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From Data to Insights: Analyzing the Gender-specific Nexus Between Obesity, Hypertension, and Diabetes Mellitus

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ABSTRACT

Global incidence of hypertension, obesity, and diabetes mellitus has been rising over years due to changed lifestyle and aging population. Recognizing gender as a biological variable is essential for deepening our understanding of disease mechanisms and their broader societal impact. To explore gender-specific variations in the correlations among hypertension, obesity, and diabetes mellitus. This study, conducted in January 2025, utilized secondary data from India's fifth National Family Health Survey (NFHS-5), carried out in collaboration with Demographic and Health Surveys (DHS). NFHS-5 collected data from 636,699 systematically selected households, covering 724,115 women and 101,839 men. Key variables analyzed included blood pressure, random blood glucose and body mass index alongside demographic data. The prevalence of diabetes mellitus ($p = 0.022$) and hypertension ($p = 0.002$) was significantly higher among males, and obesity was higher in females ($p = 0.001$). In women, a moderate positive correlation was noted between diabetes and obesity ($r = 0.641$, $p < 0.001$), obesity and hypertension ($r = 0.533$, $p = 0.001$) and hypertension and diabetes ($r = 0.487$, $p = 0.002$). Among men, while significant correlations were found between diabetes and obesity and between hypertension and obesity, association between hypertension and diabetes was not statistically significant ($p > 0.05$). Gender differences are evident in prevalence and in the interrelationship between diabetes, hypertension, and obesity. Notably, correlation between hypertension and diabetes mellitus was not significant in male subgroup, emphasizing the importance of gender- specific analyses in public health research.

Keywords: Hypertension; Obesity; Diabetes mellitus; Gender differences; Correlation between non-communicable diseases

INTRODUCTION

The global burden of hypertension, obesity, and diabetes mellitus (DM) has surged in recent years, largely driven by lifestyle changes, increasing urbanization, and aging populations.[1] Hypertension affects over 1.28 billion adults aged 30–79 globally, with a prevalence ranging from 30% to 45%.[2] Simultaneously, around 14% of the world population is affected by obesity, and 10.5% by DM.[3,4]

Evidence shows that in the United States, 40% of obese individuals suffer from hypertension and more than 70% of hypertensives are either overweight or obese.[5] Approximately 90% of people with type 2 DM are overweight or obese.[4] Moreover, hypertension coexists in about 60% to 80% of individuals with DM.[6] These associations are influenced by factors like gender, geographic setting, genetic predispositions, and lifestyle habits. However, most existing studies have limited sample sizes or geographic scope and often overlook gender-specific analyses.

Given the National Institute of Health (NIH) mandate to consider sex as a biological variable, this study aims to investigate how the relationships between these three major non- communicable diseases (NCD) differ between men and

women.[7]

MATERIALS AND METHODS

This cross-sectional study was conducted in January 2025 using secondary data extracted from the fifth round of the National Family Health Survey (NFHS-5), carried out between 2019 and 2021 by the Ministry of Health and Family Welfare, Government of India, in partnership with the Demographic and Health Surveys (DHS) Program.

NFHS-5 is one of the most comprehensive health surveys in India and employed computer-assisted personal interviewing (CAPI) across 19 regional languages. Interviewers were trained by the International Institute for Population Sciences and ICF International, Inc.

The sampling framework included a three-stage design in urban areas and a two-stage design in rural areas. Primary sampling units (PSUs) were chosen using probability proportional to size method referencing the census data. In rural areas, villages were designated as PSUs whereas in urban areas census wards were used. In urban settings, census enumeration blocks (CEBs) were randomly selected within each ward, followed by systematic random sampling of households within each CEB.[8]

A total of 636,699 households were selected. From these, 724,115 women aged 15–49 years (96.9% response rate) and 101,839 men aged 15–54 years (91.6% response rate) were interviewed. Responses from female and male participants were recorded in the IAIR7AFL and IAMR7AFL record files, respectively. Data variables used in the present study included systolic and diastolic blood pressure (BP), random blood glucose (RBG), glycated haemoglobin (HbA1c), height, weight, and demographic details.

Omron digital blood pressure monitors were used for recording blood pressure. Three readings were taken for each participant at five-minute intervals, and the average of the last two readings was used for analysis. Hypertension was defined as a mean systolic BP $\geq$130 mm Hg and/or diastolic BP $\geq$85 mm Hg, in accordance with standard guidelines.

Random blood glucose was assessed using capillary blood obtained via finger-prick, measured with the Accu-Chek Performa glucometer. HbA1c levels were measured where available. Diabetes mellitus was defined as RBG $\geq$200 mg/dL and/or HbA1c $\geq$6.5%, consistent with WHO diagnostic criteria.

Anthropometric measurements were obtained using standardized tools: height with a Seca 213 stadiometer and weight with a Seca 874 digital scale. BMI was determined by dividing a person's weight in kilograms by the square of his/her height in meters. Obesity was defined as a BMI $\geq$30 kg/m^2.[8] Statistical analysis was performed using Minitab 14 software.

The prevalence of hypertension, diabetes, and obesity was calculated for both sexes. Association between variables were assessed using Pearson's correlation coefficient (r). Values of r ranging from 0.00 to +1.00 were interpreted based on established correlation strength criteria.[9] A perfect (strongest possible) correlation, is represented by a value of +1 or −1. A very high degree of correlation falls within the range of +0.9 to < +1 or −0.9 to > −1. Likewise, a fairly high degree of correlation, moderate degree of correlation and low degree of correlation are represented by range from+0.75 to +0.9 or −0.75 to −0.9, +0.25 to +0.75 or −0.25 to −0.75, and between 0 to +0.25 or 0 to −0.25 respectively. A zero correlation implies no relationship between the variables either positive or negative. As this study involved the use of de-identified, publicly available secondary data, formal ethical approval was not required.

RESULTS

The data obtained from NFHS-5 individual record files IAIR7AFL and IAMR7AFL included information on women aged 15-49 years and men aged between 15-64 years respectively. The total number of observations in the individual record files for women and men was 724,115 and 101,839 respectively.

By statistical evaluation, a two-sample t-test [Table 1] revealed significant gender-based differences in the prevalence of these conditions. Males had a higher prevalence of DM (p- value= 0.022) and hypertension (p-value = 0.002), whereas significantly more females suffered from obesity (p-value = 0.001).

While evaluating the correlation between the variables in women, a comparatively robust correlation was found between DM and obesity ($r = 0.641$, $p < 0.001$), and a moderate degree of correlation was observed between obesity and hypertension ($r = 0.533$, $p = 0.001$) and hypertension & DM ($r = 0.487$, $p = 0.002$) [Table 2]. The findings re-emphasize the interconnected nature of metabolic disorders, where obesity plays a central role in both hypertension and glucose regulation.

As shown in Table 3, in the case of men, a positive moderate degree of correlation was observed among hypertension and obesity, obesity and DM variables pairs. However, the correlation between hypertension and DM was not statistically significant (p-value > 0.05).

DISCUSSION

Our findings indicate gender-specific trends in the prevalence of non-communicable diseases (NCDs). Hypertension and elevated blood glucose levels were more prevalent among males, while obesity was more common among females.

Globally, approximately one in three adults is hypertensive, with higher rates in men under 50 years of age. After 50, prevalence rises to nearly 49%, affecting both sexes equally.[10]

In the present study, 26.15% of men and 22.43% of women were found to be hypertensive. While many studies

Table 1: Comparison of the prevalence of diabetes, hypertension, and obesity between male and female population using two-sample t-tests *

Condition	Group	N	Mean (%)	Std Dev	SE Mean	p- value	Conclusion
Diabetes Mellitus	PF (Female)	37	13.85	4.33	0.71	0.022	The mean % in male population is significantly higher than in the female population
	PM (Male)	37	15.90	4.28	0.70		
Hypertension	PF (Female)	37	22.43	4.38	0.72	0.002	The mean % in male is significantly higher than the female.
	PM (Male)	37	26.15	5.95	0.98		
Obesity	PF (Female)	37	7.23	4.29	0.71	0.001	The mean % in female is significantly higher than the male.
	PM (Male)	37	4.60	2.46	0.41		

* PF (Female): percentage values for Female population; PM (Male): percentage values for Male population

Table 2: Correlation between hypertension, DM, and obesity in the female population

Variable pair	Correlation coefficient (r)	Significance (p-value)
PF Hypertension & PF DM	0.487	0.002
PF Hypertension & PF Obesity	0.533	0.001
PF DM & PF Obesity	0.641	0.000

* PF (Female): percentage values for Female population; DM: diabetes mellitus

Table 3: Correlation between hypertension, DM, and obesity in male population

Variable pair	Correlation coefficient (r)	Significance (p-value)
PM Hypertension & PM DM	0.277	0.097
PM Hypertension & PM Obesity	0.644	0.000
PM DM & PM Obesity	0.406	0.013

* PM (Male): percentage values for Male population: DM: diabetes mellitus

corroborate a higher male prevalence, others suggest a sharper increase in blood pressure among women from their third decade of life.[11] For instance, data from the United States (2015–2018) report hypertension in 51.7% of men and 42.8% of women aged ≥20 years.[12] Similarly, the French CONSTANCE cohort (n = 59,805) confirmed a greater prevalence in males.[13]

According to NFHS-5, diabetes mellitus affected 15.90% of males and 13.85% of females. Global studies suggest that despite a higher overall prevalence in men, women have to endure more years of diabetes mellitus.[14] In our study, obesity affected 7.23% of females and 4.60% of males. These results contrast with studies indicating higher obesity rates among men, despite a greater percentage of body fat in women—highlighting differences in obesity type and fat distribution.[15] Another study among older adults reported 49.9% with hypertension, 25.8% with diabetes, and 44.3% with obesity, with females bearing a disproportionately higher burden.[16] Leggio et al. noted that global obesity rates have nearly doubled over the past three decades, with BMI increasing by 0.4 kg/m^2 per decade in men and 0.5 kg/m^2 in women.[17]

This study explored the interrelationships among diabetes, hypertension, and obesity across genders. A moderate and significant correlation was found between most variable pairs in both sexes, except for hypertension and diabetes in males, which showed no significant association. These findings suggest that addressing obesity may simultaneously reduce the burden of hypertension and diabetes, especially in high-risk populations. Similar associations have been observed in Bangladesh, where overweight and obesity significantly increased hypertension risk.[18] Gupta et al. also reported a higher risk of hypertension in individuals with both general and abdominal obesity, even among those with normal BMI.[19] Therefore, public health initiatives should focus on preventing obesity to help reduce the increasing burden of NCDs. It is well established that higher degrees of obesity (grades II and III) are associated with increased all-cause mortality.[20]

Recent Indian health campaigns targeting a 10% reduction in dietary oil intake aim to combat obesity and related disorders. Obesity, particularly when it encompasses the build- up of visceral fat plays a significant role in the development of primary hypertension accounting for up to 75% of cases.[21] The underlying mechanisms include elevated pressure on the kidneys from fat, increased sodium retention, adipocyte-derived angiotensinogen, activation of the renin- angiotensin-aldosterone system (RAAS), and heightened sympathetic nervous activity.[21,22] Leptin-mediated stimulation of the melanocortin system is another proposed mechanism. Hypertension linked to obesity is also associated with baroreceptor dysfunction, insulin resistance, and obstructive sleep apnea. However, not all obese individuals exhibit increased cardiovascular risk—a phenomenon described as metabolically healthy obesity (MHO), which affects about 8.9% of obese adults in the U.S. who maintain good fitness levels.[22,23]

Our results also revealed a moderate positive association between obesity and DM in both sexes. It is estimated that 30–53% of new diabetes cases in the U.S. are attributable to this condition, particularly in non-Hispanic White women.[24] A meta-analysis by Babu GR et al. further confirmed a statistically significant link between obesity, hypertension, and type 2 diabetes mellitus in India.[25] Obesity is known to impair glucose metabolism, increase insulin levels, and reduce insulin sensitivity, promoting metabolic syndrome.

Interestingly, the present study noted a strong correlation between hypertension and DM among women but not men. Although these conditions have distinct pathophysiologies, however, they share lifestyle-related risk factors. Findings from the Framingham heart study indicate a high co-occurrence of diabetes in hypertensive patients.[26] High insulin levels can activate the sympathetic nervous system which in turn contributes to elevated blood pressure. This mechanism is supported by evidence indicating that reductions in insulin level lead to decreases in both sympathetic activity and blood pressure. Insulin also causes vasoconstriction and promotes renal sodium retention, both contributing to hypertension. Additionally, adipocyte-released endocannabinoids such as anandamide and 2-arachidonoylglycerol play a role in metabolic regulation and blood pressure control.[26,27]

India's integrated healthcare programs, including Ayushman Bharat, the Ayushman Bharat Digital Mission (ABDM), and Health and Wellness centers, aim to improve early detection and intervention for obesity, DM, and hypertension through better access to real-time data and trained healthcare workers.[28–30] Targeted health education campaigns focused on high- risk groups can effectively mitigate the concurrent rise of these interlinked NCDs.

Strengths of the Study

Open Government Data (OGD) ensures the systematic collection of data along with reliability, consistency, accessibility, transparency, and capability to promote evidence-based conclusions. It supports informed decision-making since comprehensive datasets encompass a broad geographical and demographic scope, and the research was conducted on a large population using standardized data collection tools.

Limitations

As a cross-sectional analysis, this study cannot determine causality. Physical activity levels were not assessed, which may influence metabolic outcomes. Additionally, the age range was limited to 15–49 years for women and 15–54 years for men.

CONCLUSION

The analysis of NFHS-5 data reveals gender-based differences not only in the prevalence but also in the interrelationship of obesity, DM, and hypertension. While significant correlations were found among all three variables in females, the association between hypertension and DM was not statistically significant in males. Further, more such studies are warranted especially in geriatric population considering their lengthier lifespan and the increasing availability of personalized medicine. Supplementary research is also needed to explore the underlying mechanisms and temporal relationships among these conditions.

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Conflicts of Interest

There were no conflicts of interest.

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