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The Diabetes Paradox in India: Case of Kerala and Bihar

Rajeshwari A. Biradar[*1], Dharmendra P. Singh[2] and Shiva S. Halli[3]

Abstract: Unlike in other populations, in India, the state with one of the worst health indicators, Bihar, has the lowest diabetes rate, whereas a state with one of the best health indicators, Kerala, shows the highest diabetes rate. In the absence of a systematic study with a national representative sample to help policymakers, this study makes an attempt to understand this paradoxical phenomenon in two Indian states. The most recent National Family Health Survey data are analysed using bivariate and multivariate logistic regression to understand the differences in diabetes prevalence among the two states. The multivariate logistic regression odds ratios do not show significant associations between diabetes prevalence and education, wealth index, caste and religion. In both the states, background variables and lifestyle factors such as drinking alcohol and tobacco consumption are not significant in explaining the geographic distributions in diabetes. Future studies may be required to highlight other geographical differences, including ethnic phenotype, genetic factors, and elevation from sea level to explain the diabetes prevalence.

Key Words: Diabetes paradox, Geographical differences, National Family Health Survey, India, Men and Women.

Introduction

Analysis of recent statistical data reveals that diabetes has several new epidemiological features. First, diabetes keeps growing steadily in high-income countries, such as the United States and Japan (Wild et al. 2004). Moreover, diabetes rates have been growing at an alarming rate in low-and middle-income countries (WHO, 2019; Aguiree, 2013). Even today, seven out of the top ten nations with the highest number of diabetes patients are from low-or middle-income countries, including India (Diamond, 2011). It is predicted that diabetes will continue to grow in the next twenty years, but more than 70% of the patients will be from developing countries (Wild, 2004). A review of the literature on diabetes in India indicates that the southern states have a higher prevalence of diabetes. The first study in South India was at Vellore, a hospital-based study of 63,356 individuals, and the prevalence of diabetes was 2.5% (Vaishnava et al., 1964). Another study conducted in 1966 showed the early signs of the looming diabetes epidemic in Hyderabad, which reported a high prevalence of 4.1% (Rao et al., 1966). In 1984, house to house surveys conducted among individuals aged 15 years and above in Tenali, a small town in Andhra Pradesh and rural population of Pondicherry (now Puducherry), reported a prevalence of 4.7% respectively (Murthy et al., 1984). Recent research also revealed that there are large differences in diabetes prevalence between states in India (Anjana et al., 2011; Anjana

[*] Corresponding Author
[1] PhD Research Scholar, School of Development Studies, Tata Institute of Social Sciences, Mumbai, Email: rajeshwaribiradar@ymail.com
[2] Professor and Associate Dean, School of Research Methodology, Tata Institute of Social Sciences, Mumbai, Email: dpsingh@tiss.edu
[3] Professor, Department of Community Health Sciences, University of Manitoba, Winnipeg, MB, Canada, Email: shivahalli@yahoo.com

et al., 2017; Tandon et al., 2018; Geldsetzer et al., 2018). Based on district-level analyses in India, other recent studies indicated that there is a strong clustering of diabetes at district level (Biradar and Singh, 2019; Ghosh et al., 2019). What is intriguing about these studies is that the southern states tend to have higher prevalence of diabetes in India although they have better health and demographic indicators (Tandon et al., 2018; Biradar and Singh, 2019; Ghosh et al., 2019).

This gave rise to our study comparing two contrasting states with respect to health indicators, Kerala and Bihar, of diabetes. Sensitive health indicators such as infant mortality rate, neonatal mortality rate, life expectation at birth, total fertility rate, nutritional status of both women and children are all very much in favour of Kerala compared to Bihar (Diamond, 2011; IIPS, 2017; SRS, 2019; SRS, 2017). Hence, the objective of the study is an attempt to examine differences in diabetes prevalence and its associated risk factors between a state with one of the worst health indicators, Bihar and a state with one of the best health indicators, Kerala, using the most recent National Family Health Survey data.

Data and Methods

The present study used the fourth round of National Family Health Survey (NFHS-IV) data, which is the Indian Demographic Health Survey under the stewardship of the Ministry of Health and Family Welfare (MoHFW), Government of India, and coordinated by the International Institute for Population Sciences (IIPS), Mumbai, India. The NFHS-IV survey has adopted a multistage stratified sampling to provide various demographic and population health outcome indicators for all 640 districts and 35 states and Union Territories (UTs) as per the 2011 Indian Census classification of districts. This is the fourth round of the NFHS conducted in India and for the first time included blood glucose and hypertension measurements. It contains information on 699,686 women from 15-49 years of age and 112,122 men from 15-54 years of age on health and family welfare to provide estimates of essential indicators. For this study, we focused on Kerala and Bihar states of India, which includes a sample of 10,450 women and 1,816 men in Kerala and 41,959 women and 5,351 men in Bihar. However, we excluded currently pregnant women and men aged 50-54 from the analysis. The NFHS-IV measured random blood glucose levels using a finger-stick blood specimen in 15–49-year-old women and 15–54-year-old men using a freestyle optimum glucometer. NFHS-IV classifies the adult men and women aged 15–49 years as high (141– 160 mg/dl) and very high glucose levels (>160 mg/dl). However, based on the Indian population data Somannavar et al., (2009) defined the cut-off of the 2-h plasma glucose >200 mg/dl (11.1 mmol/l) criterion is equivalent to the random capillary blood glucose cut-off point of 140 mg/dl (7.7 mmol/l). In the present study, we consider a random glucose level of > 140 mg/dl, similar to the NFHS-IV report and Ghosh et al., 2019 study for a high risk of diabetes in India (IIPS, 2017). Therefore, we estimated the prevalence of diabetes (including pre-diabetes), that is, the percentage of men and women aged 15–49 years with a random blood glucose level of >140 mg/dl for Bihar and Kerala states of India, and applied appropriate sampling weights.

NFHS-IV survey data were also used to compute the other social indicators and lifestyle predictors in the present analyses. These are as follows: Body Mass Index (BMI) of men and women are constructed using person's height in centimetres and weight in kilograms with

categories of Too thin for their height (less than 18.5), Normal (18.5-24.9), Overweight (25.0-29.9) and Obese (≥30). Other lifestyle factors are Alcohol consumption (no and yes) and Tobacco consumption (no and yes). Tobacco consumption includes smoking cigarettes or pipe or cigars or others, or/and chewing tobacco or use snuff or "gutkha" or "paan masala" with tobacco or paan with tobacco. We analysed data in IBM Statistical Package for the Social Sciences (SPSS) version-20. First, bivariate analysis was used to assess the association between 'diabetes prevalence among women and men with their background characteristics and presented in Table 1 and 2. Second, multivariate analysis has been used for assessing the effect of each background characteristics after controlling for the other variables on the diabetes prevalence and presented in Table 3 and 4.

Results

For almost all categories of background characteristics, the prevalence of diabetes for both women and men are much higher (some cases more than double) in Kerala compared to Bihar (Table 1 and Table 2). For instance, in Bihar and Kerala, for those who are less than 30 years old, the prevalence is 2.5% and 2.8% for women, and for men, the corresponding prevalence is 4.0% and 7.6% respectively. The significance of bivariate associations is based on the 95% level of confidence interval; many of the chi-square values are significant. As education increases, the diabetes prevalence for women in Bihar and Kerala is decreasing (Table 1) but not for men (Table 2). Geographical differences are observed in the diabetes prevalence among all wealth index categories, poor, middle and rich. In Kerala, among women, as wealth increases diabetes prevalence decreases, while the reverse is true among women in Bihar. For instance, among poor, middle and rich categories of women diabetes prevalence are 10.6%, 9.8% and 8.6% in Kerala, while the corresponding figures in Bihar are 4.0, 4.8 and 6.0 respectively. A similar trend is observed among middle and rich categories of wealth index for men in Bihar and Kerala. However, among poor men in Bihar, the diabetes prevalence is 5.7%, and the corresponding figure for poor men in Kerala is 4.4%. As far as marital status, those whose marriages were dissolved have a higher prevalence of diabetes irrespective of gender in both the states.

Similarly, though expected, BMI shows strong positive associations with diabetes prevalence for both sexes and states. For instance, for Bihar women and men, the prevalence for normal BMI are 4.0% and 6.2%, but the corresponding prevalence for obese women and men are 14.1% and 25.7% respectively. Similarly, for Kerala women and men, the prevalence for normal BMI are 6.6 and 11.2%, but the corresponding prevalence for obese women and men are 18.9% and 28.8% respectively. Because of possible confounding factors, the results of multivariate logistic regressions are presented in Table 3 and Table 4. The associations are significantly different from bivariate to multivariate. The adjusted odds ratios for age in both the states indicated that as age increases the risk of diabetes increases significantly. Similarly, BMI shows a strong positive association with diabetes risk for both the sexes in both the states but the risk of diabetes is higher in Kerala. For instance, in case of Bihar men, per unit increase in BMI increases the risk of diabetes by 4% but the corresponding risk in Kerala is 8%; and for women, the corresponding risks are 3% and 6% respectively. Unlike the bivariate, the multivariate analysis indicates that none of the other important factors such as education, wealth index (except in case of Bihar), religion, caste, marital status and occupation are significant predictors

of diabetes risk. Lifestyle factors, such as alcohol and tobacco consumption are also not significant.

Table 1: Prevalence of diabetes (>140mg/dl) among women in Bihar and Kerala, India, 2015-16

Background Characteristics	Bihar			Kerala		
	Women %	P[b]	Number	Women %	P[b]	Number
Age groups						
15-29	2.5		22390	2.8		4232
30-44	5.7	0.000	15387	11.2	0.000	4661
45-49	9.8		4182	18.3		1557
Education						
No education	5.0		19561	10.7		149
Primary	4.3	0.000	4303	17.9	0.000	443
Secondary	3.8		15850	9.2		6965
Higher	3.6		2245	6.7		2893
Wealth Index						
Poor	4.0		29718	10.6		321
Middle	4.8	0.000	6370	9.8	0.858	1539
Rich	6.0		5871	8.6		8590
Place of residence						
Rural	4.2	0.006	36231	9.1	0.201	6496
Urban	5.2		5728	8.6		3954
Religion						
Hindu	4.4	0.928	35746	8.6	0.268	6008
Others	4.4		6213	9.1		4442
Caste						
SC/ST	4.0		9222	8.3		1338
OBC	4.2	0.000	24979	8.6	0.003	5584
General	5.2		7369	9.7		3106
Marital Status						
Never Married	2.0		8815	2.3		2458
Currently Married	4.9	0.000	31967	10.7	0.000	7580
Others	8.2		1177	12.6		412
Occupation						
No occupation	4.5	0.678	5377	9.2	0.177	1758
Agricultural	4.6		769	15.8		67
Others	5.6		675	8.7		440
BMI						
Too thin for their height	2.9	0.000	12736	2.7	0.000	1046
Normal	4.0		24297	6.6		6071
Overweight	9.2		3857	13.6		2650
Obese	14.1		1015	18.9		675
Drinks alcohol						
No	4.4	0.630	41844	8.8	0.722	10302
Yes	3.5		115	9.4		148
Tobacco Consumption						
No	4.4	0.105	41544	8.8	0.478	10317
Yes	5.9		415	6.8		133

Note: b. Determined by $\chi 2$ test; $P < .05$ considered significant

Table 2: Prevalence of diabetes (>140mg/dl) among men in Bihar and Kerala, India, 2015-16

Background Characteristics	Bihar			Kerala		
	Men			Men		
	%	P[b]	Number	%	P[b]	Number
Age groups						
15-29	4.0		2840	7.6		818
30-44	8.8	0.000	1947	16.1	0.000	755
45-49	13.1		564	22.5		243
Education						
No education	6.9		1084	9.6		16
Primary	6.8	0.131	650	14.7	0.404	89
Secondary	6.1		2913	11.6		1242
Higher	8.7		704	16.6		469
Wealth Index						
Poor	5.7		3524	4.4		62
Middle	7.4	0.000	944	12.6	0.098	311
Rich	10.1		883	13.5		1443
Place of residence						
Rural	6.4	0.076	4344	12.6	0.700	1103
Urban	8.0		1007	13.7		713
Religion						
Hindu	6.4	0.028	4649	13.6	0.759	1034
Others	8.6		702	12.4		782
Caste						
SC/ST	5.7		1142	13.5		219
OBC	6.8	0.266	3300	12	0.137	902
General	7.4		888	15.1		565
Marital Status						
Never Married	3.9		1937	7.3		816
Currently Married	8.3	0.000	3350	18.1	0.000	987
Others	8.2		64	15.5		13
Occupation						
No occupation	4.7		1578	7		487
Agricultural	7.6	0.000	1645	15.3	0.000	153
Others	7.5		2128	15.4		1176
BMI						
Underweight	4.5		1351	6.5		145
Normal	6.2	0.000	3328	11.2	0.000	1141
Overweight	11.9		585	17.5		456
Obese	25.7		77	28.8		72
Drinks alcohol						
No	7.0	0.894	3738	11.6	0.010	1111
Yes	6.0		1613	15.5		705
Tobacco Consumption						
No	6.6	0.345	3839	12.8	0.812	1353
Yes	6.8		1512	14.1		463

Note: b. Determined by $\chi 2$ test; $P < .05$ considered significant

Table 3: Odds Ratios for diabetes prevalence (>140mg/dl) among women in Bihar and Kerala, India, 2015-16

Backgrounds Characteristics	Bihar				Kerala			
	Odds Ratio	p-value	95% C.I. for Odds Ratio		Odds Ratio	p-value	95% C.I. for Odds Ratio	
			Lower	Upper			Lower	Upper
Age	1.059	0.000	1.053	1.065	1.079	0.000	1.068	1.089
BMI	1.029	0.000	1.023	1.034	1.060	0.000	1.045	1.074
Education								
No education (R)								
Primary	0.980	0.811	0.827	1.161	1.652	0.102	0.906	3.013
Secondary	1.041	0.548	0.914	1.185	1.417	0.229	0.803	2.501
Higher	0.720	0.018	0.550	0.944	1.397	0.271	0.771	2.531
Wealth Index								
Poor(R)								
Middle	1.182	0.020	1.026	1.360	0.838	0.452	0.528	1.329
Rich	1.439	0.000	1.224	1.691	0.778	0.282	0.493	1.228
Place of residence								
Rural(R)								
Urban	0.973	0.720	0.839	1.129	0.874	0.076	0.753	1.014
Religion								
Hindu(R)								
Others	1.037	0.616	0.900	1.194	1.045	0.560	0.901	1.211
Caste								
SC/ST(R)								
OBC	0.999	0.991	0.882	1.132	1.100	0.455	0.857	1.412
General	1.166	0.059	0.994	1.368	1.292	0.058	0.992	1.683
Marital Status								
Married(R)								
Others	1.075	0.334	0.928	1.246	0.944	0.604	0.759	1.174
Drinks alcohol								
No(R)								
Yes	0.623	0.357	0.228	1.704	1.270	0.408	0.721	2.236
Tobacco Consumption								
No(R)								
Yes	1.071	0.744	0.708	1.620	0.769	0.465	0.380	1.556

Note: (R): Reference category.

Table 4: Odds Ratios for diabetes prevalence (>140mg/dl) among men in Bihar and Kerala, India, 2015-16

Backgrounds Characteristics	Bihar				Kerala			
	Odds Ratio	p-value	95% C.I. for Odds Ratio		Odds Ratio	p-value	95% C.I. for Odds Ratio	
			Lower	Upper			Lower	Upper
Age	1.060	0.000	1.040	1.080	1.040	0.004	1.010	1.060
BMI	1.040	0.000	1.020	1.060	1.080	0.000	1.040	1.120
Education	1.030	0.436	0.960	1.110	1.010	0.909	0.920	1.100
Wealth Index								
Poor(R)								
Middle	1.420	0.034	1.030	1.960	3.230	0.064	0.940	11.130
Rich	2.160	0.000	1.530	3.050	2.690	0.115	0.790	9.220
Place of residence								
Rural(R)								
Urban	0.770	0.149	0.550	1.100	0.930	0.662	0.690	1.270
Religion								
Hindu(R)								
Others	1.220	0.327	0.820	1.810	0.970	0.857	0.710	1.330
Caste								
SC/ST(R)								
OBC	0.960	0.820	0.690	1.350	0.860	0.540	0.520	1.410
General	0.740	0.165	0.480	1.130	1.190	0.516	0.710	1.980
Marital Status								
Married(R)								
Others	1.100	0.662	0.720	1.700	0.890	0.628	0.560	1.420
Occupation								
No occupation(R)								
Agricultural	1.260	0.255	0.850	1.890	1.080	0.825	0.540	2.160
Others	1.040	0.836	0.720	1.510	1.410	0.161	0.870	2.270
Drinks alcohol								
No(R)								
Yes	1.020	0.908	0.750	1.380	1.130	0.437	0.830	1.550
Tobacco Consumption								
No(R)								
Yes	0.970	0.841	0.720	1.310	0.960	0.792	0.680	1.340

Note: (R): Reference category.

Discussion

The results of the bivariate, as well as multivariate analyses indicate that age and BMI are the significant predictors of diabetes prevalence. On the other hand, education, wealth index, caste and marital status do not show significant associations (with a few exceptions) in the bivariate analysis but none of these are significant in multivariate analysis. Lifestyle factors, such as alcohol and tobacco consumption are not significantly associated with diabetes prevalence.

The two states for the study have been deliberately selected as they have contrasting health indicators, one with the highest diabetes prevalence with better health indicators and the other with the lowest diabetes with worse health indicators. Though the study is based on a large scale national and state-wise representative sample data, the associations between diabetes prevalence and socio-economic as well as lifestyle factors in two socially, economically and culturally different states generally do not corroborate with the findings of other studies. For instance, Singh et al., (1998) claim that throughout India, the prevalence of diabetes is lower in rural areas, but the rate increases significantly from rural to peri-urban and urban areas. However, the findings of this study based on adjusted odds ratios of multivariate logistic regression reveal that rural-urban residence does not make any difference in diabetes risk. Similarly, important factors such as education, wealth index and marital status are contradicting and do not reveal significant risk for diabetes. However, for BMI, after controlling for other confounding factors, overweight and obese women and men are at higher risk for diabetes.

Many studies have observed that alcohol consumption and smoking are significant modifiable risk factors for diabetes (Ghorpade et al., 2013; Thankappan et al., 2013; Muthukumar, 2016; Mohan et al., 2003, Biradar et al., 2020). The multivariate logistic regression adjusted odds ratios indicate that factors such as alcohol and tobacco consumption in case of the two Indian states are not significant. By and large women in India do not drink alcohol or consume tobacco, and hence, it may not be a problem among them. However, drinking alcohol and tobacco consumption among men, even in rural areas, is a problem, and yet these are not associated with diabetes in this study. Interestingly, even the bivariate associations between the prevalence of diabetes and consumption of alcohol (with the exception of Kerala men) and tobacco are not statistically significant irrespective of sex. One of the reasons for this finding could be the way these variables were measured in the survey. If one includes occasionally and moderate consumption of alcohol among those who drink heavily, then the results could be biased. Similar arguments can be made for the lack of significance of tobacco consumption for diabetes risk. These are data limitations.

The study raises lots of questions and begs to explore other possible risk factors identified in the Indian diabetes research literature but could not be done due to data limitations. Specifically, Mohan et al., (2003) based on their study in Chennai Urban Population observed that 55% of offspring of two diabetic patients had either diabetes or impaired glucose tolerance (IGT) compared to 15.6% in those with no family history of diabetes. Another possible hypothesis to explore is the diabetes prevalence in Kerala could be due to the south Indian phenotype as a risk factor (Raghupathy et al., 2010; Fall et al., 1998; Vaishnava et al., 1964). Similarly, some studies have observed that altitude and spatial location play a role in the risk of developing diabetes (Murthy et al., 1984; Vijayakumar et al., 2019; Singh et al., 2016). Kerala is located on the west coast with 50% of it into highland and is studded with more than 50 peaks with 5000 feet above mean sea level, and Anamudi located in Idukki district in Kerala is the highest peak in India outside the Himalayas. A recent district-level study has shown a higher prevalence of 140-160 mg/dl blood glucose in Idukki district (Biradar and Singh, 2020). On the other hand, Bihar is in north-central India, and its land has an average elevation above sea level of 173 feet. These are some of the possible hypotheses to explore in order to understand the Indian diabetes paradox (Bhat, 1994).

Conclusions

The NFHS-IV data analysis of socio-economic and demographic factors in explaining diabetes prevalence in Bihar and Kerala states of India do not fully corroborate earlier findings. In the states of Bihar and Kerala, lifestyle factors such as drinking and tobacco consumption are not significant at all towards diabetes risk at least as per the NFHS data. If the heterogeneity of the Indian population with respect to culture, ethnicity, environmental conditions is not fully understood, the extrapolation of regional results may give inaccurate estimates. Hence, studies are required in India to highlight other geographical differences, including ethnic phenotype, genetic factors, and elevation from sea level to explain the diabetes prevalence between states.

Limitation of the study

The present study examined prevalence of diabetes (including pre-diabetes) among men and women aged 15-49 years. NHFS-4 collected information about men aged 15-54 years, but similar data were obtained only from women aged 15-49 years, hence could not include those aged 50 years and more. The prevalence of diabetes might include persons with pre-diabetes, and therefore, the results should be interpreted accordingly.

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References

Aguiree, F., Brown, A., Cho, N.H., Dahlquist, G., Dodd, S., Dunning, T., Hirst, M., Hwang, C., Magliano, D., Patterson, C. and Scott, C., 2013, IDF Diabetes Atlas, sixth edition. Edited by Guariguata, Leonor, Nolan, Tim, Beagley, Jessica, Linnenkamp, Ute and Jacqmain, Olivier, International Diabetes Federation, Basel, Switzerland.6th ed. The global burden; pp.32-49.

Anjana, R.M., Deepa, M., Pradeepa, R., Mahanta, J., Narain, K., Das, H.K., Adhikari, P., Rao, P.V., Saboo, B., Kumar, A. and Bhansali, A., 2017, Prevalence of diabetes and prediabetes in 15 states of India: results from the ICMR–INDIAB population-based cross-sectional study. *The lancet Diabetes & endocrinology*, *5*(8): 585-596.

Anjana, R.M., Pradeepa, R., Deepa, M., Datta, M., Sudha, V., Unnikrishnan, R., Bhansali, A., Joshi, S.R., Joshi, P.P., Yajnik, C.S. and Dhandhania, V.K., 2011, Prevalence of diabetes and prediabetes (impaired fasting glucose and/or impaired glucose tolerance) in urban and rural India: Phase I results of the Indian Council of Medical Research–INdiaDIABetes (ICMR–INDIAB) study. *Diabetologia*, 54(12): 3022-3027.

Biradar, R.A. and Singh, D.P., 2020, Spatial clustering of diabetes among reproductive age women and its spatial determinants at the district level in southern India. *Clinical Epidemiology and Global Health*, (8)3: 791-796.

Biradar, R.A., Singh, D.P., Thakur, H. and Halli, S.S., 2020, Gender differences in the risk factors for high and very high blood glucose levels: A study of Kerala. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(4): 627-636.

Bhat, K.V., 1994, Physical and Anatomical Characteristics of Wood of Some Less-known Tree Species of Kerala (No. 96). KFRI Research Report. Diamond, J., 2011, Medicine: diabetes in India. *Nature*, 469(7331): 478.

Diamond J., 2011, Diabetes in India, *Nature*, 469(7331):478-9.

Fall, C.H.D., Stein, C.E., Kumaran, K., Cox, V., Osmond, C., Barker, D.J.P. and Hales, C.N., 1998, Size at birth, maternal weight, and type 2 diabetes in South India. *Diabetic medicine*, 15(3): 220-227.

Geldsetzer, P., Manne-Goehler, J., Theilmann, M., Davies, J.I., Awasthi, A., Vollmer, S., Jaacks, L.M., Bärnighausen, T. and Atun, R., 2018, Diabetes and hypertension in India: a nationally representative study of 1.3 million adults. *JAMA internal medicine*, 178(3): 363-372.

Ghorpade, A.G., Majgi, S.M., Sarkar, S., Kar, S.S., Roy, G., Ananthanarayanan, P.H. and Das, A.K., 2013, Diabetes in rural Pondicherry, India: a population-based studyof the incidence and risk factors. *WHO South-East Asia journal of public health*, 2(3): 149.

Ghosh, K., Dhillon, P. and Agrawal, G., 2019, Prevalence and detecting spatial clustering of diabetes at the district level in India. *Journal of Public Health*, 1-11.

IIPS, ICF., 2017, National Family Health Survey (NFHS-4), 2015–16: India. Mumbai: International Institute for Population Sciences. Other Adult Health Issues; p.402-403

Mohan, V., Shanthirani, C.S. and Deepa, R., 2003, 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). *The Journal of the Association of Physicians of India*, 51: 771-777.

Murthy, P.D., Pullaiah, B. and Rao, K.V., 1984, Survey for detection of hyperglycemia and diabetes mellitus in Tenali. Diabetes mellitus in developing countries. New Delhi: Interprint, p.55.

Muthukumar, T., 2016, BMI, Physical Activity and Diabetes-A Case Control Study in a Rural Area of Kancheepuram district of Tamil Nadu. *Journal of Comprehensive Health*, 4(1): 49.

Raghupathy, P., Antonisamy, B., Geethanjali, F.S., Saperia, J., Leary, S.D., Priya, G., Richard, J., Barker, D.J. and Fall, C.H., 2010, Glucose tolerance, insulin resistance and insulin secretion in young south Indian adults: Relationships to parental size, neonatal size and childhood body mass index. *Diabetes research and clinical practice*, 87(2): 283-292.

Rao, P.S., Naik, B.K., Saboo, R.V., Ramachandran, A., Dandelia, P.R. and Parley, K., 1966, Incidence of diabetes in Hyderabad. Diabetes in the tropics. Bombay: Diabetic Association of India, pp.68-75.

Singh, A., Shenoy, S. and Sandhu, J.S., 2016, Prevalence of type 2 diabetes mellitus among urban sikh population of Amritsar. *Indian Journal of Community Medicine*, 41(4): 263.

Singh, R.B., Bajaj, S., Niaz, M.A., Rastogi, S.S. and Moshiri, M., 1998, Prevalence of type 2 diabetes mellitus and risk of hypertension and coronary artery disease in rural and urban population with low rates of obesity. *International journal of cardiology*, 66(1): 65-72.

Somannavar, S., Ganesan, A., Deepa, M., Datta, M. and Mohan, V., 2009, Random capillary blood glucose cut points for diabetes and pre-diabetes derived from community-based opportunistic screening in India. *Diabetes care*, 32(4): 641-643.

Special Bulletin on Maternal Mortality in India 2014-16, Registrar General, India, 2019, https://censusindia.gov.in/vital_statistics/SRS_Bulletins/MMR_Bulletin-2015-17.pdf. Accessed on 13 July 2019.

Sample Registration System Statistical Report 2017, https://censusindia.gov.in/Vital_Statistics/SRS_Report_2017/SRS%20Statistical%20Report%202017.pdf. Accessed on 13 July 2019.

Tandon, N., Anjana, R.M., Mohan, V., Kaur, T., Afshin, A., Ong, K., Mukhopadhyay, S., Thomas, N., Bhatia, E., Krishnan, A. and Mathur, P., 2018, The increasing burden of diabetes and variations among the states of India: the Global Burden of Disease Study 1990–2016. *The Lancet Global health*, 6(12): e1352-e1362.

Thankappan, K.R., Mini, G.K., Daivadanam, M., Vijayakumar, G., Sarma, P.S. and Nichter, M., 2013, Smoking cessation among diabetes patients: results of a pilot randomized controlled trial in Kerala, India. *BMC Public Health*, 13(1): 47.

Vaishnava, H., Dixit, N.S. and Solomon, S.K., 1964, A study in retrospect of hospitalised patients of diabetes mellitus in South India. The Journal of the Association of Physicians of India, 12, p.255.

Vijayakumar, G., Manghat, S., Vijayakumar, R., Simon, L., Scaria, L.M., Vijayakumar, A., Sreehari, G.K., Kutty, V.R., Rachana, A. and Jaleel, A., 2019, Incidence of type 2 diabetes mellitus and prediabetes in Kerala, India: results from a 10-year prospective cohort. *BMC public health*, 19(1): 140.

Wild, S.H., Roglic, G., Green, A., Sicree, R. and King, H., 2004, Global prevalence of diabetes: estimates for the year 2000 and projections for 2030: response to Rathman and Giani. *Diabetes care*, 27(10): 2569-2569.

World Health Origination, Diabetes. https://www.who.int/news-room/fact-sheets/detail/diabetes. Accessed on 20 June 2019.