District Level Assessment of Spatial Clustering and Determinants of Diabetes Mellitus among Older Adolescents and Young Adults in India

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Abstract

Globally non-communicable disease is the leading cause of death. Amongst all, diabetes mellitus (DM) represents the most prevalent non-communicable disease in India. However, the burden of DM shifting towards the lower ages has received relatively little attention in India. Thus, this study aims to assess the district level spatial clustering and determinants of DM among older adolescents and young adults. The study used data from the fourth round of the National Family Health Survey. A person in the age group 15-29 years of age is considered to be older adolescents and young adults. Moran's I and LISA were used to examine the presence of spatial autocorrelation and clustering respectively. Simultaneous Autoregressive Model was used for the assessment of determinants. Prevalence of DM across 640 districts ranged from 0.15 percent to 35 percent. Global Moran's I is 0.61 implying significant spatial correlation. There is significant high-high clustering of the prevalence of DM in the districts of northeastern states, eastern states, southern states and Delhi National Capital Regions. And, significant low-low clustering of the prevalence of DM in the districts of northern states and central India. Overweight and professionals who are physically inactive are at higher risk of acquiring DM. As the older adolescent and the young adults are the potential assets to the nation, reduction in the prevalence of DM among older adolescents and young adults is important and would be possible only if area-specific measures would be adopted on those clusters of districts where DM is high considering the other intervening covariates.

Keywords: Diabetes mellitus, spatial clustering, older adolescents, young adults

Introduction

Globally, non-communicable disease is the leading cause of death. Almost 67 percent of all deaths are due to non-communicable diseases (Mote 2016). Diabetes mellitus (DM), which is one of the major contributors to the burden of non-communicable diseases, is no longer the disease of opulent developed nations; its prevalence is increasing rapidly in developing countries (Mohan *et al.* 2017). In India, the contribution of DM to the burden of non-communicable diseases represents one of the most important among all other diseases. Every fifth diabetic case in the world is an Indian, and thus India is called the capital of diabetes (Joshi *et al.* 2007). According to the International Diabetes Federation South-East Asia, there were 69.1 million cases of DM in India in 2015 with a prevalence of 8.7 percent among the adults aged 20 to 79 years. The average cost of each of these patients is \$94.9. By 2040, the figure is expected to increase to 123.5 million cases (IDF 2015). The long-term economic implications of DM in developing countries are worrying (Bjork *et al.* 2003). The socioeconomic burden due to DM in India is one of the highest in the world (Bjork *et al.* 2003; Kapur 2007; Shashank *et al.* 2008). DM is a risk factor for various other diseases like cardiovascular, renal and atherosclerotic vascular disease (Koch *et al.* 1997; Sowers *et al.* 1988; Martin *et al.* 2014;

Tuttolomonde *et al.* 2015). The rapid change in lifestyle associated with urbanization in combination with inevitable high genetic risks and behavioural risk factors are also a possible risk factor for the disease (Ramachandran *et al.* 1999; Tuomilehto *et al.* 2001; Whittemore *et al.* 2002; Simpson *et al.* 2003; Rejeski *et al.* 2012). Both in India and in the Western countries, obesity is one of the significant risk factors for DM (Chan *et al.* 1994; Steppan *et al.* 2001; Mohan *et al.* 2008). Due to urbanization, rise in living standards, increased sedentariness, and the cheap availability of calorie-rich fatty fast foods to all sections of people alike are also a few reasons for the worldwide increase in the prevalence of DM (Gupta *et al.* 2006; Diamond 2011).

The problem of DM is heterogeneous in India (Arora *et al.* 2010; Anjana *et al.* 2017). Numerous studies have discussed the relationship between DM and its associated risk factors, but particularly for the adult and elderly population. However, the burden of DM shifting towards the lower ages has received relatively less attention in developing countries like India. And as the older adolescents and the young adults are the potential assets to the nation, this paper aims to highlight the clustering of prevalence and determinants of DM among the older adolescent and young adults in India.

Methods and Materials

Data and Variables

The district-level information for all 640 districts in India was obtained from the fourth round of the National Family Health Survey. The survey was conducted in 2015-16 across all districts of all states and union territories of India. The survey collects information on population, health, and nutrition for each state and union territory. Apart from these, the survey also collects information on clinical, anthropometric and biomedical data to provide vital information on prevalence of hypertension, blood glucose levels as well as some other nutritional indicators through a series of biomarkers, tests and measurements (IIPS and ICF 2017).

We used the blood glucose level provided in the survey to identify whether a person is diabetic or not. A person whose blood glucose level is greater than 140 mg/dL is considered to be diabetic. And, persons in the age group 15 – 29 years of age are defined as older adolescents and young adults (Bleyer 2002).

The unit of analysis for the study is the districts of the states and union territories of India. The outcome variable is the prevalence of DM among older adolescents and young adults in each of the 640 districts. The choice of predictor variables are governed by the existing literature (Whittemore *et al.* 2002; Mokdad *et al.* 2003; Savoca *et al.* 2004; Pereira *et al.* 2005). The fourth round of the National Family Health Survey provides household socioeconomic characteristics and community characteristics such as wealth quintile and place of residence. The wealth quintile of a household is categorized as - poorest, poorer, middle, richer and richest. A person is categorized as professional who are physically inactive if he/she is in a managerial, clerical and sales professions. Persons whose body mass index is greater than 24.9 are categorized as overweight. The survey also provides behavioural risk factors of DM such as consumption of tobacco, smoking and drinking alcohol. Thus we used the district level percentage of urban household, percentage of household with richest wealth quintile, percentage of the overweight population, percentage of professionals who are physically inactive and the behavioural risk factors viz. prevalence of tobacco consumption, smoking and

drinking alcohol as the predictors of the prevalence of DM. The information on the frequency of intake of nine food groups was also collected in the survey out of which four are vegetarian food items viz. (milk, pulses or beans, dark green leafy vegetables and fruits), and three are non-vegetarian food items viz. eggs, fish and meat and the remaining two are fried food and carbonated drinks. Thus, we also consider these food habit patterns of the households as the prognosticator of DM.

Statistical Analysis

Univariate exploratory spatial data analysis such as Moran's I, a univariate local indicator for spatial correlation (LISA) and simultaneous autoregressive model (SAR) was used to assess the spatial clustering and determinants of DM among older adolescents and young adults.

Moran's I, statistic is defined as,

$$I = \frac{n \sum_i \sum_j w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{S_0 \sum_i (y_i - \bar{y})^2}, \quad \text{Where } S_0 = \sum_i \sum_j w_{ij}$$

Here we assume that the global means $\bar{y}$ is an adequate representation of the variable of interest y . Moran's I value ranged from -1 to $+1$. Negative values indicate negative spatial autocorrelation and positive values indicate positive spatial autocorrelation. A zero value indicates a random spatial pattern.

The index which is used to observe spatial autocorrelation at the local level is LISA, which can be seen as the local equivalent of Moran's I. For each location, LISA values allow for the computation of its similarity with its neighbours and also test its significance. Thus, five scenarios may emerge (Gupta *et.al.* 2016): (a) Locations with high values, with similar neighbours (high-high), referred to as "hot spots", (b) Locations with low values, with similar neighbours (low-low), referred to as "cold spots", (c) Locations with high values, but with low-value neighbours (high-low), referred to as potential "spatial outliers", (d) Locations with low values, but with high-value neighbours (low-high), also referred to as potential "spatial outliers", (e) Locations with no significant local autocorrelation.

The Spatial Autoregressive Models (SAR) specification uses a regression on the value from the other areas to account for the spatial dependence (Robert Gentleman *et.al.* 2008). Which means that the error terms ϵ are modelled so that they depend on each other in the following way,

$$e_i = \sum_{i=1}^m b_{ij} e_j + \epsilon_i$$

Where ϵ_i are residuals errors which are assumed to be independently distributed according to a

Normal distribution with mean zero and diagonal covariance matrix Σ_ϵ with elements σ_ϵ^2 , $i = 1, \dots, m$.

The b_{ij} values are used to represent spatial dependence between areas, b_{ij} must be set to zero so that each area is not regressed on itself.

If we express the error terms as, $e = B(Y - X^T\beta) + \varepsilon$, the model can be expressed as

$$Y = X^T\beta + B(Y - X^T\beta) + \varepsilon$$

Which implies that,

$$(I - B)(Y - X^T\beta) = \varepsilon$$

Where B is a matrix that contains the dependence parameters b_{ij} and I is the identity matrix. In order that the SAR model to be well defined, the matrix $I - B$ must be non-singular. Under this model, Y is distributed according to multivariate normal mean, $E[Y] = X^T\beta$ and covariance matrix

$$\text{Var}[Y] = (I - B)^{-1}\Sigma_\varepsilon(I - B^T)^{-1}$$

Often Σ_ε is taken to depend on a single parameter σ^2 , so that $\Sigma_\varepsilon = \sigma^2 I$ and then $\text{Var}[Y]$ simplifies to

$$\text{Var}[Y] = \sigma^2(I - B)^{-1}(I - B^T)^{-1}$$

It is also possible to specify Σ_ε as a diagonal matrix of weights associated with heterogeneity among the observations. If $B = \lambda W$, where λ is a spatial autocorrelation parameter and W is a matrix that represents spatial dependence, which is often assumed to be symmetric.

Results

Descriptive Findings

Figure 1 presents the distribution of the prevalence of DM among older adolescents and young adults across 640 districts of India. Its prevalence varied widely ranging from 0.57 percent to 35 percent and it is spread across all the districts of the country. Some of the Indian districts have a prevalence of less than 5 percent while many of them have prevalence more than 10 percent. Compared to districts in northern states, districts in eastern, northeastern, western, and southern states seem to be better as almost all the districts have prevalence less than 5 percent. Many of the districts in northern, western, central and northeastern states have prevalence more than 10 percent.

Figure 1: Prevalence of diabetes among older adolescents and young adults across 640 districts of India

Global Moran's I for Prevalence of DM in India

The results of the study are entirely based on aggregated district-level data. Overall Global Moran's I spatial autocorrelation is 0.61 ($p\text{-value} < 0.001$; 999 permutations) indicating high spatial autocorrelation and significant positive association with the levels of prevalence of DM between the districts of India. Therefore, it is necessary to analyze spatial clustering at the local level to identify the areas with significant clustering of the prevalence of DM.

LISA Maps for Prevalence of DM in India

For obtaining the significant clustering of the prevalence of DM, we generate the LISA cluster map. Figure 2 presents the LISA map for the prevalence of DM among older adolescents and young adults. There is significant high-high clustering of the prevalence of DM in the districts of northeastern states, eastern states, southern states and Delhi National Capital Regions (NCR). And, significant low-low clustering of the prevalence of DM in districts of northern states and central India for which the health care and delivery system are relatively poor.

Figure 2: LISA map for the prevalence of DM among older adolescents and young adults

Spatial Regression – Simultaneous Autoregressive Model

After confirming the presence of significant spatial autocorrelation in the prevalence of DM across 640 districts of India. The spatial effect has been model by using Simultaneous Autoregressive Model (SAR). Table 1 presents the estimates from the SAR model assessing the determinants of DM among older adolescents and young adults in India. The study found the value of lambda (λ) capturing spatial effect is positive and highly statistically significant. This indicates the substantial spatial dependence in the prevalence of diabetes across the neighbourhood districts.

Prevalence of DM is likely to increase by 0.040 times as the percentage of urban household increases. Similarly, an increase in the percentage of the overweight population is likely to increase the prevalence of DM by 0.180 times. Behavioural risk factors also have an impact on the prevalence of DM. As the prevalence of tobacco consumption, smoking and drinking of alcohol increases, the prevalence of DM is likely to increase by 0.123, 0.101, and 0.106 times respectively. The professionals who are physically inactive are also at a higher risk of having DM. As the percentage of professionals who are physically inactive increases, the prevalence of DM is likely to increase by 0.065 times. Compared to districts with a lesser percentage of household with richest wealth quintile

and median years of education, the prevalence of DM is likely to decrease as the percentage of household with richest wealth quintile and median years of education increases. Prevalence of DM is likely to decrease by 0.051 times if the percentage of household with the richest wealth quintile increases. And the prevalence of DM is likely to decrease by 0.084 times if the median years of the education of the population increases.

Table 1: Estimates from the simultaneous autoregressive model (SAR) assessing determinants of DM among older adolescents and young adults in India.

Characteristics of Interest	Estimated Coeff.
Intercept	4.241
% of Urban Household	0.040***
% of Overweight Population	0.189***
% of Household in Highest Wealth Quintile	-0.051***
% of Household Consuming Veg. & N-Veg. Occasionally	0.680
% of Household Consuming at least One Veg. Daily	0.655
% of Household Consuming at least One N-Veg. Daily	0.659
% of Household Consuming at least One Veg. & N-Veg. Daily	0.702
% of Household Consuming Fried Food Daily	0.010
Prevalence of Tobacco Consumption	0.123**
Prevalence of Smoking	0.101**
Prevalence of Drinking	0.106**
% of Professional Who are Physically Inactive	0.065**
Median Years of Education of the population	-0.084
<i>Lambda (λ)</i>	0.620***
<i>Akaike Information Criteria (AIC)</i>	3181.8

Note: ** p -value < 0.05 & *** p -value < 0.01; Veg.- Vegetarian & N-Veg. – Non-Vegetarian

Discussion

The prevalence of DM is increasing in India and is shifting towards the lower ages (Ramachandran *et al.* 2001; Wild *et al.* 2004; Joshi *et al.* 2007; IDF 2015). The data from the fourth round of National Family Health Survey reveals the prevalence of DM among older adolescents and young adults greater than 10 percent in as many as 59 districts spreading across more than 20 Indian states. In the past decades, there has been evidence of disproportionate distribution of prevalence of DM across the Indian states (Anjana *et al.* 2017; Arora *et al.* 2010). Compared to districts in other states, the districts in northern, western, central and northeastern states have a higher prevalence of DM among older adolescents and young adults. The prevalence of DM is highly influenced by the regional variation between the districts. The study indicates the substantial spatial dependence (Moran's $I = 0.61$) in the prevalence of DM between the 640 districts of Indian states. The prevalence of DM among older adolescents and young adults is high and significantly clustered in the districts of northeastern states, eastern states, southern states and Delhi National Capital Regions (NCR). While the prevalence of DM among older adolescents and young adults is low and significantly clustered in districts of northern states and central India which are typically characterized by poor health indicators accompanied with poor health care and delivery system (Kumar and Prakash 2011; Kumar and Mishra 2015). Compared to the burden of non-communicable diseases, the burden of communicable

diseases is relatively higher in these regions (Reddy *et al.* 2005; Upadhyay 2012). Many studies have highlighted the socioeconomic burden of non-communicable diseases particularly DM in India (Bjork *et al.* 2003; Kapur 2007; Shashank *et al.* 2008). The study also reveals that as the percentage of the household with the richest wealth quintile and the median years of education increases, the prevalence of DM among older adolescents and young adults is more likely to decrease. But, the impact of urbanization and change in the lifestyle plays a very significant role in increasing the prevalence of DM (Tuomilehto *et al.* 2001; Whittemore *et al.* 2002; Simpson *et al.* 2003; Kosaka *et al.* 2005; Lindstrom *et al.* 2006; Rajeski *et al.* 2012). The prevalence of DM among older adolescents and young adults in districts of Indian states are likely to increase with the increase in the percentage of urban households. Similarly, as the percentage of overweight and professionals who are physically inactive increases, there is higher risk of increasing the prevalence of DM among older adolescents and young adults. The importance of behavioural risk factors in escalating the prevalence of DM cannot be ignored (Rimm *et al.* 1995; Le *et al.* 1997; Manson *et al.* 2000; Shi *et al.* 2013). As the prevalence of the behavioural risk factors such as tobacco consumption, smoking and drinking of alcohol among older adolescents and young adults increases, the prevalence of DM is also likely to increase.

Limitations of the study

Every study is subject to limitations and the study suffers from two inevitable limitations. First, the blood glucose level provided in the survey to define the respondents as diabetic or not is based on the series of biomarkers test and measurements. But, the measurement was taken randomly i.e. whether the respondents were fasting or not prior to the test was not considered. And second, the National Family Health Survey is a cross-sectional survey. Thus, the causality of DM cannot be established from the study. And the prevalence of DM or any characteristic might vary greatly across a district.

Conclusion

The study shows increasing and widespread prevalence of DM among older adolescents and young adults in India. Since this is a disease which cannot be cured, increasing prevalence among this population would lead to a drastic change in social as well as economic conditions of the country. Urbanization and sedentary habits leading to overweight, professions with inactive physical activities and behavioral risk factors such as smoking, consumption of tobacco and drinking of alcohol are the major risk factor escalating the risk of DM among older adolescents and young adults. Therefore, reduction in the prevalence of DM among this population is necessary and would be possible only if area-specific measures would be adopted in those clusters of districts where DM is high considering the other intervening covariates.

Ethical Statement: The study used secondary data which is available in the public domain. Therefore, the author has no ethical statement to disclose.

Conflict of Interest: The author has no conflict of interest relevant to this article to disclose.

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