Original Article

Syndemic of Obesity, Hypertension and Hyperglycemia among 15-49 Year Olds in Rajasthan: District-Level Data from National Family Health Survey-4

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ABSTRACT

Introduction: Non-communicable diseases (NCDs) are the new epidemic in India. District specific prevalence of various NCD risk factors is unknown. We used National Family Health Survey-4 (NFHS-4) data to map the syndemics of overweight/obesity, hypertension and hyperglycemia among 15-49 year old women and men in each district of the state.

Methodology: Data on location-adjusted prevalence of various NCD risk factors among 15-49 year old women and men were obtained from NFHS-4 fact-sheets. Heat maps were created to determine geographic distribution of obesity (body mass index, BMI $\geq$25 kg/m^2), hypertension (known and/or BP $\geq$140/$\geq$90 mmHg) and hyperglycemia (random glucose >140 mg/dl) in all the districts (n=33). We determined correlation of obesity with prevalence of hypertension and hyperglycemia. Descriptive statistics are presented.

Results: Significant geographic variation was observed in prevalence of obesity, hypertension and hyperglycemia in men and women. High prevalence of obesity and hypertension (>15%) was observed in central and northwestern districts. Obesity >15% was observed in 9 districts in women and 6 districts in men. Prevalence of hypertension >15% and hyperglycemia >8% was low. There was a significant correlation of obesity with hypertension in women (r= 0.45) and men (r= 0.43) and hyperglycemia in women (r=0.20) ($p<0.05$). Weak correlation was observed in prevalence of hypertension and hyperglycemia.

Conclusion: There is significant geographic variation in prevalence of syndemics of obesity, hypertension and hyperglycemia among the young in Rajasthan. Significant correlation of obesity with hypertension and hyperglycemia is observed.

INTRODUCTION

Syndemics are defined as clustering of two or more diseases within a population that contributes to and results from persistent social and economic inequalities.[1] In the mid-nineties, anthropologist Merrill Singer explored clustering of substance abuse, violence and AIDS and reported adverse health outcomes from these mutually interacting factors and coined the term syndemics.[2] Currently focus has shifted from disease-specific and multimorbidity models to evaluate how social and economic conditions foster and exacerbate the diseases.[3] The identification and description of syndemics involves a clear account of the diseases and health conditions, examination of pathways or mechanisms of disease-disease interaction, clear description of the socio-environmental conditions and how they are experienced by human minds and bodies as adversity, examination of pathways of effect from socio-environmental conditions to biological or psychological states and evidence of greater health burden because of interaction of these pathologies.[3] In the present context, syndemics of infections (e.g. AIDS, tuberculosis) and non-communicable diseases (e.g. diabetes, depression) have been reported.[4]

In India there is a triple burden of disease involving communicable and mother and childhood diseases, non-communicable diseases (NCD) and injuries.[5] There have been reports of association of diabetes with AIDS and tuberculosis and diabetes with depression.[4] Sociocultural factors responsible for these associations have not been well examined.[6] Macrolevel epidemiological studies could provide an initial impetus to study these associations. We examined the data from the Fourth National Family Health Survey (NFHS-4) using state-level and district-level data from published fact-sheets.[7] Hypertension and diabetes share common pathogenetic factors and overweight and obesity are important in pathogenesis of both the conditions[8,9] especially in South Asian Indians.[10] Multiple identical sociocultural factors are also involved.[11-14] In a previous report we evaluated association of obesity and abdominal obesity with increasing prevalence of hypertension and diabetes in Jaipur.[15] To evaluate presence of NCD risk factors in Rajasthan we determined district level prevalence of overweight/obesity (body mass index $\geq$25 kg/m^2), hypertension, and hyperglycemia (random glucose >140 mg/dl) from NFHS-4 fact-sheets. Inter-correlation of these risk factors was performed to determine syndemic association of these conditions.

METHODS

We used the district level data for Rajasthan obtained during the district level health survey and published by NFHS-4.[7] This is secondary analysis of the existing data and hence ethics clearance was not obtained. National Family Health Surveys are a series of nationally representative surveys that are periodically commissioned by government of India and performed under the guidance of International Institute for Population Sciences (IIPS), Mumbai, India; ORC Macro, Calverton, MD, USA and East-West Center, Honolulu, Hawai, USA. The studies are approved by the Ministry of Health of Government of India and the research review board at IIPS, Mumbai. So far three surveys have been performed- NFHS-1 from 1992-1993, NFHS-2 from 1998-1999 and NFHS-3 from 2004-2005.[16] NFHS-1 collected extensive information on population, health, and nutrition, with an emphasis on women and young children. Eighteen Population Research Centres located in universities and institutes of national repute assisted IIPS in all stages of conducting NFHS-1. The NFHS-2 was conducted in all the 26 states of India with additional data on quality of health and family planning services, domestic violence, reproductive health, anemia, nutrition of women and status of women. NFHS-3 used 18 research organizations including 5 population research centers who carried out surveys in 29 states of India. Funding agencies for various NFHS surveys have been reported.[17] NFHS-4 was performed in 2015-16 and is focus of present article.[18]

Detailed manual for the conduct of NFHS-4 is available at the website.[17] Specific goals of NFHS-4 were: a) to provide essential data on health and family welfare needed by the Ministry of Health and Family Welfare and other agencies for policy and program purposes, and b) to provide information on important emerging health and family welfare issues. Specific objectives were to provide estimates of the levels of fertility, infant and child mortality, and other family welfare and health indicators by background characteristics at the national and state levels; and measure trends in family welfare and health indicators over time at the national and state levels. Besides the usual details of perinatal mortality, adolescent reproductive health, high-risk sexual behavior, safe injections, tuberculosis, and malaria and family welfare and health conditions among slum dwellers, this study for the first time was designed to obtain data on common non-communicable diseases such as hypertension and hyperglycemia (diabetes).

Sampling:The survey was implemented in both urban and rural areas.[18] A uniform sample design was adopted in all the districts. IIPS, Mumbai selected primary sampling units for rural (villages) and urban (Census Enumeration Blocks, CEBs) areas following the NFHS sampling design. The field agencies were given a list of selected sampling units for each state or union territories that were selected for the fieldwork. When any regional linked primary sampling unit was selected, then mapping and household listing was undertaken for all the linked villages and urban blocks as a single unit. Prior to interviewing, all households located in the selected unit were listed as per the procedure by mapping and household listing teams. The list of households in each unit was used in selecting the final sample of households to be included in the NFHS-4 survey.

NFHS-4 was designed to provide information on various demographic parameters and other family welfare and health indicators by background characteristics at the national and state level and, for the first time, at the district level also. Because of need to report health indicators at the district level, the NFHS-4 sample size was increased to approximately 571,660 households, as compared with 109,041 households in NFHS-3.[8] The survey used 4 schedules (Household, Woman's, Man's and Biomarker), and information was collected from all women aged 15-49 years and, in a sub-sample of households, men aged 15-54 years. This was expected to yield a total sample of 628,826 women and 94,324 men eligible for the interview. In these selected households, information on approximately 267,272 children below age 5 years was also obtained. In addition to the 29 states, NFHS-4 also included all six union territories and has provided estimates of most indicators at the district level for all 640 districts in the country as per the 2011 Census. The data were collected using Computer Assisted Personal Interviewing on mini-laptops. The domain of clinical, anthropometric and biochemical testing was expanded in NFHS-4 to include random blood glucose and blood pressure (BP) measurements with estimates to be reported at the district level for women age 15-49 years and men age 15-54 years. All these components in the field were evaluated using portable equipment. A recently developed, improved model of the HemoCue instrument was used for anemia testing. A battery-operated portable glucometer was used for blood glucose testing. An automatic and battery operated BP instrument was used. Lancets and all blood contaminated materials were disposed of in a biohazard bag according to an established protocol. Only medical or other personnel with specific training on the procedures and on universal precautions regarding blood-borne pathogens were involved in conducting the anemia and blood glucose testing. NFHS-4 was conducted in two phases, and each phase covered almost an equal number of states/groups of states and union territories. The two phases helped in managing the whole operation of implementation more efficiently. Identical strategy was used for Rajasthan state which was part of the second phase.

Interview and assessments: The detailed interviewer manual is available at NFHS-4 website.[19] In the first step a Household Questionnaire permits the interviewer to identify women and men who are eligible for interview with the relevant Individual Questionnaire. Women (age 15-49 years) and men (age 15-54) years who are members of the household were interviewed. The Household Questionnaire also permits the interviewer to identify women, men, and children who are eligible for anthropometric measurement, anemia testing, HIV testing, random glucose testing and BP measurement.

The Woman's Questionnaire obtained information from each woman enrolled for participation on background characteristics including age, marital status, education, employment status, occupation, religion, and duration of residence. Details of reproductive behavior, knowledge and use of contraception, availability of family planning, children's health, feeding practices for children, women's health, AIDS and sexually transmitted infections, knowledge and attitudes concerning tuberculosis, sexual life, interpersonal household relations and violence. The Man's Questionnaire obtained information on most of the same topics. Details of smoking and tobacco use and alcohol use were also obtained from both men and women. History of presence of diabetes, asthma, heart disease, thyroid swelling and cancer were inquired. However, these details are not available on the fact sheets.[17]

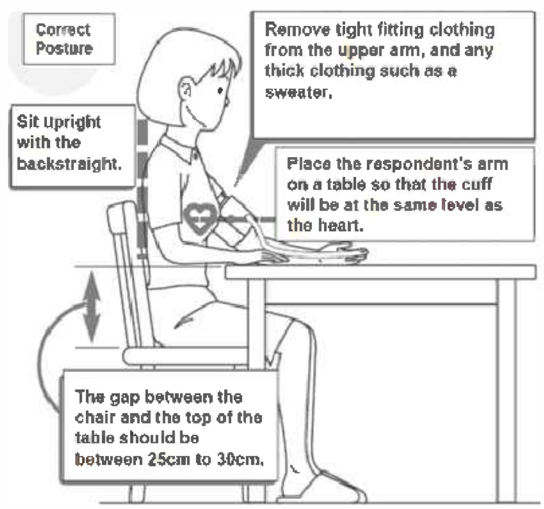


Figure 1: Blood pressure measurement method and precautions used in the NFHS-4 .[12]

Biomarkers included measurement of height, weight, hemoglobin levels, random blood glucose using standardized glucometers and BP measurement using electronic instruments.[20] For weighing children and adults the survey used SECA-874-U digital scale. This scale has a maximum capacity of 200 kg and weighs in 0.01 kg increments. 6 type AA 1.5 V batteries power the scale.

SECA-213 stadiometer was used for measuring the height of adults. For blood glucose estimation NFHS-4 used Free Style Optium H Glucometer. The readings were considered equivalent to blood glucose levels in laboratory estimations using the glucose oxidase method for glucose levels in the range of 10-600 mg/dl. BP of eligible respondents was measured using an Omron BP Monitor to determine the prevalence of hypertension. BP of each respondent was taken on three separate occasions and the readings recorded in the biomarker questionnaire with interval of 5 minutes between readings. Proper technique has been used to measure the BP (Figure 1).

The first result was discarded and the average of the last two measurements has been calculated. Informed consent was obtained from each individual for clinical evaluation, anthropometry and blood tests. Computer assisted personal interview technique was used for a majority of participants. However, when this was not possible due to logistic reasons the data were filled on paper case-report forms.

Statistical analyses: NFHS-4 data were manually obtained from the website.[7,17] Descriptive statistics are reported. Body mass index (BMI) was calculated by diving weight in kilograms by squared height in meters [BMI= weight in kg/(height in m)^2. Underweight was diagnosed when BMI was <18 kg/m^2 and overweight and obesity was considered when BMI was $\geq$25 kg/m^2.[21] Hypertension was diagnosed when either the participant was a known hypertensive on medical treatment or systolic BP was $\geq$140 mm Hg and/or diastolic BP $\geq$90 mmHg according to standard definitions.[21] Fasting blood glucose estimation was not performed in the NFHS-4 survey. Two criteria for diagnosis of hyperglycemia were adopted, high and very high glucose with random values >140 mg/dl and >160 mg/dl respectively. The urban-rural prevalence of risk factors and other conditions has been adjusted to the population proportions at each district to provide district-level estimates. Data of women and men are reported separately.

We developed heat-maps of each of the risk factors in each district of Rajasthan state using Microsoft Excel program in MS Office Version 14.0. Prevalence of various risk factors is reported from green (low prevalence) to red (high prevalence) according to percent prevalence of risk factors separately in men and women in each district of Rajasthan. Macrolevel correlation of district level prevalence of obesity, hypertension and hyperglycemia was performed using graphics program in MS Excel. Pearson's correlation coefficient (r) as well as Spearman's correlation coefficient (rho) were calculated to determine associations of these risk factors. p values less than 0.05 were considered significant.

RESULTS

NFHS-4 adopted a two-stage sampling design in rural and urban areas of each district of India. Survey interviewed 601,509 households, 699,686 women and 103,525 men from 28,583 primary sampling units composed of villages in rural areas and census enumeration blocks in urban areas in 640 districts of the country.[22] In Rajasthan data are available from all the 33 districts (Table 1). In Rajasthan 34915 households were valuated with sample size of 41965 women and 5892 men.

Data regarding various risk factors- underweight (BMI <18 kg/m^2), obesity (BMI $\geq$25 kg/m^2), hypertension and hyperglycemia (random capillary glucose >140 mg/dl) in 15-49 year old women and men are shown in Tables 1 and 2. There is a wide variation in prevalence of these risk factors in women as well as men. Prevalence of underweight (BMI <18 kg/m^2) is widespread in the state and ranges from 10-40% (Tables 1 and 2). It is more in the southern and southwestern districts. Prevalence of obesity in women and men is significantly greater in central and northwestern districts (Figure 2).

In women and men, respectively, low prevalence of obesity (<5%) is in 6 and 14 districts, moderate prevalence 5-15% in 18 and 13 districts and high prevalence (>15%) in 9 and 6 districts (Table 3).

Prevalence of hypertension also shows significant regional differences. Among women its prevalence is significantly greater in eastern districts while in men is more in central and northwestern districts of the state (Figure 3). Prevalence of hypertension is more in men than in women. Number of districts with low, moderate and high prevalence of hypertension is reported in Table 3. Hypertension prevalence among women is low in most of the districts of the state while in men almost a third of districts have high prevalence. Regional variation is also observed in prevalence of hyperglycemia (Figure 4).

Among women prevalence of hyperglycemia is significantly greater in eastern regions of the state while in men is more in southeastern and central districts. Number of districts with low, moderate and high prevalence of hyperglycemia is shown in Table 3 and shows a low

Table 1: Prevalence (%) of various non-communicable disease risk factors in different districts of Rajasthan in women

District (alphabetic)	Underweight (BMI <18 Kg/m2)	Overweight (BMI >25 Kg/m2)	Hypertension (known or BP >140/90 mmHg)	Hyperglycemia (glucose >140 mg/dl)	Hyperglycemia (glucose >160 mg/dl)
Ajmer	24.7	16.8	6.5	5.7	1.8
Alwar	25.4	10.9	8	2.4	0.9
Banswara	33.3	9	3.5	4.5	2
Baran	30.7	9.7	5.4	3.9	1.4
Barmer	26.1	11.7	7.1	3	0.7
Bharatpur	25.1	14.4	10.1	3.1	1.4
Bhilwara	24.3	14.1	3.8	3	0.9
Bikaner	23.7	15.4	6.1	3.9	0.9
Bundi	33.5	10.9	5.1	4.3	1.7
Chittaurgarh	28.7	17.6	9	3.9	2.2
Churu	26.8	13.5	7.6	2.6	1.2
Dausa	29.6	10.2	7.3	2.5	0.5
Dhaulpur	29.8	10.3	4.2	2.5	0.9
Dungarpur	38.1	6.2	5.2	4.6	1.2
Ganganagar	21.1	20.5	8	5.3	1.9
Hanumangarh	23	14.8	9.5	3.7	1.5
Jaipur	22.7	17.4	9.7	3	1
Jaisalmer	25.8	12.8	4.6	1.9	1.3
Jalor	31.2	9.3	6.2	3.8	1
Jhalawar	28.7	8.6	5.2	4.3	1.7
Jhunjhunun	19.3	17.3	8.1	2.4	0.8
Jodhpur	20.8	18.3	6	3.2	1.2
Karauli	32.2	10.2	7.7	3.1	1.3
Kota	26.4	20.6	5.7	4.6	2.1
Nagaur	25.2	14.1	8.6	3	0.8
Pali	32.6	14.5	5.9	3.7	1.8
Pratapgarh	35	7.8	6	3.6	1.2
Rajsamand	28.6	12.5	6.1	4.4	1.5
Sawaimadhopur	30	11.2	7.3	3.4	0.9
Sikar	23.2	18.4	7.9	3.9	1.3
Sirohi	34.2	10.1	4.7	3	1.4
Tonk	32.7	10.5	3.8	2.6	1.1
Udaipur	37.7	10.4	6.2	2.3	1

prevalence of hyperglycemia among women in most of the state while in men more than half of the districts have moderate or high prevalence.

We also performed a macrolevel correlation analysis of prevalence of underweight and obesity with hypertension and hyperglycemia in the young women and men (Table 4). There is a significant negative correlation of underweight with obesity and hypertension prevalence ($p<0.001$). Obesity prevalence shows a significant positive correlation with hypertension in both women ($r= 0.45$, $rho= 0.48$) and men ($r= 0.43$, $rho= 0.57$) ($p<0.001$). Similar trends are also observed in graphic calculations (Figure 5).

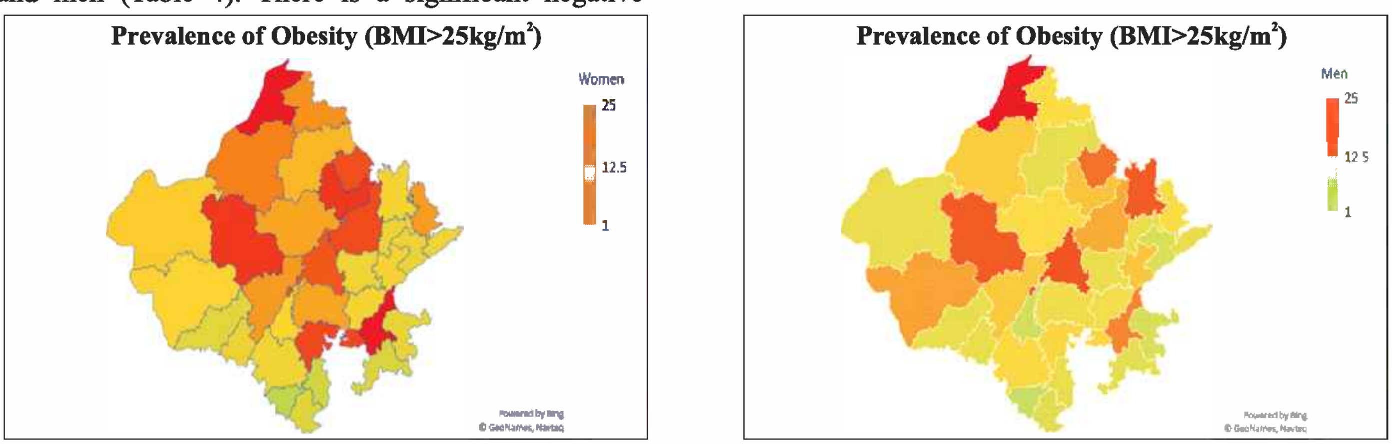


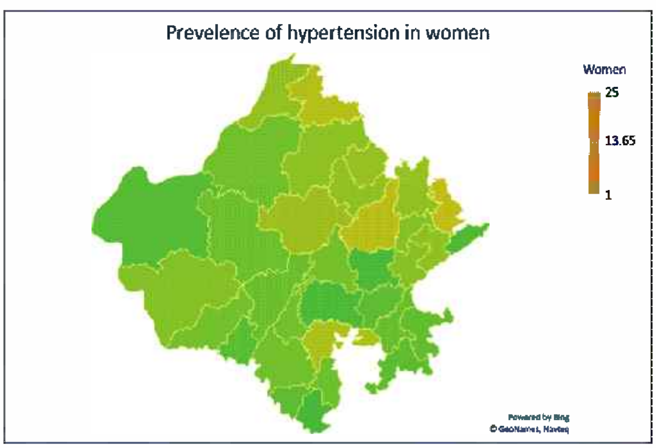
Figure 2: Prevalence of overweight or obesity in various districts of Rajasthan in women and men.

Table 2: Prevalence (%) of various non-communicable disease risk factors in different districts of Rajasthan in men

District (alphabetic)	Underweight (BMI <18 Kg/m2)	Overweight (BMI >25 Kg/m2)	Hypertension (known or BP >140/90 mmHg)	Hyperglycemia (glucose >140 mg/dl)	Hyperglycemia (glucose >160 mg/dl)
Ajmer	18.7	18.5	14.3	7.1	1.7
Alwar	13.4	18.1	15.7	8.4	1.5
Banswara	32.3	8.7	4.9	7.1	4.4
Baran	25.8	7.6	7.2	9.2	4.7
Barmer	29.8	15	10.9	3.7	2.8
Bharatpur	26	12.5	13.2	4.7	2.4
Bhilwara	23.1	10.2	5.5	6.7	3.5
Bikaner	19.1	13.2	11.8	5.3	1.5
Bundi	23.8	10.5	12.6	7	3.8
Chittaurgarh	23.5	12.8	11.3	5.5	3.5
Churu	30.6	9.3	10.7	2.5	0.7
Dausa	21.3	9.6	12.5	7.2	2.3
Dhaulpur	24.5	9.5	7	5.7	2.4
Dungarpur	23.1	5.7	11	5	2.1
Ganganagar	13.9	24.4	14.5	4.4	3.1
Hanumangarh	15.8	12.1	22.4	7.8	2.7
Jaipur	21.3	14.6	19.1	6.2	1.9
Jaisalmer	21.9	9.7	10.5	3.1	0.8
Jalor	27.3	9.6	8.6	6.1	3.6
Jhalawar	27.2	9	9.9	10.1	3.2
Jhunjhunun	17	17.1	14.3	2.4	0.7
Jodhpur	17.3	18.1	13.6	8.9	4.3
Karauli	40.1	7.5	13.2	4.5	1
Kota	26.5	16.3	11.3	7.7	3.7
Nagaur	15	11.6	14.7	1.8	1.3
Pali	21.1	13.3	10.4	2.1	0
Pratapgarh	16.9	9.5	5.5	5.1	2.5
Rajsamand	26.6	6.7	8.9	3.5	0.7
Sawaimadhopur	24.4	13.5	11.6	4.4	2.6
Sikar	15.1	13.6	12.4	3.8	0
Sirohi	23.7	9.6	9.3	4.6	0.7
Tonk	33.8	9.7	18.4	9.9	3.8
Udaipur	38.7	12.7	9.1	6.8	3.9

Table 3: Number of districts (n=33) with low, medium and high prevalence of various risk factors

	Obesity			Hypertension			Hyperglycemia		
		Women	Men		Women	Men		Women	Men
Low	<10%	6 (18.2)	14 (42.4)	<10%	32 (97.0)	10 (30.3)	<5%	31 (93.9)	13 (39.4)
Medium	10-15%	18 (54.5)	13 (39.4)	10-15%	1 (3.0)	20 (60.6)	5-8%	2 (6.1)	15 (45.5)
High	>15%	9 (27.3)	6 (18.2)	>15%	0 (0.0)	3 (9.1)	>8%	0 (0.0)	5 (15.1)



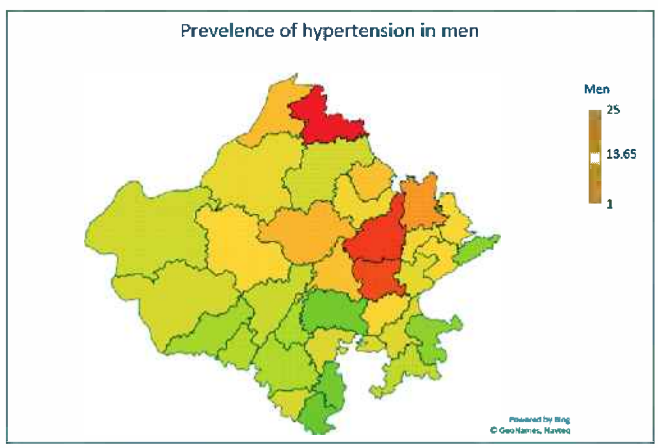


Figure 3: Prevalence of hypertension in various districts of Rajasthan in women and men.

Table 4: Correlation of underweight and obesity with hypertension and hyperglycemia

		Underweight		Obesity		Hypertension		Hyperglycemia	
		Pearson r	Spearman rho	Pearson r	Spearman rho	Pearson r	Spearman rho	Pearson r	Spearman rho
Obesity	Women	-0.777**	-0.787**	–	–	0.452**	0.482**	0.202	0.105
	Men	-0.501**	-0.521**	--	--	0.427**	0.566**	-0.011	-0.025
Hypertension	Women	-0.487**	-0.523**	0.452**	0.482**	--	--	-0.067	-0.098
	Men	-0.304*	-0.444**	0.427**	0.566**	--	--	0.109	0.065
Hyperglycemia	Women	0.020	0.045	0.202	0.105	-0.067	-0.098	--	--
	Men	0.137	0.131	-0.011	-0.025	0.109	0.065	--	--

*** p<0.05, ** p<0.01**

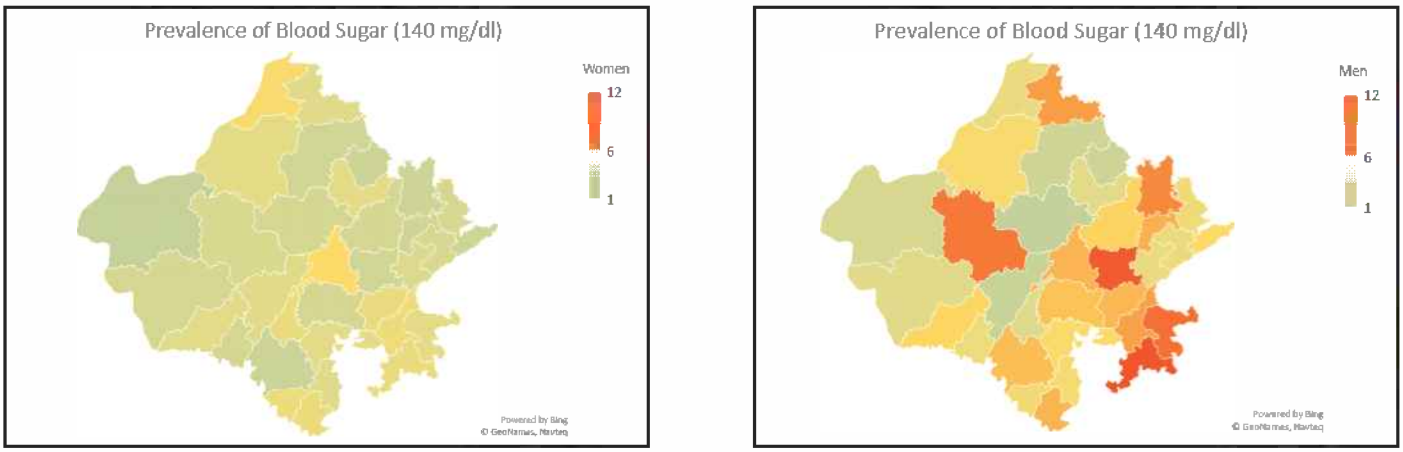


Figure 4: Prevalence of hyperglycemia (random blood glucose >140 mg/dl) in various districts of Rajasthan in women and men.

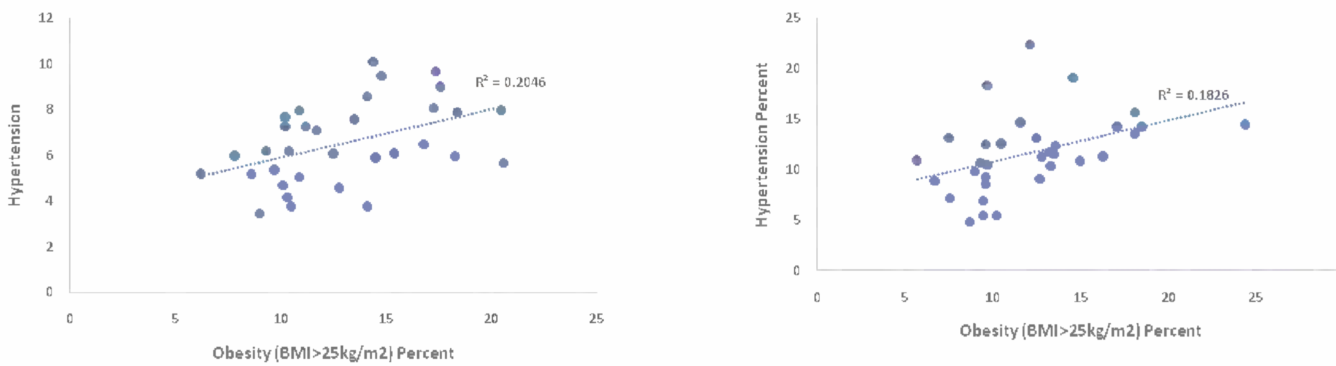


Figure 5: Correlation of prevalence of overweight or overweight/obesity with hypertension in women and men.

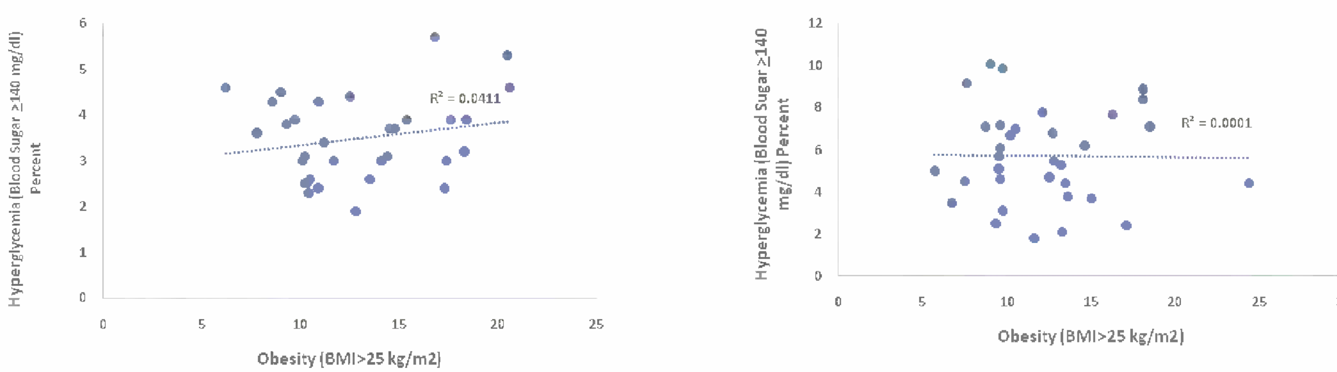
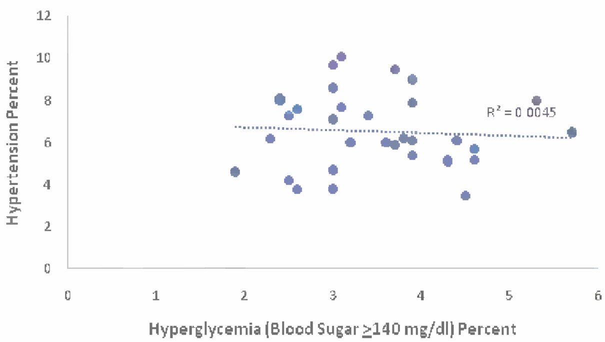


Figure 6: Correlation of prevalence of overweight/ obesity with hyperglycemia in women and men.



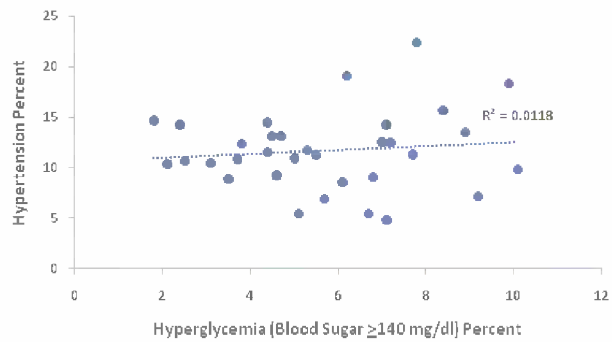


Figure 7: Correlation of hypertension with hyperglycemia in women and men.

Prevalence of obesity shows a significant positive correlation with hyperglycemia in women (r= 0.20, rho= 0.11) but not in men (Figure 6). Analysis of association with hypertension and hyperglycemia prevalence shows a weak positive correlation in men (r= 0.11, rho= 0.07) and an insignificant negative correlation in women (r= -0.7, rho= -0.10). Insignificant correlation is also observed in graphic calculations (Figure 7). Correlation of hypertension prevalence with severe hyperglycemia (blood glucose >160 mg/dl) also shows insignificant results (r value, women -0.07, men 0.11; rho value, women -0.10, men 0.07).

DISCUSSION

This study shows that there are significant regional differences in prevalence of major non-communicable diseases risk factors- obesity, hypertension and hyperglycemia- in Rajasthan. There is a strong positive correlation of obesity with hypertension and weaker correlation with hyperglycemia. The study also shows that syndemics of hypertension and hyperglycemia are related to obesity.

Previous studies from India have reported regional differences in prevalence of cardiovascular diseases and their risk factors.[23] Preliminary data from the Million Death Study showed greater age-adjusted cardiovascular mortality in southern and eastern states of the country.[24] Coronary heart disease (CHD) mortality was greater in south India while stroke was more common in the eastern Indian states.[24] Cardio vascular disease (CVD) mortality was higher in urban Indian populations while stroke mortality was similar in urban and rural regions.[24] Epidemiological studies have reported that CHD prevalence is greater in South Indian states as compared to others.[25] Geographic variation in cardiovascular risk factors has been reported in India Heart Watch.[26] This study was performed in 11 cities in the country and reported that compared with national average, prevalence of most risk factors was significantly different in cities of eastern region. There was a significantly lower prevalence of overweight, hypertension, hypercholesterolemia, diabetes and metabolic syndrome in eastern region as compared with other regions. It was also observed that cities with low social development index had lowest prevalence of these risk factors. However, there are no epidemiological studies that compared within-state differences in prevalence of risk factors and our results cannot be compared to such data from India. On the other hand multiple studies from India have reported greater prevalence of cardiometabolic risk factors in urban as compared to rural populations in Chandigarh, Haryana, Rajasthan, Delhi and Tamilnadu.[25] Multiple studies from US, UK and other developed countries have reported large regional differences in prevalence of various cardio metabolic risk factors.[27-29] Our data shows that similar differences exist in Rajasthan, the largest state in the country.

Previous NFHS reports have highlighted regional differences in multiple social determinants of health including literacy, access to health care, family violence and smoking.[16] The present study, derived from the NFHS-4 data, for the first time has reported that there are significant difference within state in various non-communicable disease risk factors. Important omissions in NFHS-4 are lack of data on important lifestyle determinants of various cardiovascular risk factors. We have no district specific data on smoking, alcohol intake, healthy dietary patterns and physical activity. This is a major study limitation. We hope that the next rounds of NFHS shall focus on these important determinants or causes of cardiovascular and other non-communicable diseases.

Our study shows that there is a strong correlation of obesity with hypertension and a negative association with underweight (Table 4). Stronger association of obesity with hypertension suggests a direct effect. The mechanisms by which obesity leads to hypertensive disease are still under intense research scrutiny and include altered hemodynamics, impaired sodium homeostasis, renal dysfunction, autonomic nervous system imbalance, endocrine alterations, oxidative stress and inflammation, and vascular injury.[30] Most of these contributing factors interact with each other at multiple levels. On the other hand association of obesity with hyperglycemia and diabetes is more complex.[9,10] Epidemiological studies have reported that abdominal obesity is more strongly associated with hyperglycemia than generalized obesity.[15] In obese individuals, adipose tissue releases increased amounts of non-esterified fatty acids, glycerol, hormones, pro-inflammatory cytokines and other factors that are involved in the development of insulin resistance. When insulin resistance is accompanied by dysfunction of pancreatic islet beta-cells, failure to control blood glucose levels results.[31] Thus, the adipocyte is the "common soil" responsible for syndemics of hypertension and hyperglycemia/ diabetes.[32]

White adipocyte dysfunction leads to adverse adipocyte secretory profile, increased pro-inflammatory factors such as TNF alpha, interleukin-1β, interleukin-6, interleukin-8, leptin, resistin and MCP-1 and decrease in anti-inflammatory factors such as interleukin-10 and adiponectin. All these factors are important for hypertension and diabetes.[32] Although the association of obesity with hyperglycemia is weak in our study it is likely that individual level data may provide better correlations. On the other hand, in India, abdominal obesity may be a better marker of hyperglycemia and diabetes.[33]

This study has a few strengths and multiple limitations. Strengths include population wide sampling and vast geographic representation. The foremost limitation is inclusion of only young individuals 15-49 years for assessment of various NCD risk factors- obesity, hypertension and hyperglycemia. This has resulted in a significantly lower prevalence in the NFHS as compared to earlier population based studies in different regions of India.[25] Secondly, although the criteria for diagnosis of hypertension is according to international guidelines and methodology is appropriate,[21] the diagnosis of hyperglycemia is based on inferior criteria. WHO has recommended measurement of either a fasting glucose alone or fasting and 2-hour post-glucose estimation of measurement of glucose.[21] In the present study the random capillary blood glucose of >140 mg/dl has been taken as hyperglycemia and >160 mg/dl as significant hyperglycemia. Both cutoffs are off the mark and do not follow any national or international guidelines.[33] This may have resulted in a falsely skewed distribution of hyperglycemia. This is apparent when we correlate prevalence of obesity and hyperglycemia and hypertension with hyperglycemia and the results do not achieve any statistical significance (Table 4). This also is a major shortcoming of this round of NFHS. Thirdly, we have performed only a macrolevel analysis using the NFHS-4 fact-sheets available at the website. It is likely that when individual level data are similarly analyzed different results are possible. Fourthly, we have not correlated the social determinants of health available in the NFHS-4 fact sheet. These social determinants of obesity, hypertension and hyperglycemia are important "causes of causes" and it is likely that we shall have greater insight into syndemics of hypertension and diabetes using these determinants.[4] Fifthly, we have not reported on other major lifestyle risk factors for NCD epidemic in India including smoking, tobacco use, alcohol abuse, unhealthy diet and sedentary lifestyle as these data are not available. We have also not evaluated associations of the prevalence of hypertension and hyperglycemia with available health systems and availability of appropriate health care. And finally, we have not identified regional differences in causes of deaths in the present study, nor gleaned data from Registrar General of India database on district level mortality, as this question is not part of the present study. Other limitations are sampling bias, lack of urban representation in smaller districts and failure to adjust for regression-dilution bias especially in hypertension.

CONCLUSION

The present study shows that there are significant regional differences in prevalence of various NCD risk factors in Rajasthan. Inverse association of underweight and positive association of obesity with hypertension shows that increasing obesity, which is outcome of multiple social determinants,[34] is important. Obesity also shows a weak correlation with hyperglycemia and shows that these modern syndemics can be prevented by addressing the social determinants through appropriate policy measures.[4] Global epidemic of cardiovascular and other non-communicable diseases can be curtailed if a syndemic approach is utilized to address social determinants of health.[35]

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