Analyzing Gender Differences in the Changing Trends of Diabetes and Modifiable Risk Factors in India

Abstract

Objectives

This study aims to analyse gender-specific trends in diabetes and modifiable risk factors (MRFs) over time across various socio-economic and demographic groups. In addition, this study looked into MRFs exposure among diabetes and non-diabetes patients across women and men.

Methods

This study used cross-sectional data from the National Family Health Survey (NFHS) rounds: NFHS-3 (2006), NFHS-4 (2016), and NFHS-5 (2021). Multivariate logistic and negative binomial regression analyzed gender-specific associations between diabetes and modifiable risk factors (MRFs) across various socio-economic and demographic groups.

Results

From 2006 to 2016, diabetes was more prevalent in women, but from 2016 to 2021, men experienced a higher increase. Most MRFs exposure, like abnormal BMI, alcohol, and tobacco use, decreased, except for a rise in less diet diversity among women between 2016 and 2021. Older age, lower education, and poorer wealth were significantly linked to diabetes and MRFs in both genders. In 2016 and 2021, diabetic women had higher MRF exposure, as did diabetic men in 2021. Men consistently showed higher MRF exposure than women in all survey rounds. Higher education and wealth generally reduced MRFs exposure among diabetic patients.

Conclusions

The study reveals changing diabetes trends between genders in India, highlighting the need for tailored interventions. While some MRFs have decreased, rising dietary homogeneity among women is concerning. Socio-economic factors like education and wealth have protective effects. Targeted, gender-specific strategies are crucial for effectively managing India's diabetes burden.

Keywords: Gender; diabetes; modifiable risk factors; patients.

Introduction

Diabetes has emerged as a significant contributor to morbidity and mortality in India. Due to this increasing burden, India is often called the 'diabetes capital of the world' [1,2]. Studies typically indicate that diabetes is more prevalent among men than women in India, affecting 9.0% of men and 7.2% of women nationwide [3]. This disparity may stem from lifestyle factors like varying rates of smoking, alcohol consumption, body mass index, and dietary habits between genders [4–7]. Despite the higher prevalence among men, the annual percentage change in the death rate due to diabetes is higher in women (3.3%) compared to men (2.3%) [8]. Therefore, the surge in diabetes presents a complex challenge, influenced by the interplay of various socio-economic, cultural, and health-related factors, including gender, within the country [9]. Each gender has unique health needs in diabetes, influenced by various biological and social factors. Amidst this rise, understanding gender differences in both prevalence and associated risk factors is crucial for effective healthcare planning and interventions [3,10–12].

The exact cause of diabetes remains unknown, but various social, environmental, behavioural, and biological factors increase the risk of developing the condition [13]. Studies have classified diabetes risk factors into two categories: modifiable (those that can be changed) and non-modifiable (those that cannot be changed) [14–16]. Modifiable risk factors (MRFs) predominantly encompass behaviours such as tobacco and alcohol consumption, sedentary lifestyle, dietary preferences, and others. Conversely, non-MRFs comprise age, ethnicity, race, family history of diabetes, and similar attributes. Researchers hypothesise that the interaction of these MRFs and non-MRFs contributes to the development of diabetes [17,18]. Likewise, it has been noted that managing MRFs can mitigate the severity of non-MRFs' impacts. For instance, modifying diet

can improve insulin sensitivity among diabetes patients, reducing the risk of further vascular complications [19].

In the country, men often have a nutritional advantage over women, a disparity linked to different social and cultural norms [20,21]. Furthermore, the higher consumption of alcohol among men compared to women is attributed to a combination of biological, psychological, social, and cultural factors in the country [6]. Tobacco use is also deeply rooted in Indian culture and is intertwined with social status and socio-cultural norms among both men and women [22]. In the past, smoking among women was seen as taboo in Indian patriarchal society. However, now, it has become increasingly accepted as a symbol of liberation, individuality, and modernity. In rural India, hookah and other tobacco products continue to be offered to men as a gesture of harmony and communal bonding among people from various castes and social groups [7]. The Global Adult Tobacco Survey of 2016–17 estimated that approximately 42.4% of men and 14.2% of women in India use tobacco, highlighting how gender norms influence tobacco consumption in the country.

In India, notable differences in cultural norms and societal roles between genders are evident, underscoring the importance of studying the patterns of MRFs influencing diabetes. Therefore, a comprehensive trend analysis across diverse socio-economic and demographic groups, as well as across states and regions, is necessary to understand gender differences in diabetes and MRFs completely. Therefore, this study aims to study gender-specific trends in diabetes and MRFs over time across various socio-economic and demographic groups. The study efforts seek to contribute towards developing tailored strategies for diabetes prevention and management in India. It analyses a range of MRFs to gain a comprehensive understanding of the intricate interplay between gender, MRFs and diabetes across various socio-economic and demographic groups over time. Our findings will assist policymakers in understanding broader socio-economic determinants of diabetes and reducing gender-based health inequalities.

Methods

Data

The International Institute for Population Sciences conducted five rounds of the National Family Health Survey (NFHS) across India in 1992–93 (NFHS-1), 1998–99 (NFHS-2), 2005–06 (NFHS-3), 2015–16 (NFHS-4), and 2019–21 (NFHS-5). This study utilized data from NFHS-3 (2006), NFHS-4 (2016), and NFHS-5 (2021) to explore gender disparities in diabetes-related modifiable risk factors (MRFs). NFHS-3 was the first to include diabetes-related information. Each NFHS round used a multistage stratified cluster sampling design based on the latest Census of India. The final sample included 118,867 women and 67,526 men (NFHS-3), 670,384 women and 98,012 men (NFHS-4), and 689,454 women and 89,077 men (NFHS-5) (Table 1).

Description of variables

The present study uses two dependent variables: self-reported diabetes and a person's MRFs exposure. We analyzed self-reported diabetes using multivariate logistic regression, coding the dependent variable as 0 for "no" and 1 for "yes." Biomarker data on blood glucose levels were excluded for consistency across all NFHS rounds, as they were unavailable for NFHS-3. Negative binomial regression (NBR) was used for the count variable representing a person's MRFs exposure score. All three NFHS rounds included data on four MRFs: alcohol consumption, tobacco use, body mass index (BMI), and diet diversity. Alcohol consumption was coded as 0 for "no" and 1 for "yes" based on the question, "Do you currently drink alcohol?" Tobacco use was similarly coded based on responses to questions about smoking and chewing various tobacco products.

BMI was categorized as underweight (<18.5), normal (18.5-24.9), overweight (25-29.9), and obese (≥30). These categories were further recoded into a binary classification: normal BMI

(0) and non-normal BMI (1), including underweight, overweight, and obese. This binary classification is based on studies linking non-normal BMI to increased diabetes risk [23–25]. Diet diversity was assessed based on the consumption of seven healthy food items over the past month: milk/curd, pulses/beans, dark green leafy vegetables, fruits, eggs, fish, and chicken/meat. Consumption frequency was scored as daily (3), weekly (2), occasionally (1), and never (0), with total scores ranging from 0 (none consumed) to 21 (all consumed daily). A diverse diet, as recommended by the Indian Council of Medical Research and the Food and Agriculture Organization, is linked to better health outcomes. The diet diversity score was categorized into more diverse (0) and less diverse (1) using the equal width binning method. The MRFs exposure score, calculated by summing alcohol consumption, tobacco use, BMI, and diet diversity, ranged from 0 (no exposure) to 4 (exposure to all MRFs). This score was used as a count-dependent variable in the NBR model.

The independent variables include socio-economic and demographic factors: age, education, wealth index, religion, social category, marital status, place of residence, and zones. NFHS data covers women aged 15-49 and men aged 15-54 in selected households. Ages were grouped into seven categories: 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, and 45-49 years. Men aged 50 and above were excluded to facilitate gender comparison. Educational qualifications were categorized into four groups: no education, primary, secondary, and higher education. The wealth index classified households into the poorest, poorer, middle, richer, and richest. This index was computed using principal component analysis on indicators related to consumer goods, construction materials, and water and sanitation facilities, dividing the population into five equal quintiles.

Religions were categorized as Hindu, Muslim, Christian, Sikh, Buddhist, and others (including Jainism, Zoroastrianism, etc.). Social categories included general (others), scheduled castes (SCs), scheduled tribes (STs), and other backward classes (OBCs). Missing social category

data were excluded. Marital status was categorized as unmarried, married, and others (widowed, divorced, separated, deserted). Place of residence indicated urban or rural locations. NFHS data were analyzed based on a six-zone division of India's administrative divisions. Detailed zonal descriptions and changes over time are provided in Supplementary File – Appendix 1 and Appendix 2.

Statistical analysis

To investigate gender differences in the burden of diabetes, we initially conducted a descriptive analysis of all data rounds (Table 1). We computed the proportion of diabetes and MRFs exposure across various socio-economic and demographic variables for India and by states/UTs for all rounds. Exposure was calculated as the number of people in the sample with the characteristic of interest (diabetes and MRFs) multiplied by 100, divided by the total sample size within the group. We also calculated the change in percentage points of diabetes and MRFs exposure using the formula: change = Px - Py, where Px is the proportion in the most recent year (NFHS-5-2021) and Py is the proportion in the previous year (NFHS-4-2016). A negative value indicates a decrease, while a positive value indicates an increase in exposure over time.

We used multivariate logistic regression and NBR to examine the association between diabetes and MRFs exposure across various socio-economic and demographic variables. Additionally, we conducted two-sample t-tests for unequal variance to determine statistically significant differences in MRFs exposure scores across self-reported diabetes cases. Following this, we used NBR to calculate the association of MRFs exposure across various socio-economic and demographic variables among diabetes patients (Supplementary File - Appendix 3). All analyses were conducted using STATA 17, with values weighted using sample survey weights. We also developed an online interactive dashboard using Tableau to visualize diabetes and

MRFs exposure trends for both genders across states/UTs of India (Supplementary File - Appendix 4).

"https://public.tableau.com/app/profile/prateek.singh3051/viz/GenderwiseprevalenceofmodifiableriskfactorsofdiabetesacrossIndianstates_UTsforNFHS-3NFHS-4andNFHS-5/Dashboard1"

[insert Table 1 here]

Results

Table 2 reveals a general decline in nationwide exposure to MRFs over the period, except for a notable increase in lower dietary diversity exposure among women (5.55%) from 2016 to 2021. Diabetes exposure in India increased throughout the period, with a more significant rise among women (0.76%) compared to men (0.66%) from 2006 to 2016. From 2016 to 2021, the increase was more pronounced in men (0.32%) than in women (0.19%). Both men and women aged 30 and above experienced increased diabetes exposure from 2016 to 2021, although men aged 40-44 years saw a decrease (-0.28%).

[insert Table 2 here]

In Table 3, NBR analyses the relationship between MRFs and various socio-economic and demographic variables across all seleted surveys. An increase in age is significantly associated with higher exposure to MRFs for both men and women in all three rounds, except for women aged 20-29 in 2016 and 2021, with IRR ranging from 1.03 to 1.34. Education correlates with a slightly reduced exposure to MRFs for both genders across all surveys. Wealth also shows a significant trend of reduced risk with increased wealth for both genders across all surveys, with the richest group having the lowest risk, showed by IRR as low as 0.71 for women in 2006.

Among religion, Muslims, Christians (except for men in 2021), and Buddhists (except for women in 2006) consistently show a significantly reduced risk for both genders across all surveys, particularly in 2021. For Sikhs, there is a mixed association, with women's risk being higher than men's in all surveys. In the case of social categories, all groups compared to the SCs category show higher risks across all surveys, with some exceptions for men in OBCs and other categories. Compared to the northern zone, all other zones exhibit significantly reduced risks, especially in the western and eastern zones across all surveys for both genders.

Multivariate logistic regression models (Model 1) examine the relationship between diabetes and various socio-economic and demographic variables across all surveys. As age increases, the likelihood of having diabetes rises for both women and men in all surveys. For women, the odds ratios (OR) increase over time across all age groups, whereas for men, the OR generally decrease, though there are some mixed results. The gender-wise analysis of different education levels shows that men with higher education typically have a significantly lower risk of diabetes, except in 2016. Conversely, women with more education are at a greater risk of diabetes. In terms of wealth, individuals from the richest quintile, both women and men, are significantly more likely to suffer from diabetes compared to their less affluent counterparts in all surveys. Men in the "Others" category (OR: 3.62) in 2021 have a significantly higher likelihood of being affected by diabetes compared to other groups. When compared to the SCs category, the likelihood of diabetes is lower for both genders across all surveys, except for men in 2021. Women residing in rural areas are less likely to suffer from diabetes than their urban counterparts, whereas the opposite pattern is observed for men.

Model 2 extends the analysis of Model 1 by adjusting for MRFs, revealing a similar overall picture for both women and men across all surveys. Alcohol consumption is identified as a significant risk factor for diabetes, with an increased risk observed in 2021 for men (OR: 1.33) and in 2016 for women (OR: 1.38). However, tobacco consumption shows no significant

association with diabetes, except for a reduced risk in 2006 for men (OR: 0.81) and an increased risk for women in 2016 (OR: 1.14). A non-normal BMI is consistently associated with a significantly increased risk of diabetes for both women and men across all surveys. No significant association is found between less dietary diversity and diabetes across the surveys.

[insert Table 3 here]

Additionally, our analysis explored the bivariate relationship between MRFs exposure scores and diabetes across all NFHS rounds for both genders, as shown in Table 4. In the 2006, the average difference in MRFs exposure scores between women with diabetes and those without is -0.02 ($\sigma = 0.03$), with a t-value of -0.584 and a p-value of 0.559, indicating no significant difference. Similarly, the average MRFs exposure score difference for men is 0.01 ($\sigma = 0.04$), with a t-value of 0.050 and a p-value of 0.961, indicating no significant difference. However, in the 2016, we found a significant mean difference in MRFs exposure scores for women, with higher scores for those with diabetes than those without. The MRFs exposure score difference was higher for men with diabetes, but this was not statistically significant. In 2021, we found substantial differences in MRFs exposure scores for both women and men, with higher scores for those with diabetes. Throughout all rounds, men's average MRFs exposure score was higher than women's, regardless of diabetes status.

Additionally, the average MRFs exposure score for women with diabetes has been increasing over time, while it has been decreasing for men with diabetes. For non-diabetic patients, the average MRFs exposure scores for both women and men have decreased over time. Significant differences in MRFs exposure scores between individuals with and without diabetes were found for women in 2016 and 2021 and for men in 2021 only. No significant differences were found for both genders in 2006 or for men in 2016.

[insert Table 4 here]

Table 5 presents the results of an NBR analysis, highlighting the association between MRFs exposure for diabetes patients across various socio-economic and demographic variables for women and men. For women, older age groups generally exhibit risk compared to the reference group, but results are insignificant across all surveys. For men, the risk varies more across age groups, with significant increases observed in the 35-49 age groups in 2016 and 2021. Regarding education, both men and women with higher education levels generally show a reduced IRR, except for women with primary education in 2016 and men with primary and secondary education in 2021. Wealthier individuals of both genders typically have a significantly reduced IRR across all surveys, with the richest groups displaying the lowest IRR. In 2021, women who are Sikh (IRR: 1.05) or belong to other religions (IRR: 1.34) experience significantly higher MRFs exposure, whereas men show decreased MRFs exposure in all religious categories compared to Hindus. Compared to SCs, women in all social categories show increased risk across all surveys, with significant results for SCs and others in 2016 and others in 2021. For men, results are mixed across all surveys, with a significantly lower risk for OBCs in 2006. Men who are married or in the others category show increased IRRs, with significant results for the married category in 2016, but the results are insignificant for women across all surveys. For both genders, living in rural areas shows an increased IRR in 2006, a decrease in 2016, and an increase in 2021 only for women compared to their urban counterparts. Compared to the northern zone, all other zones generally exhibit a reduced risk for both women and men across all surveys.

[insert Table5 here]

Discussion

This study comprehensively analyses gender-specific trends in diabetes and associated MRFs exposure in India between 2006 - 2021. Our findings indicate that the burden of diabetes has

increased across all demographic and socio-economic groups, with pronounced differences between men and women. Diabetes prevalence was consistently higher among men in all periods compared to women, corroborating the Indian Council of Medical Research – India diabetes (ICMR-INDIAB) report which found a higher prevalence in men (12.10%) compared to women (10.70%) in 2021 [26]. Moreover, the increasing prevalence of diabetes among men may be contributing to a larger rise in Disability-Adjusted Life Years (DALYs) for men (209.09%) compared to women (176.92%) between 1990 and 2016, as reported by the India State-Level Disease Burden Initiative [27]. The India State-Level Disease Burden Initiative reported a 119.05% increase in DALYs in the eastern and central zones, a 109% rise in the western, southern, and northern zones, and a 100% increase in the northeastern zone [27]. Our study found that the eastern zone consistently had a higher diabetes burden for both women and men compared to the northern zone across all periods, indicating a significant regional burden. In the central zone, while the diabetes burden varied over time, men consistently experienced a higher burden than women, pointing to a greater impact on men. This trend underscores the need for targeted interventions to address gender-specific diabetes risk factors in different regions.

The exposure of most MRFs, such as tobacco use and alcohol consumption, has decreased over time for both genders. This reduction can be attributed to the collective efforts of the government, non-governmental organisations, and society in India. For instance, the launch of the Government of India's National Tobacco Control Programme in 2007 aimed at creating awareness about the harmful effects of tobacco consumption, reducing the production and supply of tobacco products, helping people quit tobacco use, and facilitating the implementation of strategies for tobacco prevention and control as advocated by the WHO Framework Convention on Tobacco Control. Additionally, the reduction may be linked to the Central Sector Scheme of Assistance for Prevention of Alcoholism and Substance Abuse,

launched in 2008, which aims to provide financial assistance to various organisations for running de-addiction centres and conducting awareness programs. In 2012, the government approved a new National Policy on Narcotic Drugs and Psychotropic Substances to combat drug abuse, with provisions for treatment, rehabilitation, and social re-integration of victims.

However, there has been a significant increase in less-diverse diets among women from 2016 to 2021, especially among those with higher education and wealth. A study by Gupta et al. (2020) in India found that women consistently consume less diverse diets than other household members, supporting our results [28]. In India, educated and wealthy women often have demanding careers and busy lifestyles, leading them to rely on unhealthy convenient foods [29]. Therefore, it is recommended that awareness and understanding of balanced diets and healthy eating practices be enhanced while regulating the marketing of unhealthy foods.

Diabetes has increased, with a more significant rise observed from 2006 to 2016 for both genders compared to 2016 to 2021. It implies that the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke, introduced in 2010, might have played a crucial role in reducing diabetes. Throughout the period, significant gender differences in diabetes were observed, with higher exposure among women from 2006 to 2016 and among men from 2016 to 2021. These differences in exposure could be linked to a lack of gender-disaggregated health-related policy in the country. Our findings also indicate that additional attention is needed for older age groups, individuals with lower education levels, and those in poorer wealth categories, as they show significant increases in diabetes and MRFs exposure. The WHO STEPS surveys from 2004, 2007, and 2017 reveal persistent low levels of physical activity and increased obesity among women, while men exposed to higher rates of smoking and alcohol consumption [30]. These factors likely contribute to the rising diabetes prevalence in India, as highlighted by the 2021 International Diabetes Federation's Diabetes

Atlas [31]. Therefore, maintaining a healthy BMI through balanced nutrition, regular exercise, and reducing alcohol consumption are the most effective strategies to prevent diabetes [32].

Throughout all rounds, the average MRFs exposure for diabetes patients was higher than that of the general population, implying non-adherence to medical recommendations. Diabetes patients are usually advised to follow a healthy lifestyle to minimise the risk of further complications and mortality. Likewise, a gender difference was found in non-adherence across all surveys, with women's average MRFs exposure scores increasing and men's average MRFs exposure decreasing. However, men's MRFs exposure scores remained higher than those of women, aligning with the 2005 Chennai Urban Rural Epidemiology Study [33], which may explain the higher prevalence of diabetes retinopathy among men in this survey [34]. Nonetheless, the increasing MRFs exposure among women could be contributing to a higher prevalence of diabetes retinopathy in women, especially in rural areas, while men are more affected in urban areas [35]. Consistent with this, the 2021 NFHS survey findings show greater MRFs exposure among rural women and urban men, emphasizing the need for targeted policies that consider these urban-rural distinctions.

Therefore, proactive cooperation between medical practitioners and patients is needed to identify and address potential constraints to adherence. Furthermore, implementing national programs akin to Kerala's Sashradham health survey, which concentrates on monitoring lifestyle diseases and risk factors, is essential for obtaining valuable data on public health status [36]. Our findings align with other studies, indicating that education and wealth are protective against exposure to MRFs, ultimately promoting medical adherence [37,38]. It underscores the importance of social and economic interventions in mitigating diabetes MRFs exposure. This suggests that tailored intervention strategies are essential to address the specific needs of each

gender. Interventions should be multifaceted, considering disparities across various socio-economic and demographic groups.

Conclusions

This study highlights the complex interplay of socio-economic, demographic, and MRFs contributing to the rising diabetes burden differently across genders in India. The gender-specific trends in diabetes and associated MRFs emphasise the need for tailored public health strategies. Our findings suggest that improving diet diversity, reducing alcohol and tobacco consumption, and managing BMI could be crucial in diabetes prevention and management. Addressing socio-economic disparities is essential to mitigate the growing diabetes epidemic in India. However, the use of repeated cross-sectional data limits the study's ability to infer causality between MRFs and diabetes. The absence of biomarkers in the 2006 round, led to reliance on self-reported diabetes, might result in underreporting or misreporting of study's estimate accuracy.

Despite these limitations, the study suggests developing gender-sensitive public health campaigns to promote healthy dietary practices, physical activity, and regular health check-ups. Implementing community-based programs to raise awareness about the risks of alcohol and tobacco consumption, primarily targeting men, is recommended. Improving access to diabetes screening and management services, especially in rural and underserved areas, and implementing school-based health education programs to inculcate healthy lifestyle habits from a young age will be crucial for long-term improvements in public health outcomes across the country. By addressing the identified MRFs and tailored interventions to the unique exposure of different demographic groups, policymakers can develop more effective strategies to combat the rising tide of diabetes in India.

References

1 Joshi SR, Parikh RM. India--diabetes capital of the world: now heading towards hypertension. *J Assoc Physicians India* 2007; **55**: 323–4.

2 Pandey S, Sharma V. World diabetes day 2018: Battling the Emerging Epidemic of Diabetic Retinopathy. *Indian J Ophthalmol* 2018; **66**: 1652.

3 Dhakad M. Diabetes and Hypertension Among Indian Women. In: Guilmoto CZ, ed. Atlas of Gender and Health Inequalities in India. Cham: Springer Nature Switzerland, 2023: 41–51.

4 Duggal S. An exploration of the social and cultural factors which influence Indian Punjabi men's health beliefs and risk perceptions of type 2 diabetes. 2014. https://etheses.bham.ac.uk/id/eprint/5535/ (accessed June 25, 2024).

5 Subramanian SV, Smith GD. Patterns, distribution, and determinants of under- and overnutrition: a population-based study of women in India. *Am J Clin Nutr* 2006; **84**: 633–40.

6 Kumar K, Kumar S, Singh AK. Prevalence and socio-demographic correlates of alcohol consumption: Survey findings from five states in India. *Drug and Alcohol Dependence* 2018; **185**: 381–90.

7 Gaur M. Tobacco use in India: an Epidemic of Smoking, Chewing and Snuffing. *IOSR JESTFT* 2017; **11**: 11–3.

8 Institute for Health Metrics and Evaluation. GBD Compare. 2021 https://vizhub.healthdata.org/gbd-compare/.

9 Upadhayay P, Singh N, Pandey M, Gupta H, Sikka R. Unveiling the link between lifestyle risk factors and diabetic retinopathy. *Int J Diabetes Dev Ctries* 2024; published online April 6. DOI:10.1007/s13410-024-01332-6.

10 Sahadevan P, Kamal VK, Sasidharan A, Bagepally BS, Kumari D, Pal A. Prevalence and risk factors associated with undiagnosed diabetes in India: Insights from NFHS-5 national survey. *Journal of Global Health* 2023; **13**. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10704946/ (accessed June 11, 2024).

11 Tripathy JP, Thakur JS, Jeet G, *et al*. Prevalence and risk factors of diabetes in a large community-based study in North India: results from a STEPS survey in Punjab, India. *Diabetol Metab Syndr* 2017; **9**: 8.

12 Agrawal S, Millett CJ, Dhillon PK, Subramanian S, Ebrahim S. Type of vegetarian diet, obesity and diabetes in adult Indian population. *Nutr J* 2014; **13**: 89.

13 National Institutes of Health. Symptoms & Causes of Diabetes. U.S. Department of Health and Human Services, 2016 https://www.niddk.nih.gov/health-information/diabetes/overview/symptoms-causes.

14 Issaka A, Paradies Y, Stevenson C. Modifiable and emerging risk factors for type 2 diabetes in Africa: a systematic review and meta-analysis protocol. *Syst Rev* 2018; **7**: 139.

15 Salzberg L. Risk Factors and Lifestyle Interventions. *Prim Care* 2022; **49**: 201–12.

16Scanlon PH, Aldington SJ, Stratton IM. Epidemiological issues in diabetic retinopathy. *Middle East Afr J Ophthalmol* 2013; **20**: 293–300.

17Ismail L, Materwala H, Al Kaabi J. Association of risk factors with type 2 diabetes: A systematic review. *Computational and Structural Biotechnology Journal* 2021; **19**: 1759–85.

18Wu Y, Ding Y, Tanaka Y, Zhang W. Risk factors contributing to type 2 diabetes and recent advances in the treatment and prevention. *Int J Med Sci* 2014; **11**: 1185–200.

19Mirabelli M, Russo D, Brunetti A. The Role of Diet on Insulin Sensitivity. *Nutrients* 2020; **12**: 3042.

20Aurino E. Do boys eat better than girls in India? Longitudinal evidence on dietary diversity and food consumption disparities among children and adolescents. *Economics & Human Biology* 2017; **25**: 99–111.

21Kulkarni VS, Kulkarni VS, Gaiha R. "Double burden of malnutrition" reexamining the coexistence of undernutrition and overweight among women in India. *International Journal of Health Services* 2017; **47**: 108–33.

22Chhabra A, Hussain S, Rashid S. Recent trends of tobacco use in India. *J Public Health (Berl)* 2021; **29**: 27–36.

23Ramachandran A, Snehalatha C. Current scenario of diabetes in India: Diabetes in India. *Journal of Diabetes* 2009; **1**: 18–28.

24Gupta S, Bansal S. Does a rise in BMI cause an increased risk of diabetes?: Evidence from India. *PLoS ONE* 2020; **15**: e0229716.

25 Resnick HE, Valsania P, Halter JB, Lin X. Differential effects of BMI on diabetes risk among black and white Americans. *Diabetes Care* 1998; **21**: 1828–35.

26 Anjana RM, Unnikrishnan R, Deepa M, *et al*. Metabolic non-communicable disease health report of India: the ICMR-INDIAB national cross-sectional study (ICMR-INDIAB-17). *The Lancet Diabetes & Endocrinology* 2023; **11**: 474–89.

27 Indian Council of Medical Research, Public Health Foundation of India, Institute for Health Metrics and Evaluation. India: Health of the Nation's States — The India State-Level Disease Burden Initiative. New Delhi, India, 2017 https://phfi.org/the-work/research/the-india-state-level-disease-burden-initiative/.

28 Gupta S, Sunder N, Pingali PL. Are Women in Rural India Really Consuming a Less Diverse Diet? *Food Nutr Bull* 2020; **41**: 318–31.

29 Kumar GS, Kulkarni M, Rathi N. Evolving Food Choices Among the Urban Indian Middle-Class: A Qualitative Study. *Front Nutr* 2022; **9**: 844413.

30 World Health Organization. STEPwise approach to NCD risk factor surveillance (STEPS). 2024. https://www.who.int/teams/noncommunicable-diseases/surveillance/data/india.

31 Magliano D, Boyko EJ. IDF diabetes atlas, 10th edition. Brussels: International Diabetes Federation, 2021.

32 Deepa M, Anjana RM, Mohan V. Role of lifestyle factors in the epidemic of diabetes: lessons learnt from India. *European journal of clinical nutrition* 2017; **71**: 825–31.

33 Mohan V, Deepa R, Deepa M, Somannavar S, Datta M. A simplified Indian Diabetes Risk Score for screening for undiagnosed diabetic subjects. *The Journal of the Association of Physicians of India* 2005; **53**: 759–63.

34 Rema M, Premkumar S, Anitha B, Deepa R, Pradeepa R, Mohan V. Prevalence of Diabetic Retinopathy in Urban India: The Chennai Urban Rural Epidemiology Study (CURES) Eye Study, I. *Invest Ophthalmol Vis Sci* 2005; **46**: 2328.

35 Raman R, Vasconcelos JC, Rajalakshmi R, *et al*. Prevalence of diabetic retinopathy in India stratified by known and undiagnosed diabetes, urban–rural locations, and socioeconomic indices: results from the SMART India population-based cross-sectional screening study. *The Lancet Global Health* 2022; **10**: e1764–73.

36 Government of Kerala. Careful health survey to detect lifestyle diseases in adolescents. 2023; published online Nov 10. https://kerala.gov.in/articledetail/NjMzNTQyMjM5LjQ0/0.

37 Gupta R, Kaur M, Islam S, *et al*. Association of household wealth index, educational status, and social capital with hypertension awareness, treatment, and control in South Asia. *American journal of hypertension* 2017; **30**: 373–81.

38 Gonarkar SB, Dhande PP. Medication adherence and its determinants in myocardial infarction patients: An Indian scenario. *Journal of Clinical and Preventive Cardiology* 2016; **5**: 2–8.

Table 1: Samples distribution across various socio-economic and demographic groups among women and men aged 15–49 years, 2006-2021

Characteristics	NFHS-3 (2006)		NFHS-4 (2016)		NFHS-5 (2021)	
	Women	Men	Women	Men	Women	Men
	f (%)	f (%)	f (%)	f (%)	f (%)	f (%)
All India	118867	67526	670384	98012	689454	89077
Age group						
15-19	23671 (19.92)	12536 (18.57)	116773 (17.42)	17829 (18.20)	116800 (16.95)	15795 (17.74)
20-24	21730 (18.29)	11662 (17.28)	117728 (17.57)	15791 (16.12)	113916 (16.53)	13674 (15.35)
25-29	19520 (16.43)	10507 (15.56)	110168 (16.44)	15306 (15.62)	111429 (16.17)	13506 (15.17)
30-34	16889 (14.21)	9418 (13.95)	92603 (13.82)	13792 (14.08)	95515 (13.86)	12630 (14.18)
35-39	15174 (12.77)	8991 (13.32)	86976 (12.98)	13054 (13.32)	92901 (13.48)	12547 (14.09)
40-44	12484 (10.51)	7857 (11.64)	74625 (11.14)	11384 (11.62)	77939 (11.31)	10285 (11.55)
45-49	9402 (7.91)	6559 (9.72)	71514 (10.67)	10858 (11.08)	80958 (11.75)	10645 (11.95)
Education						
No education	48344 (40.67)	12132 (17.97)	185711 (27.71)	11575 (11.81)	156771 (22.74)	9355 (10.51)
Primary	17334 (14.59)	11127 (16.48)	83532 (12.47)	11697 (11.94)	80365 (11.66)	9957 (11.18)
Secondary	44493 (37.44)	35746 (52.94)	315523 (47.07)	57315 (58.48)	343721 (49.86)	51984 (58.36)

Higher	8699 (7.32)	8523 (12.63)	85620 (12.78)	17427 (17.78)	108599 (15.76)	17784 (19.97)
Wealth						
Poorest	20725 (17.44)	10690 (15.84)	119993 (17.90)	14627 (14.93)	125775 (18.25)	14651 (16.45)
Poorer	22423 (18.87)	12206 (18.08)	130555 (19.48)	18309 (18.68)	137022 (19.88)	17336 (19.47)
Middle	23973 (20.17)	13877 (20.55)	137514 (20.52)	20864 (21.29)	142614 (20.69)	19303 (21.68)
Richer	24993 (21.03)	14962 (22.16)	141420 (21.1)	21721 (22.17)	144421 (20.95)	20086 (22.55)
Richest	26755 (22.51)	15793 (23.39)	140904 (21.02)	22494 (22.95)	139625 (20.26)	17703 (19.88)
Religion						
Hindu	97845 (82.32)	56716 (84.00)	550905 (82.18)	81608 (83.27)	574563 (83.34)	73145 (82.12)
Muslim	14344 (12.07)	7159 (10.61)	81091 (12.10)	11239 (11.47)	79256 (11.50)	11330 (12.72)
Christian	2719 (2.29)	1405 (2.08)	15907 (2.38)	2127 (2.18)	16176 (2.35)	2313 (2.60)
Sikh	2145 (1.81)	1234 (1.83)	11524 (1.72)	1598 (1.64)	11256 (1.64)	867 (0.98)
Buddhist	977 (0.83)	587 (0.87)	6375 (0.96)	935 (0.96)	4333 (0.63)	1013 (1.14)
others	840 (0.71)	428 (0.64)	4585 (0.69)	507 (0.52)	3873 (0.57)	413 (0.47)
Social category						
SCs	22682 (19.09)	13163 (19.50)	142093 (21.20)	20262 (20.68)	158459 (22.99)	19629 (22.04)

STs	9901 (8.33)	5716 (8.47)	63908 (9.54)	9027 (9.21)	67253 (9.76)	8731 (9.81)
OBCs	47904 (40.31)	27176 (40.25)	302717 (45.16)	44589 (45.50)	310736 (45.07)	40325 (45.27)
Others	38381 (32.29)	21473 (31.8)	161668 (24.12)	24136 (24.63)	153007 (22.20)	20394 (22.9)
Marital status						
Unmarried	24275 (20.43)	24437 (36.19)	152358 (22.73)	37450 (38.21)	164638 (23.88)	34969 (39.26)
Married	89037 (74.91)	42165 (62.45)	489866 (73.08)	59353 (60.56)	495516 (71.88)	52976 (59.48)
Others	5556 (4.68)	925 (1.37)	28162 (4.21)	1211 (1.24)	29301 (4.25)	1133 (1.28)
Place of residence						
Urban	39331 (33.09)	24828 (36.77)	230844 (34.44)	37234 (37.99)	222485 (32.27)	31144 (34.97)
Rural	79537 (66.92)	42699 (63.24)	439541 (65.57)	60779 (62.02)	466970 (67.74)	57934 (65.04)
Zone						
Northern	14609 (12.29)	8985 (13.31)	85458 (12.75)	13111 (13.38)	93519 (13.57)	7693 (8.64)
Central	29356 (24.70)	17022 (25.21)	169490 (25.29)	22795 (23.26)	184453 (26.76)	11194 (12.57)
Eastern	26204 (22.05)	13562 (20.09)	143590 (21.42)	17736 (18.10)	150009 (21.76)	21096 (23.69)
Western	26742 (22.50)	14524 (21.51)	153133 (22.85)	22932 (23.40)	145410 (21.10)	23099 (25.94)
Southern	17927 (15.09)	11132 (16.49)	98145 (14.65)	18605 (18.99)	96665 (14.03)	21974 (24.67)

Northeastern	4032 (3.40)	2303 (3.42)	20571 (3.07)	2836 (2.90)	19401 (2.82)	4023 (4.52)

F= frequency, % = percentage.

Table 2: Change in the percentage point of diabetes and modifiable risk factors exposure from NFHS-3 to NFHS-1 (2006–2016) and from NFHS-4 to NFHS-5 (2016–2021).

Characteristics	Percentage point change																			
	Alcohol consumption				Tobacco use				Non-normal BMI				Less diverse diet				Diabetes			
	2006 - 2016		2016 - 2021		2006 - 2016		2016 - 2021		2006 - 2016		2016 - 2021		2006 - 2016		2016 - 2021		2006 - 2016		2016 - 2021	
	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men
All India	-0.95	-2.74	-0.50	-6.49	-3.55	-12.59	-2.58	-7.49	-3.37	-3.40	-1.26	-1.05	-4.32	-5.60	5.55	-8.75	0.76	0.66	0.19	0.32
Age group																				
15-19	-0.47	-2.26	-0.29	-2.87	-1.67	-10.04	-0.76	-4.74	-1.50	-8.56	-1.95	-3.69	-2.38	-4.58	4.96	-7.86	0.17	0.25	0.01	0.16
20-24	-0.64	-4.49	-0.37	-7.26	-2.24	-15.08	-1.30	-7.57	-4.89	-5.07	-1.95	-2.69	-2.70	-0.40	5.71	-10.59	0.20	0.14	0.09	0.27
25-29	-1.22	-3.47	-0.41	-9.83	-3.85	-14.59	-2.11	-8.64	-5.03	-4.31	-1.26	-0.11	-4.41	-4.90	6.16	-8.16	0.42	0.32	-0.01	0.20
30-34	-1.24	-3.47	-0.62	-8.29	-5.43	-12.78	-2.74	-9.86	-4.51	-1.26	-0.84	0.74	-5.73	-5.58	5.27	-9.87	0.50	0.66	0.06	0.43
35-39	-1.48	-3.31	-0.54	-5.08	-6.21	-12.51	-3.65	-8.64	-3.70	-0.16	-0.18	0.80	-6.30	-6.93	6.12	-8.73	0.70	0.71	0.19	0.42
40-44	-1.46	-1.28	-0.59	-8.04	-5.54	-13.90	-4.69	-7.58	-2.01	0.06	-1.51	-0.47	-5.25	-10.64	4.96	-7.76	1.15	1.02	0.37	-0.28
45-49	-0.96	-1.82	-1.04	-6.69	-5.23	-11.90	-5.54	-8.84	-1.93	-1.19	-1.72	-1.28	-4.96	-9.78	5.54	-7.99	2.21	1.80	0.33	0.63
Education																				
No education	-1.56	-2.43	-0.83	-7.95	-3.13	-9.57	-4.71	-8.87	-5.71	-8.08	-2.59	-0.69	-5.25	-11.73	2.32	-12.44	0.87	0.25	0.49	0.77
Primary	-0.26	-2.40	-0.37	-2.98	-1.63	-6.06	-2.50	-5.74	-2.23	-4.20	-1.95	-3.57	-3.57	-7.08	5.78	-10.79	0.96	0.77	0.37	0.30
Secondary	0.01	-0.65	-0.25	-5.86	-0.94	-9.07	-1.02	-6.55	-2.21	-3.46	-1.03	-0.63	0.01	-2.62	7.38	-7.98	0.62	0.74	0.12	0.44
Higher	-0.02	-0.61	-0.22	-7.89	-0.52	-12.01	-0.29	-6.07	-2.34	1.89	0.00	-1.28	5.05	0.26	9.47	-6.65	0.56	0.46	-0.11	-0.32
Wealth																				
Poorest	-3.39	-5.42	-0.94	-6.53	-7.07	-11.39	-4.62	-5.58	-9.10	-11.59	-3.62	-3.78	-7.42	-12.36	0.26	-14.54	0.41	0.31	0.28	-0.01
Poorer	-0.76	-3.78	-0.72	-5.68	-4.32	-13.66	-4.24	-8.80	-7.62	-6.97	-1.86	-2.28	-8.21	-11.16	3.50	-10.48	0.27	0.41	0.35	0.36
Middle	-0.97	-2.72	-0.50	-7.66	-3.75	-14.84	-2.31	-9.56	-3.11	-5.04	-0.12	0.58	-6.12	-7.11	5.03	-9.34	0.66	0.85	0.45	0.57
Richer	-0.27	-1.29	-0.25	-6.36	-2.70	-13.29	-1.72	-8.77	1.54	1.57	-0.56	0.04	-4.65	-2.37	7.94	-6.58	1.14	0.95	0.11	0.47

Richest	0.09	-1.41	-0.21	-7.35	-1.36	-9.81	-0.63	-8.21	0.18	1.73	-0.2	0.16	2.51	1.96	9.78	-5.90	1.27	0.68	-0.13	0.32
Religion																				
Hindu	-1.04	-2.74	-0.52	-6.45	-3.66	-12.69	-2.49	-7.74	-3.78	-3.68	-1.1	-0.81	-3.92	-5.64	5.61	-8.01	0.72	0.63	0.20	0.45
Muslim	-0.14	0.15	-0.08	-5.06	-3.35	-14.48	-3.60	-8.13	-1.42	-1.58	-3.24	-3.99	-6.59	-5.34	2.69	-11.37	0.97	0.53	0.20	-0.28
Christian	0.24	-2.40	-1.85	-7.34	-1.72	-10.98	-2.56	-3.08	2.41	2.00	0.81	3.48	-2.21	-10.00	6.27	-1.74	0.71	2.66	0.25	-2.14
Sikh	0.04	-8.50	0.08	-6.19	0.02	-5.17	-0.06	-3.65	-4.43	-4.27	4.18	-1.6	-2.24	17.95	8.31	-9.38	0.71	0.35	0.56	0.32
Buddhist	0.04	-5.68	0.23	-5.09	-7.73	-14.73	-2.12	-5.73	-5.88	-9.82	-3.02	1.65	-2.75	-5.61	6.32	-12.96	1.39	0.34	-0.72	0.03
Others	-12.2	-3.61	-2.81	-6.97	-6.45	1.34	-0.64	-17.64	-1.58	-4.12	-4.95	9.02	-17.26	-26.24	16.72	-4.22	0.05	1.43	0.06	6.31
Social category																				
SCs	-1.06	-5.45	-0.34	-5.19	-5.68	-15.03	-2.85	-6.55	-5.97	-6.57	-1.31	0.12	-7.09	-8.25	4.66	-9.16	0.67	0.60	0.38	0.07
STs	-7.70	-8.63	-2.61	-7.76	-8.31	-14.85	-5.64	-7.29	-7.18	-9.03	-3.56	-1.74	-10.57	-11.14	5.41	-9.54	0.75	0.58	-0.08	0.62
OBCs	-0.44	-1.28	-0.32	-8.14	-2.64	-12.34	-2.18	-8.73	-2.40	-2.53	-1.05	-1.03	-4.77	-5.56	4.27	-9.47	0.89	0.80	0.10	0.21
Others	-0.06	-3.51	-0.18	-5.27	-2.84	-11.96	-2.05	-7.00	-1.67	-0.75	-0.43	-1.62	-1.24	-2.61	9.00	-6.66	0.73	0.62	0.35	0.67
Marital status																				
Unmarried	-0.11	-1.09	-0.29	-5.53	-0.92	-9.95	-0.83	-6.01	-4.18	-6.93	-2.49	-2.04	-0.91	-2.36	6.02	-8.60	0.27	0.37	0.01	0.13
Married	-1.13	-3.10	-0.53	-6.85	-3.98	-13.19	-2.93	-8.01	-3.19	-1.43	-0.85	-0.41	-5.13	-7.39	5.39	-8.77	0.90	0.87	0.24	0.48
Others	-1.20	-3.49	-0.93	-5.36	-4.74	-14.41	-4.93	-7.18	-3.29	-4.10	-1.47	-2.10	-7.42	-6.92	4.48	-12.48	1.44	1.96	0.81	-0.07
Place of residence																				
Urban	0.09	-2.24	-0.27	-6.39	-2.03	-11.12	-1.75	-8.10	-0.23	0.92	-1.19	-0.99	-2.22	-0.44	6.83	-7.24	1.11	0.71	0.06	0.32
Rural	-1.45	-3.01	-0.63	-6.60	-4.24	-13.27	-3.08	-7.59	-5.00	-5.98	-1.16	-0.93	-5.06	-8.39	4.46	-10.08	0.55	0.62	0.31	0.35
Zone																				
Northern	-0.02	-3.98	0.08	-5.32	-1.36	-12.64	-0.76	-4.32	-4.22	-6.28	-0.85	-0.06	-3.90	-0.42	3.33	-10.32	0.51	0.61	0.40	0.56
Central	-0.76	-1.89	-0.60	-7.78	-4.63	-10.92	-4.92	-10.96	-2.40	-5.23	-2.83	-4.39	-3.80	-3.81	2.15	-6.89	0.54	0.42	0.18	0.44
Eastern	-2.21	-4.54	-0.26	-7.57	-7.07	-13.59	-2.86	-3.11	-6.80	-4.69	-1.73	-2.92	-7.37	-10.74	2.99	-4.25	0.28	0.35	0.51	-0.11
Western	-0.96	0.46	-0.99	-9.75	-1.19	-13.22	-0.93	-9.07	-2.09	-0.97	2.97	2.76	-4.70	-11.34	5.09	-0.79	1.65	1.44	-0.17	-0.18
Southern	-0.24	-4.53	-0.08	-3.35	-1.98	-9.45	-1.30	-7.24	-1.66	-1.70	-3.23	-2.90	-0.99	5.08	10.39	-6.48	0.72	0.30	0.22	0.74
Northeastern	0.07	1.17	-1.34	-8.7	-1.09	-5.74	-7.10	-13.52	-1.14	-1.16	-2.57	0.17	-10.37	-14.95	12.29	-4.87	0.31	0.64	0.71	-0.03

Table 3: Regression table showing the association between modifiable risk factors exposure and diabetes across different socio-economic and demographic variables, 2006-2021

Characteristics	Negative binomial regression						Multivariate logistic regression – Model 1						Multivariate logistic regression – Model 2					
	NFHS 3 (2006)		NFHS 4 (2016)		NFHS 5 (2021)		NFHS 3 (2006)		NFHS 4 (2016)		NFHS 5 (2021)		NFHS 3 (2006)		NFHS 4 (2016)		NFHS 5 (2021)	
	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men
	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)	OR (σ)
Age Group (Ref: 15-19)																		
20-24	1.03 (0.01)*	1.11 (0.02)*	0.96 (0.01)*	1.16 (0.02)*	0.94 (0.01)*	1.13 (0.02)*	0.82 (0.25)	2.67 (1.28)*	1.01 (0.13)	1.35 (0.33)	1.25 (0.12)*	1.48 (0.43)	0.83 (0.26)	2.80 (1.33)*	1.04 (0.14)	1.41 (0.35)	1.29 (0.13)	1.48 (0.43)
25-29	1.08 (0.02)*	1.17 (0.02)*	0.98 (0.01)*	1.23 (0.02)*	0.96 (0.01)*	1.23 (0.03)*	1.04 (0.31)	2.64 (1.29)*	1.60 (0.22)*	2.02 (0.51)*	1.61 (0.16)*	1.60 (0.48)	1.06 (0.32)	2.78 (1.35)*	1.64 (0.23)*	2.11 (0.54)*	1.65 (0.17)	1.56 (0.47)
30-34	1.16 (0.02)*	1.18 (0.02)*	1.04 (0.01)*	1.26 (0.02)*	1.01 (0.01)	1.26 (0.03)*	2.53 (0.74)*	2.74 (1.36)*	2.74 (0.37)*	3.27 (0.86)*	2.86 (0.29)*	2.36 (0.69)*	2.56 (0.75)*	2.89 (1.44)*	2.75 (0.37)*	3.39 (0.90)*	2.88 (0.30)	2.29 (0.67)*
35-39	1.21 (0.02)*	1.21 (0.02)*	1.07 (0.01)*	1.30 (0.02)*	1.06 (0.01)*	1.34 (0.03)*	4.46 (1.22)*	6.11 (3.02)*	4.41 (0.57)*	5.53 (1.46)*	4.79 (0.47)*	3.35 (1.03)*	4.49 (1.24)*	6.47 (3.22)*	4.37 (0.57)*	5.67 (1.51)*	4.78 (0.47)	3.19 (0.97)*
40-44	1.26 (0.02)*	1.22 (0.02)*	1.14 (0.01)*	1.30 (0.02)*	1.09 (0.01)*	1.31 (0.03)*	7.60 (2.06)*	11.98 (5.93)*	7.71 (0.99)*	9.94 (2.59)*	8.46 (0.81)*	4.55 (1.35)*	7.63 (2.08)*	12.82 (6.39)*	7.52 (0.98)*	10.17 (2.66)*	8.37 (0.81)	4.38 (1.31)*
45-49	1.29 (0.02)*	1.23 (0.02)*	1.17 (0.01)*	1.31 (0.02)*	1.11 (0.01)*	1.32 (0.03)*	10.77 (2.91)*	16.00 (7.77)*	12.57 (1.60)*	15.03 (3.86)*	13.12 (1.24)*	8.32 (2.43)*	10.84 (2.96)*	17.11 (8.38)*	12.21 (1.58)*	15.36 (3.98)*	12.96 (1.23)	7.97 (2.37)*
Education (Ref: No education)																		
Primary	0.97 (0.01)*	0.99 (0.01)*	0.97 (0.01)*	1.00 (0.01)	1.00 (0.01)	1.01 (0.02)	1.48 (0.2)*	0.79 (0.16)	1.46 (0.08)*	1.41 (0.24)*	1.34 (0.06)*	1.02 (0.18)	1.46 (0.20)*	0.79 (0.16)	1.45 (0.08)*	1.40 (0.24)*	1.32 (0.06)	1.01 (0.18)
Secondary	0.93 (0.01)*	0.90 (0.01)*	0.92 (0.01)*	0.90 (0.01)*	0.97 (0.01)*	0.90 (0.02)*	1.66 (0.21)*	0.80 (0.14)	1.4 (0.07)*	1.76 (0.25)*	1.39 (0.06)*	1.20 (0.18)	1.62 (0.20)*	0.80 (0.14)	1.40 (0.07)*	1.76 (0.25)*	1.36 (0.06)	1.19 (0.18)

Higher	0.81 (0.02)*	0.76 (0.01)*	0.85 (0.01)*	0.77 (0.01)*	0.91 (0.01)*	0.73 (0.02)*	1.17 (0.21)	0.84 (0.17)	1.17 (0.09)*	1.92 (0.32)*	1.11 (0.07)	0.88 (0.17)	1.15 (0.21)	0.81 (0.17)	1.18 (0.09)*	1.95 (0.34)*	1.11 (0.07)	0.90 (0.18)
Wealth (Ref: Poorest)																		
Poorer	0.91 (0.01)*	0.94 (0.01)*	0.91 (0.01)*	0.94 (0.01)*	0.92 (0.01)*	0.93 (0.02)*	1.64 (0.36)*	1.09 (0.31)	1.09 (0.07)	0.98 (0.15)	1.13 (0.06)*	1.45 (0.27)*	1.63 (0.36)*	1.10 (0.31)	1.10 (0.07)	0.99 (0.15)	1.13 (0.06)	1.47 (0.27)*
Middle	0.83 (0.01)*	0.9 (0.01)*	0.86 (0.01)*	0.90 (0.01)*	0.90 (0.01)*	0.87 (0.02)*	1.36 (0.29)	0.95 (0.26)	1.29 (0.09)*	1.10 (0.17)	1.38 (0.08)*	1.83 (0.34)*	1.37 (0.30)	0.94 (0.26)	1.31 (0.09)*	1.11 (0.17)	1.36 (0.08)	1.84 (0.34)*
Richer	0.75 (0.01)*	0.81 (0.01)*	0.83 (0.01)*	0.86 (0.01)*	0.89 (0.01)*	0.85 (0.02)*	1.88 (0.39)*	1.77 (0.45)*	1.92 (0.14)*	1.39 (0.23)*	1.71 (0.1)*	2.22 (0.42)*	1.90 (0.39)*	1.74 (0.45)*	1.92 (0.14)*	1.39 (0.23)*	1.67 (0.10)	2.21 (0.42)*
Richest	0.71 (0.01)*	0.76 (0.01)*	0.82 (0.01)*	0.82 (0.01)*	0.90 (0.01)*	0.82 (0.02)*	2.18 (0.47)*	3.89 (1.07)*	2.34 (0.18)*	1.92 (0.33)*	1.88 (0.12)*	2.90 (0.63)*	2.15 (0.47)*	3.71 (1.05)*	2.30 (0.18)*	1.89 (0.33)*	1.81 (0.12)	2.86 (0.63)*
Religion (Ref: Hindu)																		
Muslim	0.86 (0.01)*	0.81 (0.01)*	0.83 (0.01)*	0.80 (0.01)*	0.78 (0.01)*	0.74 (0.02)*	1.32 (0.17)*	1.15 (0.21)	1.39 (0.07)*	1.10 (0.15)	1.35 (0.06)*	0.62 (0.10)*	1.31 (0.18)*	1.19 (0.22)	1.37 (0.07)*	1.14 (0.15)	1.35 (0.06)	0.66 (0.10)*
Christian	0.86 (0.02)*	0.94 (0.02)*	0.98 (0.01)*	0.97 (0.03)	0.96 (0.01)*	1.04 (0.03)	1.59 (0.3)*	0.77 (0.22)	1.01 (0.09)	1.49 (0.28)*	1.18 (0.09)*	0.65 (0.20)	1.61 (0.31)*	0.74 (0.22)	1.00 (0.09)	1.50 (0.28)*	1.17 (0.09)	0.63 (0.19)
Sikh	1.07 (0.02)*	0.86 (0.02)*	1.05 (0.01)*	0.96 (0.02)*	1.10 (0.01)*	0.92 (0.02)*	1.16 (0.29)	1.86 (0.66)**	1.17 (0.11)**	1.23 (0.29)	1.17 (0.09)*	0.97 (0.21)	1.12 (0.28)	1.63 (0.59)	1.14 (0.11)	1.18 (0.28)	1.13 (0.08)	0.95 (0.20)
Buddhist	0.89 (0.03)*	1.01 (0.03)	0.87 (0.02)*	0.92 (0.03)*	0.85 (0.02)*	0.90 (0.06)**	0.73 (0.37)	0.95 (0.57)	1.42 (0.31)	0.81 (0.50)	0.65 (0.12)*	0.68 (0.39)	0.75 (0.38)	0.92 (0.55)	1.43 (0.31)**	0.79 (0.48)	0.65 (0.12)	0.65 (0.37)
Others	1.26 (0.03)*	1.12 (0.03)*	1.16 (0.02)*	1.05 (0.03)**	1.18 (0.02)*	1.13 (0.05)*	1.18 (0.47)	0.45 (0.26)	0.80 (0.37)	1.24 (0.56)	0.69 (0.13)*	3.62 (2.29)*	1.22 (0.49)	0.45 (0.26)	0.79 (0.36)	1.22 (0.56)	0.70 (0.13)	3.57 (2.22)*
Social Category (Ref: SCs)																		
STs	1.17 (0.02)*	1.04 (0.01)*	1.12 (0.01)*	1.04 (0.01)*	1.08 (0.01)*	1.03 (0.02)**	0.61 (0.14)*	0.54 (0.17)*	1.04 (0.10)	0.77 (0.12)**	0.67 (0.04)*	1.22 (0.22)	0.65 (0.16)**	0.54 (0.17)*	1.01 (0.10)	0.77 (0.12)**	0.67 (0.04)	1.22 (0.21)
OBCs	1.01 (0.01)	0.96 (0.01)*	1.07 (0.01)*	1.00 (0.01)	1.08 (0.01)*	0.98 (0.02)*	0.80 (0.1)**	0.73 (0.12)*	0.87 (0.04)*	0.88 (0.10)	0.80 (0.03)*	1.03 (0.13)	0.80 (0.11)**	0.74 (0.12)**	0.87 (0.04)*	0.88 (0.10)	0.80 (0.03)	1.07 (0.13)

Others	1.00 (0.01)	0.97 (0.01)*	1.05 (0.01)*	0.98 (0.01)*	1.09 (0.01)*	0.99 (0.02)	0.95 (0.13)	0.86 (0.15)	0.95 (0.05)	0.98 (0.13)	0.93 (0.05)**	1.44 (0.22)*	0.95 (0.13)	0.88 (0.15)	0.95 (0.05)	0.97 (0.13)	0.92 (0.04)	1.49 (0.23)*
Marital status (Ref: Unmarried)																		
Married	0.90 (0.01)*	1.10 (0.02)*	0.95 (0.01)*	1.10 (0.02)*	0.97 (0.01)*	1.10 (0.02)*	3.14 (0.85)*	1.91 (0.54)*	1.44 (0.15)*	1.02 (0.16)	1.48 (0.12)*	1.43 (0.24)*	3.16 (0.86)*	1.92 (0.54)*	1.43 (0.15)*	0.99 (0.15)	1.46 (0.12)	1.40 (0.23)*
Others	0.98 (0.02)*	1.17 (0.03)*	1.02 (0.01)*	1.20 (0.03)*	1.03 (0.01)*	1.23 (0.04)*	2.80 (0.85)*	1.70 (0.94)	1.36 (0.16)*	1.49 (0.55)	1.62 (0.15)*	1.71 (0.60)	2.84 (0.87)*	1.71 (0.95)	1.34 (0.16)*	1.44 (0.54)	1.61 (0.15)	1.67 (0.59)
Place of residence (Ref: Urban)																		
Rural	1.04 (0.01)*	1.00 (0.01)	1.04 (0.01)*	0.97 (0.01)*	1.07 (0.01)*	0.98 (0.02)*	0.65 (0.06)*	1.01 (0.13)	0.75 (0.03)	1.02 (0.10)	0.81 (0.03)*	1.02 (0.11)	0.65 (0.06)*	1.02 (0.13)	0.76 (0.03)*	1.04 (0.10)	0.82 (0.03)	1.04 (0.12)
Zone (Ref: Northern)																		
Central	0.95 (0.01)*	1.01 (0.01)	0.96 (0.01)*	1.06 (0.01)*	0.93 (0.01)*	1.00 (0.01)	0.91 (0.14)	1.44 (0.36)	1.14 (0.06)*	1.03 (0.14)	0.97 (0.05)	1.03 (0.12)	0.93 (0.15)	1.46 (0.37)	1.12 (0.06)*	1.02 (0.14)	0.97 (0.05)	1.04 (0.12)
Eastern	0.80 (0.01)*	0.93 (0.01)*	0.69 (0.01)*	0.89 (0.01)*	0.70 (0.01)*	0.89 (0.02)*	2.00 (0.28)*	3.64 (0.93)*	1.71 (0.10)*	1.93 (0.27)*	1.60 (0.08)*	1.38 (0.20)*	2.08 (0.30)*	3.65 (0.94)*	1.66 (0.11)*	1.94 (0.28)*	1.59 (0.08)	1.35 (0.2)*
Western	0.65 (0.01)*	0.80 (0.01)*	0.62 (0.01)*	0.78 (0.01)*	0.67 (0.01)*	0.76 (0.01)*	1.80 (0.24)*	3.78 (0.86)*	2.42 (0.13)*	2.60 (0.32)*	1.63 (0.07)*	1.78 (0.21)*	1.84 (0.25)*	3.50 (0.82)*	2.30 (0.14)*	2.52 (0.34)*	1.57 (0.07)	1.65 (0.22)*
Southern	0.89 (0.01)*	0.90 (0.01)*	0.90 (0.01)*	0.95 (0.01)*	0.94 (0.01)*	0.93 (0.02)*	0.80 (0.13)	1.56 (0.39)**	1.04 (0.08)	0.93 (0.16)	0.94 (0.06)	1.02 (0.17)	0.81 (0.14)	1.56 (0.39)**	1.01 (0.08)	0.93 (0.16)	0.94 (0.06)	1.05 (0.17)
Northeastern	0.80 (0.01)*	0.95 (0.02)*	0.75 (0.01)*	0.96 (0.02)*	0.77 (0.01)*	0.86 (0.02)*	1.19 (0.21)	2.39 (0.71)*	1.07 (0.08)	1.45 (0.24)*	1.41 (0.09)*	1.01 (0.18)	1.31 (0.24)	2.39 (0.71)*	1.00 (0.09)	1.44 (0.24)*	1.41 (0.09)	0.95 (0.18)
Alcohol consumption (Ref: no)																		
yes	-	-	-	-	-	-	-	-	-	-	-	-	0.61 (0.25)	1.18 (0.16)	1.38 (0.20)*	1.15 (0.11)	1.06 (0.14)	1.33 (0.16)*
Tobacco consumption (Ref: no)																		
yes	-	-	-	-	-	-	-	-	-	-	-	-	0.83 (0.14)	0.81 (0.11)**	1.14 (0.08)*	1.00 (0.09)	1.06 (0.07)	1.02 (0.12)

BMI (Ref: normal)																		
non-normal	-	-	-	-	-	-	-	-	-	-	-	-	1.31 (0.11)*	1.14 (0.13)	1.51 (0.05)*	1.52 (0.12)*	1.48 (0.05)	1.36 (0.13)*
Diet diversity (Ref: more diverse)																		
less diverse	-	-	-	-	-	-	-	-	-	-	-	-	1.05 (0.1)	0.94 (0.12)	0.97 (0.04)	1.05 (0.10)	1.01 (0.04)	0.94 (0.10)

IRR incidence Rate Ratio, OR odds ratio, σ Standard error, * Significant at 5%, ** Significant at 10%, Model 1 is adjusted to socio-economic and demographic variables, Model 2 is adjusted to modifiable risk factors along with socio-economic and demographic variables.

Table 4: Gender-wise bivariate associations between diabetes and modifiable risk factor scores, 2006-2021

Characteristics	NFHS 3 (2006)		NFHS 4 (2016)		NFHS 5 (2021)	
	Women	Men	Women	Men	Women	Men
	μ (σ)	μ (σ)	μ (σ)	μ (σ)	μ (σ)	μ (σ)
Diabetes						
No	1.11 (0.01)	1.80 (0.01)	1.10 (0.01)	1.74 (0.01)	1.07 (0.01)	1.52 (0.01)
Yes	1.12 (0.03)	1.80 (0.04)	1.15 (0.01)	1.78 (0.03)	1.16 (0.01)	1.68 (0.03)
Combined	1.11 (0.01)	1.80 (0.01)	1.10 (0.01)	1.74 (0.01)	1.08 (0.01)	1.53 (0.01)
Difference	-0.02 (0.03)	0.01 (0.04)	-0.06 (0.01)	-0.05 (0.03)	-0.09 (0.01)	-0.16 (0.03)
t value	-0.584	0.050	-6.833	-1.526	-11.820	-6.2237
p value	0.559	0.961	0.000*	0.127	0.000*	0.000*

μ Mean, σ Standard error, * Significant at 5%.

Table 5: Negative binomial regression showing the association between modifiable risk factors exposure for diabetes patients across different socio-economic and demographic variables, 2006-2021

Characteristics	Negative binomial regression					
	NFHS 3 (2006)		NFHS 4 (2016)		NFHS 5 (2021)	
	Women	Men	Women	Men	Women	Men
	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)	IRR (σ)
Age group (Ref: 15-19)						
20-24	1.12 (0.22)	0.98 (0.24)	1.11 (0.13)	1.07 (0.18)	0.97 (0.07)	0.80 (0.14)
25-29	1.22 (0.18)	0.98 (0.28)	1.07 (0.13)	1.09 (0.15)	1.06 (0.08)	0.95 (0.15)
30-34	1.11 (0.17)	1.00 (0.28)	1.24 (0.14)**	1.23 (0.16)	1.14 (0.08)**	1.01 (0.18)
35-39	1.10 (0.16)	1.02 (0.29)	1.26 (0.15)*	1.14 (0.15)	1.13 (0.08)**	1.25 (0.23)

40-44	1.19 (0.16)	1.02 (0.29)	1.33 (0.15)*	1.20 (0.16)	1.19 (0.08)*	1.11 (0.19)
45-49	1.19 (0.16)	0.99 (0.28)	1.38 (0.16)*	1.23 (0.16)	1.18 (0.08)*	1.11 (0.18)
Education (Ref: No education)						
Primary	1.02 (0.09)	0.93 (0.10)	0.97 (0.04)	1.14 (0.07)	0.97 (0.03)	1.11 (0.11)
Secondary	1.02 (0.09)	0.99 (0.10)	0.95 (0.03)**	0.97 (0.06)	0.94 (0.03)*	1.05 (0.09)
Higher	0.96 (0.11)	0.86 (0.10)	0.87 (0.04)*	0.90 (0.09)	0.86 (0.04)*	0.97 (0.11)
Wealth (Ref: Poorest)						
Poorer	0.73 (0.09)*	0.97 (0.12)	0.86 (0.04)*	1.00 (0.07)	0.91 (0.04)*	0.92 (0.10)
Middle	0.72 (0.08)*	0.71 (0.09)*	0.81 (0.04)*	0.77 (0.07)*	0.92 (0.04)*	0.87 (0.10)
Richer	0.66 (0.07)*	0.77 (0.10)*	0.83 (0.04)*	0.79 (0.07)*	0.91 (0.04)*	0.78 (0.09)*
Richest	0.62 (0.08)*	0.81 (0.11)	0.80 (0.05)*	0.72 (0.06)*	0.93 (0.04)*	0.82 (0.11)
Religion (Ref: Hindu)						
Muslim	1.04 (0.09)	0.92 (0.09)	0.91 (0.03)*	0.84 (0.07)*	0.83 (0.03)*	0.74 (0.08)*
Christian	0.91 (0.12)	0.97 (0.20)	0.98 (0.06)	0.94 (0.12)	0.88 (0.05)*	0.87 (0.2)
Sikh	1.12 (0.17)	0.78 (0.11)**	1.02 (0.06)	0.89 (0.10)	1.05 (0.03)**	0.84 (0.09)**
Buddhist	1.16 (0.43)	0.96 (0.52)	0.96 (0.10)	0.88 (0.18)	0.86 (0.10)	0.23 (0.14)*

Others	1.20 (0.34)	1.40 (0.46)	1.31 (0.18)*	0.81 (0.14)	1.34 (0.10)*	0.64 (0.15)*
Social Category (Ref: SCs)						
STs	1.01 (0.12)	1.04 (0.11)	1.13 (0.07)*	1.04 (0.08)	1.03 (0.04)	1.13 (0.11)
OBCs	1.10 (0.09)	0.86 (0.07)**	1.04 (0.04)	1.02 (0.06)	1.04 (0.03)	1.08 (0.07)
Others	1.01 (0.09)	0.97 (0.08)	1.10 (0.04)*	1.07 (0.07)	1.07 (0.03)*	1.01 (0.10)
Marital status (Ref: Unmarried)						
Married	1.14 (0.18)	1.14 (0.22)	0.99 (0.09)	1.20 (0.11)*	1.02 (0.06)	1.06 (0.12)
Others	1.33 (0.24)	1.16 (0.29)	1.06 (0.11)	0.97 (0.17)	1.09 (0.07)	1.37 (0.26)
Place of residence (Ref: Urban)						
Rural	1.11 (0.07)	1.17 (0.09)*	0.98 (0.03)	0.94 (0.05)	1.03 (0.03)	0.96 (0.07)
Zone (Ref: Northern)						
Central	1.00 (0.09)	0.86 (0.09)	1.01 (0.03)	0.98 (0.07)	0.95 (0.02)*	0.91 (0.06)**
Eastern	0.69 (0.07)*	0.84 (0.09)**	0.73 (0.03)*	0.86 (0.07)**	0.66 (0.02)*	0.90 (0.08)
Western	0.64 (0.06)*	0.78 (0.07)*	0.69 (0.03)*	0.90 (0.08)	0.71 (0.02)*	0.73 (0.06)*
Southern	0.89 (0.09)	0.96 (0.09)	0.90 (0.04)*	0.91 (0.08)	0.92 (0.04)*	0.97 (0.09)
Northeastern	0.75 (0.09)*	0.82 (0.12)	0.83 (0.04)*	0.92 (0.09)	0.82 (0.03)*	0.93 (0.09)

IRR incidence Rate Ratio, OR odds ratio, σ Standard error, * Significant at 5%, ** Significant at 10%.