Introduction

Globally the prevalence of diabetes has nearly doubled since 1980, rising from 4.7% to 8.5% in 2014 in the adult population so that the mortality is also increased contributing to the economic fragility of healthcare systems (1). People with diabetes had a 25- 75% higher risk of dying from cancer, infections, liver disease, lung disease, mental disorders, intentional self-harm, external causes, and falls, independent of other risk factors(such as age, gender, smoking, and weight) (2) shortening 7 years of life expectancy (3) .Studies shown that genetic variation solely explains 15–20% of the burden of type 2 diabetes (4).Whereas the burden of type 2 diabetes is attributed to modifiable and/or environmental risk factors (5).The external contributors comprises aspects of the built environment, the social environment, the physicochemical environment and the lifestyle/food environment (6).

The world health organization projected that the maximum increase of diabetes in India in the world (7). The prevalence of diabetes in adults aged 20 years and above in India increased from 5.5% in 1990 to 7.7% in 2016, India is also no exceptional then the global trend (8).

North east India is a linguistically, culturally, and socio-economically region. Its physically challenging terrain severely restricts the availability of resources for diabetes care and the expenses for diabetes care is comparatively higher than the other regions of the country (9). At the same time, its strong socio-cultural ethos can be utilized to manage diabetes more efficiently at the individual, family, and community level (10). Studies has revealed in some pockets of north east India that people are not well aware about the diabetes (11). The situation of diabetes in North East India shows similar trends to Urban areas of south India despite being distinct sociodemographic condition (12). Study revealed that district on the risk of diabetes was not similar to the neighbouring district. This indicate geographical and environmental factors which surpass the boundaries of district do not playing a significant role (13). Significant relationship revealed with the food habit, wealth and obesity with diabetes, consumption of fatty acid, salt, betel-nut chewing and tobacco is attributing the risks of being diabetic. (14,15).

Focusing on the environment, studies indicated a potential link between higher altitude and lower diabetes risk, which can be due to increased exercise intensity (16, 17). An association between the hilliness of a neighbourhood and the level of diabetes is also established, hilly neighbourhood is protective for diabetes.(18)Climate factors like ambient temperature and season, with higher prevalence noted in summer and elevated glucose levels linked to higher temperatures, rise of mean temperature could lead to increase in the diabetes cases.(19,20,21,22,23)People living in high humidity areas had almost double prevalence of diabetes, as compared with those living in low humidity residences.(24). In conclusion, the variation in the prevalence of diabetes is almost superimposable to that of precipitation; the hospital admission rate of diabetes patients is slightly higher during the rainy season. (19)

But only a limited number of studies had actually investigated the effect of environmental conditions on diabetes. Diabetes is a clinical condition, often asymptomatic, given the lack of data regarding the effect of environmental factors, the aim of the present work is to evaluate

the spatiality and to understand the impact of environment on diabetes along with other independent factors.

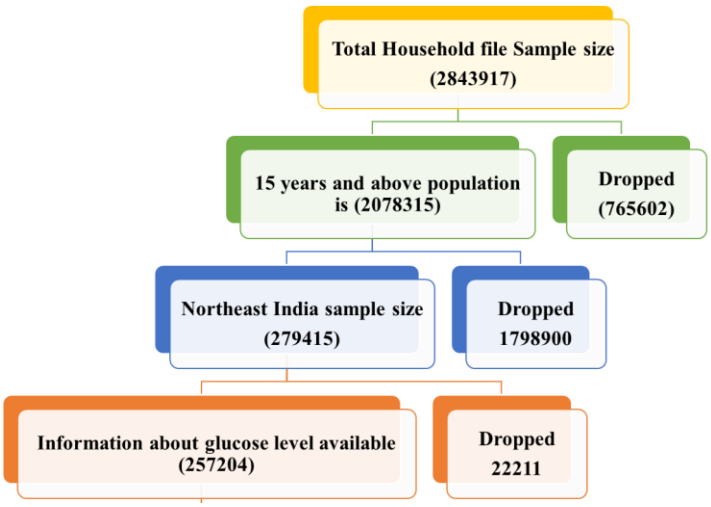
Data and method

The data for this study taken from the National Family Health Survey 2019-21 (NFHS-5) (25), the fifth in the NFHS series, provides information on population, health, and nutrition for India, for each state/union territory (UT) and 707 districts as on March 31st, 2017. All five NFHS surveys have been conducted under the Ministry of Health and Family Welfare (MoHFW), Government of India. The MoHFW, Government of India, designated the International Institute for Population Sciences (IIPS), Mumbai, as the nodal agency to conduct NFHS-5. NFHS-5 fieldwork for India was conducted in two phases (phase one from 17 June 2019 to 30 January 2020 and phase two from 2 January 2020 to 30 April 2021). The survey used the 2011 Census of India as the sampling frame, with a two-stage sample stratification. The primary sampling units were villages in rural areas and the census enumeration blocks in urban areas were selected with a probability proportional to the size within each stratum. The strategic oversampling of the minority group makes this data for well suited for the study of general patterns. The analysis in the present study is addressing the North-Eastern part of India consist of 8 states, i.e. Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim.

Outcome variable

The key outcome variable for this study is Diabetes. The measure for diabetes is persons who are currently taking medicine to control diabetes and persons who were diagnosed having glucose label more than 140mg/dl (While this does not differentiate between type1 and Type2 diabetes), researcher use this as a measure of type 2 diabetes. This variable is dichotomous variable.

Chart1: Chart showing description of the Sample Size



Independent variables

The study includes some selected risk factors along with socioeconomic, demographic and environmental variables which explain the prevalence of diabetes among 15+ population. The socioeconomic and demographic variables are sex (male, female), age groups, education (highest attainment), religion (Hindu, Muslim, others), caste (SC, ST, OBC, others), wealth (Poorest, poorer, middle, richer, richest), marital status (Married, never married, others), smoking tobacco (No, yes), consumption alcohol (No, yes), Household-size, healthcare insurance Covered (Yes, No). For environmental variables the data taken from Geographical file i.e. annual Rainfall [Low(<1000mm), Moderate(1000mm-2500mm) and high(>2500mm)), Annual mean Temperature [Low(<10°C), moderate(10°C-25°C) and High(>25°C)], altitude [Low(<1000 meter) and High(>1000 meter)], but for logistic analysis Altitude and Residence variable have been combined and four categories have been created (Urban and high altitude, Rural and high altitude, urban and low altitude and urban and high altitude).

Statistical Analysis and software used

To understand the prevalence pattern of diabetes across district prevalence rate was calculated and plotted in map using Arc GIS 10.5. To examine the spatial autocorrelation in diabetes prevalence across districts, Univariate Local Moran's I (the autocorrelation among neighbouring values) was computed using GeoDa software. This was used to determine if there was any clustering of similar prevalence of diabetes across the districts situated near each other (26). The value of Moran's I ranged from −1 (perfect dispersion) to 1 (perfect clustering) showing the strength of spatial relation with the bordering districts.

The first step in analysing spatial autocorrelation is to compose a spatial weight matrix consisting of information on neighbourhood districts for each locale (27). Moran's I is the test for spatial autocorrelation examining the existence of any clustering of similar prevalence in the study area, while Local Indicators of Spatial Association (LISA) show the location of significant clustering or spatial outliers (28). The cluster maps show the local spatial significant clustering of diabetes prevalence at the district level by the type of spatial correlation: red for high–high associations, dark blue for low–low associations, light blue for low– high and pink for high–low associations. Depending on the significance level, LISA significant maps represent districts with various shades of green.

Later on, to understand the contributing factors of diabetes descriptive statistics have been calculated along with the chi square test to understand relationship of diabetes with other independent factors. Afterward logistic regression has been run to understand the contributing factors of diabetes.

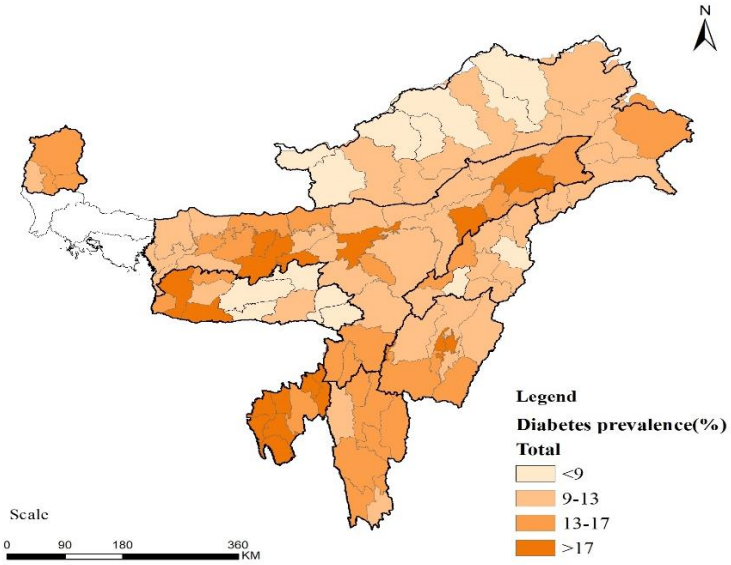
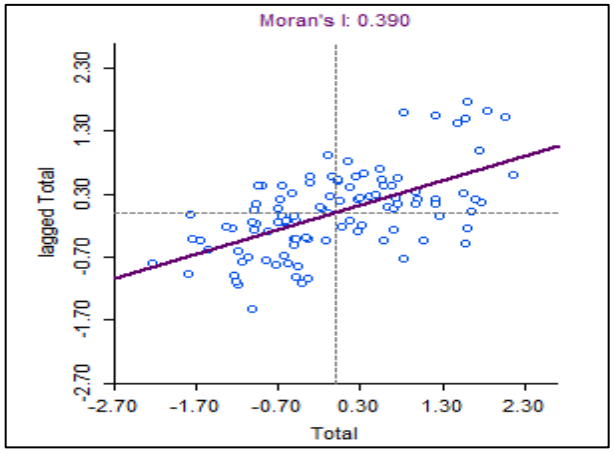


Figure 1. Prevalence rates of diagnosed diabetes by district of population aged 15 years and above in Northeast India of 2019-2021

Figure 4-(a)



(b) (c)

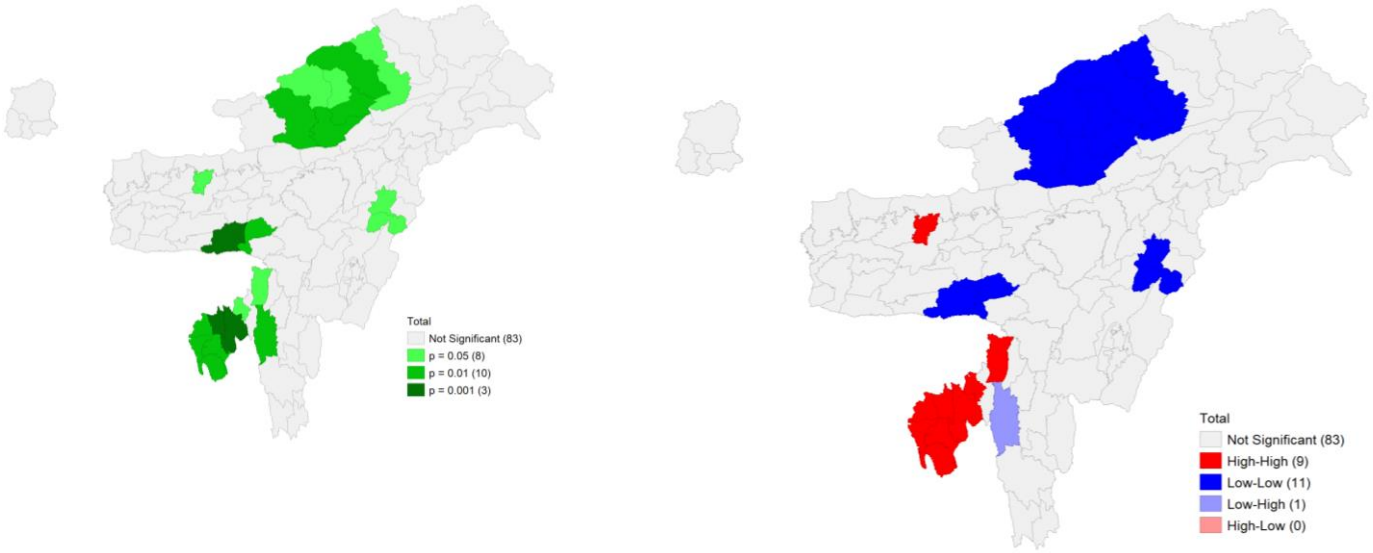


Figure 4. a) Moran's, I scatter plot, (c) LISA cluster map and (b) LISA significant map for diagnosed diabetes prevalence rates aged 15 years and over in Northeast India,2019-2021.

Statistical analysis

Table 1 summarizes the descriptive statistics of the weighted whole sample, rural and urban sample description. After cleaning the data and applying the sampling strategy, the final sample included 257204 observations who are15+ in north-east India. In the whole sample, 14.4% either diagnosed or taking medicine to control diabetes having the prevalence of diabetes. Whereas among this 24.04% is the Urban population(n-48440) and Rural population is rest 75.95%(n=208765). Where 17.31% urban population and 13.55% rural population having diabetes.

Among the sample 53.16% was male and 46.84% were female, Bivariate analysis showing that they have significant relationship with Diabetes. age group wise also 16.97% were in the age of 15-29, 26.03% in the age of 30 to 44 years, 14.84% in age of the 45-59 years, 21.71% are in the age group 60-74, rest are above 74 years of age. Age group is also showing significant relationship with diabetes. Other important Variables like Educational attainment, residence, religion, caste, Marital status, smoke, alcohol consumption, household size has shown significant relationship with the prevalence of diabetes, chi square analysis revealed that. Variation can be observed in case of environmental variable also, for example people living in lower altitude are more prevalent to get diabetic than the people living in higher altitude. Wide variation can also be observed in case of rainfall and temperature also. Bivariate analysis

reveals that environmental variables like altitude, rainfall and temperature have significant relationship with diabetes prevalence.

The analysis has shown that in all the groups the prevalence of diabetes is different. The difference is highest in residence that is 17.61 percent for urban and 13.55 percent in rural. In all the independent variables difference in the prevalence of diabetes for urban and rural population are different. The most meaningful differences between the rural sample and the urban sample are in sex, age, education, wealth index and in other socioeconomic determinants is clearly seem. In total population among all the categories of independent variable difference in the prevalence can be clearly seen, among male female the prevalence gap is quite big, same as about wealth Index where richest (13.13%) peoples having higher prevalence whereas the poorest have lower (11.6%), in education also prevalence rate is i.e. prevalence rate among uneducated people is 16.91% whereas secondary educated people have prevalence rate of 12.78. Among socioeconomic groups like religion, caste also prevalence rates are different for example Hindu population have higher prevalence (15.54%) whereas Christians having lowest prevalence rate (11.63%). Among marital status, Smoking, Drinking, household size and health insurance coverage also seem statistically significant relation with diabetes. Variation can be observed for environmental variable also, for example people living in lower altitude are more prevalent to get diabetic than the people living in higher altitude. Wide variation can also be observed in case of rainfall and temperature also. Among all the taken variables showing chi-square p value of less than 0.5, which depicts these variables have relationship with diabetes.

Table 1: Participants characteristics (sample size, percentage) and bivariate analysis by total sample

Diabetes	**Total**			
	Sample Size	**%of sample**	**Diabetes prevalence**	**Chi Square**
Overall	257204	-	14.35	
Demographic Variables				
Sex				
Male	124179	53.16	15.95	0.001
Female	133025	46.84	12.88	
Age- group				
15-29	91250	36.16	5.4	
30-44	77501	30.1	12.81	
45-59	57148	21.71	22.9	
60-74	25156	9.81	29.78	
>74	6149	2.23	29.1	0.001
Socioeconomic Variables				
Residence				
Urban	48440	24.04	17.61	
Rural	208764	75.95	13.55	0.001

Wealth Index				
Poorest	73867	31.88	11.6	
Poorer	82693	32.02	13.02	
Middle	55155	19.07	15.71	0.001
Richer	33255	11.94	19.34	
Richest	12234	5.08	23.13	
Education				
No education	51688	20	16.94	
Primary	42801	16.94	16.11	
Secondary	137121	53.8	12.78	0.001
Higher	25475	9.26	14.63	
Don’t know	119	0.05	13.45	
Religion				
Hindu	97022	56.13	15.54	
Muslim	29908	26.03	13.5	
Christian	102448	14.84	11.63	
Others	27826	3	12.94	0.001
Caste				
Scheduled Castes	21308	12.67	14.72	
Scheduled Tribes	145863	25.55	12.58	
Other Backword castes	34471	21.54	14.69	
others	23430	14.93	16.5	0.001
Missing	31361	25.31	14.42	
Marital Status				
Unmarried	63677	23.19	5.98	
Currently married	173549	69.15	16.2	
others	19922	7.66	22.92	0.001
Missing	56	0.02	23.21	
Smoke				
No	149443	60.06	12.56	
yes	107139	39.94	17.06	0.001
Don’t know	622	0.24	6.11	
Alcohol				
No	200746	83.23	14.06	
yes	55688	16.77	15.88	0.001
Don’t know	770	0.3	6.36	
Household size				
Less Than 3	70047	23.91	16.62	
4 to 6	147452	59.56	13.78	
7+	39705	16.53	13.12	0.001
Health Insurance				
Covered	128702	39.21	14.99	
Not covered	127510	60.79	13.91	0.927
Don’t know	992	0.39	11.9	
Environmental Variables				
Rainfall				
Low Rainfall(<1000 mm)	6,573	0.23	8.06	

Moderate Rainfall(1000mm-2500mm)	1,46,175	54.32	14.85	
High Rainfall(>2500mm)	1,02,314	43.59	13.75	0.001
Missing	2,142	0.83	16.01	
Temperature				
Low Temperature(<10℃)	5,773	0.46	13.88	
Moderate Temperature(10℃-25℃)	2,44,478	95.81	14.19	
High Temperature(>25℃)	4,811	3.73	19.69	0.001
Missing	2,142	0.83	16.01	
Altitude				
High Altitude Urban	13,109	5.1	11.64	
High Altitude Rural	47,765	18.57	9.87	
Low Altitude Urban	35,331	13.74	15.91	
Low Altitude Rural	1,60,999	62.6	13.06	0.001

Table2 Estimated the odds ratio for diabetes by the risk factors and sociodemographic characteristics. Results found that people females have lower chance of having diabetes (OR-0.81) than male. Prevalence is increasing with the increasing of economic condition; Richest people have 2.01 times (OR=2.01, CI=2.017-2.018) higher odds to having diabetes than poorest people. Higher variation can be seen in among age group, people of age group >74 5.99 times (OR=5.99, CI= 5.991-5.993) higher odds of getting diabetes than age group 15-29. Among religious groups Muslims have slightly higher chance of getting diabetes than Hindus. By caste also OBCs (OR=0.98, CI=09837-09839) have slightly lower odds of having diabetes than others categories. Whereas by marital status currently married (OR=1.35, CI=1.3530-1.3532) and others (OR=1.45, CI=1.4500-1.4503) (divorced, widowed) have higher odds of having diabetes than the unmarried. People who smokes (OR=1.07 CI=1.0723-1.0724) having 1.07 times higher chance of having diabetes, same pattern is followed in rural and urban also. People who consume alcohol (OR=0.93, CI= 0.9380-0.9381) slightly lesser chance of getting diabetes. Household size also impacting the prevalence of diabetes, larger the family size, lower the odds of getting diabetes. For regression three environmental variable have taken i.e. rainfall, temperature and altitude. To understand the composite effect of altitude and residence, a combining variable have been created. People residing in moderate rainfall zone showing higher odds (OR=1.41, CI=1.4175-1.4193) of getting diabetes than the remaining category. People who are residing in moderate temperature zone having lower odds (OR=0.79, CI=0.7924-0.7930) of getting diabetes. In case of altitude and residence variable people who are residing in High altitude urban areas have lower odds of getting diabetes then the other categories.

Table 2: Logistic regression with diabetes as the dependent variable

	Odds Ratio	Std. Error	Z value	P Value	CI	
Sex (Male)						
Female	0.8151593***	2.16E-05	-7696.42	0	0.815117	0.815202
age_group(15-29)						
30-44	2.201126***	9.17E-05	1.90E+04	0	2.200947	2.201306
45-59	4.3632***	0.00019	3.40E+04	0	4.362828	4.363572
60-74	6.10486***	0.000302	3.70E+04	0	6.104268	6.105452
>74	5.992463***	0.000441	2.40E+04	0	5.991599	5.993327
Eduacation(No Education)						
primary	1.126853***	4.15E-05	3243.75	0	1.126771	1.126934
secondary	1.153381***	4.01E-05	4108.41	0	1.153302	1.153459
higher	1.142055***	6.27E-05	2419.97	0	1.141932	1.142178
dont know	1.153611***	0.000574	287.37	0	1.152487	1.154736
Religion(Hindu)						
Muslim	1.030532***	4.38E-05	706.86	0	1.030447	1.030618
Christian	0.8436702***	4.06E-05	-3530.38	0	0.843591	0.84375
Others	0.866782***	6.45E-05	-1919.84	0	0.866656	0.866909
Caste(Scheduled Caste)						
Scheduled Tribe	1.02039***	4.81E-05	427.77	0	1.020296	1.020484
Other backward caste	0.9838277***	4.03E-05	-397.9	0	0.983749	0.983907
Others	1.030758***	4.62E-05	675.62	0	1.030667	1.030848
dont know	1.097107***	5.45E-05	1864.56	0	1.097	1.097214
wealth_index(Poorest)						
Poorer	1.14333***	3.61E-05	4245.58	0	1.14326	1.143401
middle	1.394461***	5.17E-05	8964.03	0	1.39436	1.394562
richer	1.69843***	7.54E-05	1.20E+04	0	1.698283	1.698578
Richest	2.017769***	0.00012	1.20E+04	0	2.017534	2.018003
marital_status(No)						
yes	1.353177***	6.13E-05	6681.71	0	1.353057	1.353297
others	1.450194***	8.79E-05	6130.01	0	1.450022	1.450367
missing	1.198474***	0.000884	245.41	0	1.196743	1.200209
smoking(No)						
yes	1.072361***	2.81E-05	2666.75	0	1.072306	1.072416
don't know'	1.164639***	0.000539	329.51	0	1.163584	1.165695
alcohol(No)						
yes	0.9381302***	3.27E-05	-1831.42	0	0.938066	0.938194
don't know'	0.8840579***	0.000394	-276.25	0	0.883285	0.884831

Household Size(1-3)						
4 to 6	0.9287452***	2.55E-05	-2692.67	0	0.928695	0.928795
7+	0.9009053***	3.41E-05	-2753.35	0	0.900838	0.900972
insurance (Not covered)						
covered	0.9835539***	0.000024	-679.85	0	0.983507	0.983601
don't know'	1.15233***	0.000217	754.42	0	1.151905	1.152754
rainfall (Low rainfall)						
moderate rainfall	1.418421***	0.000448	1106.44	0	1.417543	1.4193
high rainfall	1.360449***	0.000431	971.76	0	1.359605	1.361294
missing	1.176692***	0.000429	446.42	0	1.175851	1.177532
Temperature (Low Temp)						
moderate temp	0.7927342***	0.000144	-1282.59	0	0.792453	0.793016
high temp	1.022991***	0.000197	118.15	0	1.022606	1.023377
Altitude and Residence (Urban and Low Altitude)						
rural high	1.037629***	0.000108	355.24	0	1.037418	1.03784
urban low	1.457656***	0.000131	4192.32	0	1.457399	1.457913
rural low	1.440556***	0.000128	4094.4	0	1.440304	1.440808
_cons	0.0263986***	9.53E-06	-1.00E+04	0	0.02638	0.026417

Discussion

Spatial analysis of diabetes prevalence of 104 district revealed that clustering exists in the north east region, where Tripura region and in some part of Assam and Mizoram have clustering of high prevalent districts and Arunachal Pradesh shows clustering of low prevalent districts, studies recommends that public health programmes target hot-spot clusters with high prevalence of diabetes (29).Whereas earlier studies on north east revealed importance should be given to district-specific factors in the prevalence of diabetes within a region, The results suggest that district-specific factors (that is, factors not related to neighbouring districts) are most likely to increase the prevalence of diabetes (30).

The result indicates that Muslims have higher odds of being diabetic than the Hindus and Christians. Whereas people belonging to Scheduled Tribe have higher chance of being diabetic than the scheduled castes. People who have health insurance coverage are less prevalent to diabetes than the people who don’t have, which is concerning again because maybe people who are richer, educated and working on formal sector have more insurance coverage due to the awareness. Further research needed to identify the reasons behind the disparity of prevalence.

Another fact that people who are consuming alcohol having lower chance of having diabetes in North East India. Research have confirmed the U-shaped relationships between average amount of alcohol consumed per day and risk of incident type 2 diabetes among men and

women, moderate consumption of alcohol can be one reason behind this inverse relationship. (31)

The result demonstrate correlation between environmental variables like rainfall, temperature and altitude with diabetes. Result shows People residing at the low rainfall zone having lesser chance of getting diabetes, may be its not generalizable for all population as no studies have shown direct link to rainfall but studies have shown correlation between seasonality and diabetes prevalence (32), one earlier study have shown the variation in the incidence of diabetes is almost superimposed to that of precipitation, the hospital admission rate of diabetes patients is slightly higher during the rainy season. (33).

Correlation between temperature and diabetes is not directional, result shows that people who lives in moderate temperature having lower chance of getting diabetes than the others. Whereas the Earlier studies have suggested diabetes incidence rate in the USA and prevalence of glucose intolerance worldwide increase with higher outdoor temperature. (34)

Altitude have shown direct relationship with the prevalence of diabetes (35)(36); combined variable of altitude and residence have shown interesting result. When we see by residence people who are residing in urban areas having higher chance of getting diabetes, but wen we see that in combination of altitude it may not be always like that. Data of northeast have shown people who are residing in High altitude urban areas are less prone to getting diabetes than the rural high-altitude areas whereas people who are residing at low altitude urban areas are more prone be diabetic than the low altitude rural people.

Although this study was based on a socioeconomically developing regions, with changing age structures and epidemiological scenarios, it is possible that the prevalence of diabetes will increase further day by day in the absence of appropriate intervention.

A significant limitation of this study was its does not distinguish between type 1 and type 2 diabetes. A further limitation was that the survey does not give data about body mass index, Waist circumference, food habit about all the population above 15 years as these are only given for 15-49(men-15-54) years of people only, inclusion of these major variable would give a more reliable result. Furthermore, some important factors that could have been potential determinants of diabetes could not be included in the study due to the data unavailability, i.e. family history of diabetes, physical activity, dietary habits, and the presence of anxiety.

However, the study can be useful to understand the broader scenario without having any age constraint as this one included all the samples above 15 years, no major study was done for this cohort and it also contributing by giving reasons behind higher prevalence of diabetes among urban population.

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