevalence of glucose intolerance even among young adults in south India. *Diabetes Res Clin Pract* 2007;77:269-79.
38. Mohan V, Mathur P, Deepa R, Deepa M, Shukla DK, Menon GR, Anand K, Desai NG, Joshi PP, Mahanta J, Thankappan KR, Shah B. Urban rural differences in prevalence of self-reported diabetes in India-The WHO-ICMR Indian NCD risk factor surveillance. *Diabetes Res Clin Pract* 2008 2008;80: 159-68.
39. Ramachandran A, Mary S, Yamuna A, Murugesan N, Snehalatha C. High Prevalence of Diabetes and Cardiovascular Risk Factors Associated with urbanization in India. *Diabetes Care* 2008;31:893-8.
40. Rema M, Ponnaiya M, Mohan V. Prevalence of retinopathy in non insulin dependent diabetes mellitus in southern India. *Diab Res Clin Practice* 1996;24:29-36.
41. Dandona L, Dandona R, Naduvilath TJ, et al. Population based assessment of diabetic retinopathy in an urban population in southern India. *Br J Ophthalmol* 1999;83:937-40.
42. Ramachandran A, Snehalatha C, Satyavani K, Latha E, Sasikala R, Vijay V. Prevalence of vascular complications and their risk factors in type 2 diabetes. *J Assoc Physicians India* 1999;47:1152-6.
43. Narendran V, John RK, Raghuram A, Ravindran RD, Nirmalan PK, Thulasiraj RD. Diabetic retinopathy among self reported diabetics in southern India: a population based assessment. *Br J Ophthalmol* 2002;86:1014-8.
44. Rema M, Premkumar S, Anitha B, Deepa R, Pradeepa R, Mohan V. Prevalence of Diabetic Retinopathy in Urban India: The Chennai Urban Rural Epidemiology Study (CURES) Eye Study-1. *Invest Ophthalmol Vis Sci* 2005;46:2328-33.
45. John L, Sundar Rao PSS, Kanagasabhapathy AS. Prevalence of diabetic nephropathy in non insulin dependant diabetes mellitus. *Indian J Med Res* 1991;94:24-9.
46. Gupta DK, Verma LK, Khosla PK, Dash SC. The prevalence of microalbuminuria in diabetes: a study from north India. *Diabetes Res Clin Pract* 1991;12:125-8.
47. Yajnik CS, Naik SS, Raut KN, Khade AD, Bhat DS, Nagarkar VD, Deshpande JA, Shelgikar KM. Urinary albumin excretion rate (AER) in newly-diagnosed type 2 Indian diabetic patients is associated with central obesity and hyperglycaemia. *Diabetes Res Clin Pract* 1992;17:55-60.
48. Vijay V, Snehalatha C, Ramachandran A, Viswanathan M. Prevalence of proteinuria in non-insulin dependent diabetes. *J Assoc Physicians India* 1994;42:792-4.
49. Mohan V, Meera R, Premalatha G, Deepa R, Priya M, Rema M. Frequency of proteinuria in Type 2 diabetes mellitus seen at a diabetes centre in Southern India. *Postgrad Med J* 2000;76:569-73.
50. Varghese A, Deepa R, Rema M, Mohan V. Prevalence of microalbuminuria in Type 2 diabetes mellitus at a diabetes centre in southern India. *Postgraduate Medical Journal* 2001;77:399-402.
51. Ranjit Unnikrishnan I, Rema M, Pradeepa R, Deepa M, Shanthirani CS, Deepa R, Mohan V. Prevalence and risk factors of diabetic nephropathy in an Urban South Indian population

: The Chennai Urban Rural Epidemiology Study (CURES-45). *Diabetes Care* 2007;30:2019-24.

52. Mohan V, Premalatha G, Sastry NG. Ischaemic heart disease in south Indian NIDDM patients – A clinic based study on 6597 NIDDM patients. *Int J Diab Dev Countries* 1995;15: 64-7.
53. Ramachandran A, Snehalatha C, Latha E, Satyavani K, Vijay V. Clustering of cardiovascular risk factors in urban Asian Indians. *Diabetes Care*. 1998;21:967-71.
54. Mohan V, Deepa R, Shanthirani CS, Premalatha G. Prevalence of coronary artery disease and its relationship to lipids in a selected population in south India. *J Am Coll Cardiol* 2001;38:682-7.
55. Premalatha G, Shanthirani CS, Deepa R, Markovitz J, Mohan V. Prevalence and risk factors of peripheral vascular disease in a selected south Indian population – The Chennai Urban Population Study (CUPS). *Diabetes Care* 2000;23: 1295-1300.
56. Ashok S, Ramu M, Deepa R, Mohan V. Prevalence of neuropathy in type 2 diabetic patients attending a diabetes centre in south India. *J Assoc Physicians India* 2002;50: 546-50.
57. Pradeepa R, Rema M, Vignesh J, Deepa M, Deepa R, Mohan V. Prevalence and risk factors for diabetic neuropathy in an urban south Indian population: the Chennai Urban Rural Epidemiology Study (CURES-55). *Diabet Med* 2008;25: 407-12.
58. Mohan V, Ravikumar R, Shanthirani S, Deepa R. Intimal medial thickness of the carotid artery in south Indian diabetic and non diabetic subjects: the Chennai Urban Population Study (CUPS). *Diabetologia* 2000;43:494-9.
59. Deepa M, Deepa R, Shanthirani CS, Datta M, Unwin NC, Kapur A, Mohan V. Awareness and knowledge of diabetes in Chennai—the Chennai Urban Rural Epidemiology Study [CURES-9]. *J Assoc Physicians India* 2005;53:283-7.
60. Murugesan N, Snehalatha C, Shobhana R, Roglic G, Ramachandran A. Awareness, about diabetes and its complications in the general and diabetic population in a city in southern India. *Diabetes Res Clin Pract* 2007;77:433-7.
61. Kapur A, Shishoo S, Ahuja MMS, Sen V, Mankame D. Diabetes Care in India: Patient's Perceptions Attitudes and Practices (DIPPAP-1 Study). *Int J Diab Dev Countries* 1997;17:2-12.
62. Raheja BS, Kapur A, Boraskar A, Sathe SR, Jorgensen LN, Moorthi SR, Pendsey S, Sahay BK. DiabCare Asia—India Study: diabetes care in India—current status. *J Assoc Physicians India* 2001;49:717-22.
63. American Diabetes Association (ADA) Recommendations Regarding Glycated Hemoglobin Standardization. American Diabetes Association Position Statement. Tests of Glycemia in Diabetes. *Diabetes Care* 2004;27:S91-S93.
64. Guidelines for Management of Type 2 diabetes by the Indian Council of Medical Research. 2005. http://www.icmr.nic.in/guidelines_diabetes/guide_diabetes.htm
65. Dilley J, Ganesan A, Deepa R, Deepa M, Sharada G, Williams OD, Mohan V. Association of A1C with cardiovascular disease and metabolic syndrome in Asian Indians with normal glucose tolerance. *Diabetes Care* 2007;30:1527-32.
66. Lawrence S. Phillips, MD; William T. Branch Jr., MD; Curtiss B. Cook, MD; Joyce P. Doyle, MD; Imad M. El-Kebbi, MD; Daniel L. Gallina, MD; Christopher D. Miller, MD; David C. Ziemer, MD; and Catherine S. Barnes, PhD – Clinical Inertia - *Ann Intern Med* 2001;135:825-34.
67. <http://www.nih.gov/news/health/feb2008/nhlbi-06.htm>. For Safety, NHLBI Changes Intensive Blood Sugar Treatment Strategy in Clinical Trial of Diabetes and Cardiovascular Disease. February 6, 2008 News Release - National Institutes of Health (NIH). Accessed on April 9, 2008.
68. Couzin J. Clinical Research: Deaths in Diabetes Trial Challenge a Long-Held Theory. *Science*. 884-885, 15 February 2008.
69. Kapur A. Economic analysis of diabetes care. *Indian J Med Res* 2007;125:473-82
70. Nagpal J, Bhartia A. Quality of diabetes care in the middle- and high-income group populace: the Delhi Diabetes Community (DEDICOM) survey. *Diabetes Care* 2006;29: 2341-8.
71. Kapur A, Shishoo S, Ahuja MMS, Sen V, Mankame K. Diabetes care in India: Physicians perceptions, attitudes and practices. *Int J Diab Dev Countries* 1998;18:124-30.
72. Chuang LM, Tsai ST, Huang BY, Tai TY. The status of diabetes control in Asia—a cross-sectional survey of 24 317 patients with diabetes mellitus in 1998. *Diabet Med* 2002;19:978-85.