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Original Research Article

# The association between obesity, dyslipidaemia, and pre-diabetes: Insights from current evidence

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## Abstract

**Background:** This study examines the relationship between obesity, dyslipidemia, and pre-diabetes in a large Indian population. It also assesses the potential of triglycerides (TG) as an early biomarker for pre-diabetes and looks at gender-based differences, especially in younger males.

**Materials and Methods:** Between October 2022 and July 2023, a cross-sectional, quantitative investigation was carried out at a clinical diagnostic centre in India. Based on glyceated haemoglobin (HbA1c) levels (5.7%–6.4%), 404 people with pre-diabetes and 336 non-diabetic controls were identified among 5,687 screened adults (≥18 years). Chi-square and independent t-tests were used to examine the demographic, body mass index (BMI), waist circumference (WC), and lipid profile data.

**Results:** The prevalence of pre-diabetes was 7.1%. A substantial relationship was found between increased BMI and pre-diabetes, with the majority of those affected being overweight or obese. Central obesity, as measured by waist circumference, was also strongly associated with pre-diabetes. Although a gender-wise subgroup analysis revealed a higher incidence of pre-diabetes among younger males (<40 years), the difference was not statistically significant ($\chi^2 = 0.976$, $p = 0.32$). Dyslipidaemia, namely higher low-density lipoprotein cholesterol (LDL-C), was strongly associated with pre-diabetes ($p = 0.0174$). TG levels were greater in the pre-diabetic group, although the association was not statistically significant ($p = 0.103$).

**Conclusion:** Obesity and increased LDL-C levels emerge as important predictors of pre-diabetes. Early detection and focused therapies are critical, especially in people with obesity and lipid problems. Additional large-scale investigations are needed to validate these findings and investigate the function of TG in pre-diabetes progression.

**Keywords:** Obesity, Dyslipidemia, Pre-diabetes, Metabolic syndrome, Insulin resistance

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## 1. Introduction

Pre-diabetes is a metabolic disorder defined by high blood glucose levels that do not match the diagnostic criteria for diabetes. It is an important intermediate stage in the transition of type 2 diabetes mellitus (T2DM) and is linked to an increased likelihood of developing cardiovascular disease,[1] nephropathy,[2] and neuropathy.[3] Although pre-diabetes is reversible, many individuals advance to T2DM due to delayed diagnosis and insufficient intervention.[4] Early detection of at-risk persons and prompt preventive treatments can dramatically lower the prevalence of diabetes and its consequences.

Pre-diabetes is becoming more common worldwide, with the International Diabetes Federation claiming that roughly 540 million adults, or 10.6% of those aged 20 to 79, are affected.[5] In India, T2DM has become a major public health concern, affecting about 14% of adults (77 million people).[6] Factors such as urbanization, sedentary behaviour, shifts toward high-caloric diets, and escalating obesity rates have intensified metabolic dysfunction, contributing to an increasing prevalence of pre-diabetes and T2DM among younger individuals.[7] However, India-specific data on the influence of metabolic and demographic factors on pre-diabetes remain limited, restricting the development of targeted interventions.[8]

Obesity and dyslipidemia are significant contributors to insulin resistance and metabolic disturbances.[9] Central obesity, assessed through body mass index (BMI) and waist circumference (WC), has been strongly correlated with

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impaired glucose regulation. Dyslipidaemia, defined by high triglyceride levels and low HDL, contributes to pre-diabetes by worsening insulin resistance and β-cell dysfunction. Although global studies have extensively explored these associations, limited research in India has investigated their combined impact on pre-diabetes prevalence, particularly among younger adults.[10]

Emerging research indicates gender-related variations in pre-diabetes susceptibility, with younger males appearing more prone to the condition than females.[11] While the precise mechanisms underlying this disparity are not fully understood, hormonal, behavioural, and metabolic factors are believed to contribute. However, there remains a scarcity of Indian data examining gender-specific risk factors, underscoring the need for further research to develop targeted screening and prevention strategies based on age and gender.

In view of these shortcomings, the purpose of this study is to assess the prevalence of pre-diabetes in a large Indian cohort and investigate its correlations with obesity, dyslipidaemia, and demographic characteristics. Specifically, the study investigates:

1. The correlation between BMI and pre-diabetes, emphasizing the role of obesity.
2. Gender differences in pre-diabetes prevalence, particularly in younger males.
3. The link between dyslipidemia, triglyceride levels, and pre-diabetes, assessing whether TG could serve as an early biomarker.

By identifying key metabolic predictors, this research seeks to provide clinically relevant insights for early detection and targeted preventive strategies, ultimately contributing to the reduction of pre-diabetes progression to T2DM in high-risk populations.

## 2. Materials and Methods

### *2.1. Study design and setting*

This observational cross-sectional study examined associations among demographic, anthropometric, and lipid profile variables with pre-diabetes prevalence. The study was conducted at the Wellness Assessment Centre, Aditya Birla Memorial Hospital, Pune**,** over a 10-month period (October 2022–July 2023)**.**

### *2.2. Study population and sample selection*

Individuals aged ≥18 years attending the diagnostic facility for routine health check-ups and metabolic screenings were included. A purposive sampling method was employed to select individuals meeting diagnostic criteria for pre-diabetes, with non-diabetic controls included for comparative analysis.

A total of 5,687 individuals were screened, of whom 740 had available HbA1c reports**.** Based on HbA1c levels**,** 404 (54.6%) were classified as pre-diabetic (HbA1c 5.7%–6.4%) as per the diagnostic criteria of the American Diabetes Association (ADA),[12] while 336 (45.4%) were categorized as non-diabetic (HbA1c <5.7%).

### *2.3. Inclusion and exclusion criteria*

The study recruited participants aged 18 and up with fasting glucose levels ranging from 100 to 125 mg/dL or HbA1c between 5.7% and 6.4%. Individuals having a confirmed diagnosis of diabetes mellitus, severe cardiovascular or chronic kidney illness, pregnancy, or taking drugs that affect glucose metabolism were excluded.

### *2.4. Data collection*

Data were gathered using a structured tool that captured demographic information, anthropometric measurements, and laboratory parameters.

### *2.5. Anthropometric measurements*

Height and weight were recorded using calibrated instruments, and BMI was computed as weight (kg) divided by height squared (m²). BMI classifications followed National Health Service guidelines: normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30 kg/m²).[13] WC was measured using a non-stretchable measuring tape at the midpoint between the lower rib and iliac crest, with classification based on WHO (2008)[14] standards (<102 cm for men, <88 cm for women).

### *2.6. Lipid profile and blood sample analysis*

Venous blood samples were obtained analysed for fasting glucose, HbA1c, total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides (TG). Dyslipidemia was defined as HDL levels below 40 mg/dL, TG levels of 150 mg/dL or higher, and LDL levels of 130 mg/dL or greater.

### *2.7. Statistical analysis*

Descriptive statistics, including mean, standard deviation, frequencies, and percentages, were used to summarize demographic, anthropometric, and laboratory data. Comparative analyses were conducted using chi-square tests for categorical variables and independent t-tests for continuous variables. A p-value of <0.05 was considered statistically significant.

## 3. Comorbidities and Dietary Assessment

Participant's self-reported medical conditions, including hypertension, hypothyroidism, ischemic heart disease (IHD), rheumatoid arthritis (RA), and benign prostatic hyperplasia. Dietary habits were categorized as either vegetarian or mixed diet.

## 4. Results

### *4.1. Prevalence of pre-diabetes and demographic characteristics*

Among the 5,687 screened individuals, 740 participants had available HbA1c reports. Based on HbA1c levels, 404 (54.6%) were classified as pre-diabetic, and 336 (45.4%) as non-diabetic. The prevalence of pre-diabetes in the study cohort was 7.1%.

The mean age of pre-diabetic individuals was significantly higher (47.41 ± 9.2 years) than that of non-diabetic individuals (39.20 ± 8.4 years, $p < 0.001$) **Table 1**. A significant association was observed between age and pre-diabetes prevalence ($\chi^2 = 76.44$, $p < 0.00001$), with the highest proportions of pre-diabetic individuals in the 40–55 years (42.1%) and >55 years (26.5%) age groups.

Gender distribution was comparable between groups, with males comprising 59.9% of the pre-diabetic group and 64.0% of the non-diabetics. However, the difference was not statistically significant ($\chi^2 = 1.2974$, $p = 0.2547$) **Table 1**

In individuals under 40 years of age, a higher proportion of males (67.7%) were pre-diabetic compared to females (32.3%). This difference was not statistically significant ($\chi^2 = 0.976$, $p = 0.32$) (**Figure 1**).

**Table 1:** Anthropometric characteristics of study participants

| **Variable** | **Pre-diabetic (n = 404)** | **Non-diabetic (n = 336)** | **Grand total (n= 740)** | **Statistical analysis** |
|---|---|---|---|---|
| Age Group (Years) | | | | |
| <25 | 2 (0.5%) | 7 (2.1%) | 9 (1.2%) | $\chi^2 = 76.44$, p-value< 0.00001 |
| 25–39 | 125 (30.9%) | 184 (54.8%) | 309 (41.8%) | |
| 40–55 | 170 (42.1%) | 126 (37.5%) | 296 (40.0 %) | |
| >55 | 107 (26.5%) | 19 (5.7%) | 126 (17.0%) | |
| Gender | | | | |
| Female | 162 (40.1%) | 121 (36.0%) | 283 (38.2) | $\chi^2 = 1.2974$, *p*-value= 0.2547 |
| Male | 242 (59.9%) | 215 (64.0%) | 457 (61.8%) | |

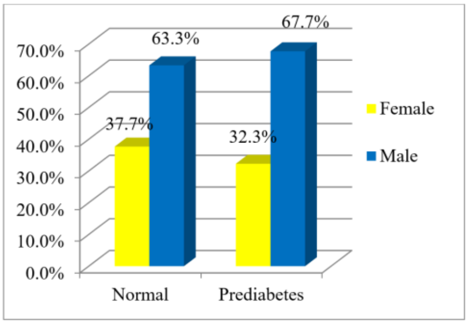


**Figure 1:** Distribution of pre-diabetes status by gender in individuals under 40 years

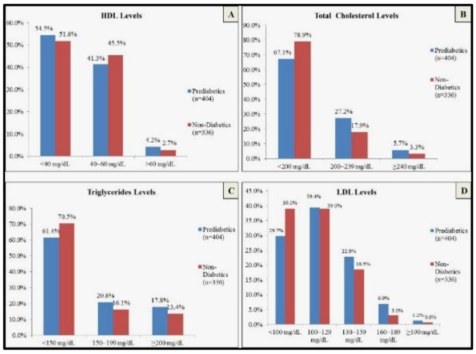


**Figure 2:** Comparative lipid profile distribution among pre-diabetic and non-diabetic individuals

### *4.2. Anthropometric characteristics and pre-diabetes*

A strong association was observed between BMI and pre-diabetes prevalence ($\chi^2 = 47.47$, $p < 0.00001$). The majority of pre-diabetic participants were overweight (49.5%) or obese (29.2%), with significantly fewer individuals classified as underweight (0.2%) or severely obese (0.7%)(**Table 2**). The mean BMI was significantly higher in the pre-diabetic group (28.12 ± 3.5 kg/m²) compared to non-diabetic individuals (26.12 ± 3.2 kg/m², $p < 0.0001$).

Central adiposity, measured by WC, was significantly associated with pre-diabetes ($\chi^2 = 40.3087$, $p < 0.00001$). A higher proportion of pre-diabetic individuals (14.4%) had a WC >102 cm compared to only 5.4% in the non-diabetic group (**Table 2**).

### *4.3. Comorbidities and dietary patterns*

The prevalence of comorbidities was significantly higher in the pre-diabetic group (34.4%) than in the non-diabetic group (9.8%). The most common conditions included Hypertension (19.1%), Hypothyroidism (5.45%) and Hypertension with other conditions (3.7%). Other illnesses (5.7%) such as benign prostatic hyperplasia, rheumatoid arthritis, and IHD.

**Table 2**: Anthropometric characteristics of study participants

| Variable | Pre-diabetic (n = 404) | Non-diabetic (n = 336) | Grand total (n= 740) | Statistical analysis |
|---|---|---|---|---|
| BMI category (kg/m²) | | | | |
| Underweight (<18.5) | 1 (0.2%) | 4 (1.2%) | 5 (0.7%) | $\chi^2$ = 47.47 (p-value <0.00001); t-test statistic = 6.7202 (p-value <0.0001) |
| Healthy (18.5–24.9) | 82 (20.3%) | 131 (39.0%) | 213 (28.8%) | |
| Overweight (25–29.9) | 200 (49.5%) | 156 (46.4%) | 356 (48.1%) | |
| Obese (30–39.9) | 118 (29.2%) | 45 (13.4%) | 163 (22.0%) | |
| Severe Obesity (>40) | 3 (0.7%) | 0 (0%) | 3 (0.4%) | |
| Waist circumference (cm) | | | | |
| <88 | 128 (31.7%) | 178 (53.0%) | 306 (41.4%) | $\chi^2$ = 40.3087, p-value <0.00001 |
| 88–102 | 218 (54.0%) | 140 (41.7%) | 358 (48.4%) | |
| >102 | 58 (14.4%) | 18 (5.4%) | 76 (10.3%) | |

Conversely, 76.8% of participants reported no comorbidities, with a higher proportion in the non-diabetic group (90.2%). Regarding dietary habits, 31.1% of participants followed a vegetarian diet, while the majority (68.5%) consumed a mixed diet. Compared to the pre-diabetic group (66.1%), the non-diabetic group had a higher prevalence of mixed dietary patterns (71.4%).

**Table 3:** Association between dyslipidemia and pre-diabetes

| | Pre-diabetic (n=404) | Non-diabetic (n=336) | Grand Total (n= 740) | Chi- sqaure | p -value |
|---|---|---|---|---|---|
| Dyslipidemia | 155 (38.4%) | 101 (30.1) | 256 (34.6%) | 5.65 | 0.0174 |
| Non- Dyslipidemia | 249 (61.6 | 235 (69.9%) | 484 (65.4) | | |

*4.4. Association between dyslipidemia and pre-diabetes*

A significant association was observed between dyslipidemia and pre-diabetes ($p = 0.0174$, $\chi^2 = 5.65$), with a higher proportion of pre-diabetic individuals exhibiting dyslipidemia (38.4%) compared to non-diabetic individuals (30.1%) (**Table 3**).

**Figure 2** illustrates the comparative distribution of lipid profile parameters. The majority of individuals in both groups had HDL levels <40 mg/dL or within the 40–60 mg/dL range (Panel A). TC levels below 200 mg/dL were predominant in both groups (Panel B). TG levels <150 mg/dL were most common across both groups (Panel C). Low-density lipoprotein (LDL) levels between 100–129 mg/dL were more prevalent in pre-diabetic individuals than in non-diabetics (Panel D).

*4.5. Triglyceride levels and pre-diabetes prevalence*

While a trend was observed for higher TG levels (≥150 mg/dL) in the pre-diabetic group, the association was not statistically significant ($p = 0.103$). Individuals with TG levels of 150–249 mg/dL and ≥250 mg/dL were more commonly represented in the pre-diabetic category, but statistical significance was not achieved.

## 5. Discussion

This study underscores the association between dyslipidemia, obesity, and pre-diabetes**,** highlighting the metabolic risks faced by individuals with these conditions. The 7.1% prevalence of pre-diabetes observed in this study suggests a significant proportion of individuals are at risk of progressing to type 2 diabetes. These findings reinforce the need for early screening and targeted interventions**,** particularly in populations with metabolic dysfunction.

*5.1. Obesity and pre-diabetes risk*

A significant association between BMI and pre-diabetes was observed, with a higher proportion of pre-diabetic individuals being overweight (49.5%) or obese (29.2%)**.** These findings align with existing literature indicating that central obesity is a key contributor to insulin resistance and metabolic disorder.[15] Given the rising prevalence of obesity in India due to urbanization, sedentary lifestyles, and dietary transitions**,** targeted weight management programs could play a crucial role in reducing the burden of pre-diabetes and type 2 diabetes.[16]

Contrary to the initial hypothesis that younger males would have a higher risk of pre-diabetes, no statistically significant gender difference was observed. While a higher proportion of young males were diagnosed with pre-diabetes, other factors, such as lifestyle behaviours, hormonal influences, and genetic predisposition, may have a more substantial role in disease progression.[17] These findings suggest the need for further research exploring gender-specific risk factors for pre-diabetes in the Indian population**.**

### *5.2. Dyslipidemia and its prognostic role in pre-diabetes*

The study also highlights the association between dyslipidemia and pre-diabetes, with elevated LDL-C levels being significantly correlated with glycaemic disturbances even after adjusting for age and BMI.[18] This finding is in agreement with previous research suggesting that LDL-C may serve as an early marker of dysglycemia progression.[19] Although TG levels were elevated in pre-diabetic individuals**,** the association was not statistically significant, warranting further investigation with larger sample sizes as well as prospective designs.[20]

The role of dyslipidemia in glycaemic dysregulation has important clinical implications,[21] particularly for screening strategies. Given that 38.4% of pre-diabetic individuals exhibited dyslipidemia,[22] routine lipid profile assessments in individuals at risk for metabolic disorders could aid in early detection and preventive interventions**.**

The findings of this study hold significant importance in the Indian context, where rapid economic and lifestyle transitions have contributed to a rising burden of obesity, dyslipidemia, and diabetes.[23] The strong association between BMI, LDL-C, and pre-diabetes suggests that integrating lipid profile screening into routine pre-diabetes assessments[24] could enhance early detection efforts. Moreover, targeted public health programs promoting lifestyle modifications including nutritional counselling and physical activity interventions are crucial in mitigating the progression of pre-diabetes to T2DM.

This study's cross-sectional design precludes causal inferences, making it difficult to determine whether dyslipidemia contributes directly to pre-diabetes or represents a common metabolic pathway. Additionally, while adjustments were made for age and BMI**,** other potential confounders, such as dietary habits, physical activity levels, and socioeconomic status, were not accounted for, which may have influenced the observed associations. Future longitudinal studies with larger, more diverse populations are necessary to establish causal relationships and further explore the mechanisms linking dyslipidemia, obesity, and pre-diabetes progression**.**

## 6. Conclusion

Prediabetes is closely linked to dyslipidemia, particularly LDL-C, highlighting the importance of lipid monitoring in at-risk groups. This study underscores the need for further research on triglycerides as a potential early biomarker and gender-specific variations in prediabetes risk. Future studies should include larger, more diverse populations and consider lifestyle and genetic factors to better understand the interplay between dyslipidemia, obesity, and prediabetes. Routine screening and early interventions are crucial in preventing type 2 diabetes and reducing its healthcare burden.

## 7. Ethical Considerations

The study received ethical approval from the Institutional Ethics Committee of Aditya Birla Memorial Hospital on December 23, 2022 with reference no. ABMH/EC/07/22. Written informed consent was obtained from all participants, and confidentiality of personal data was strictly maintained in accordance with institutional data protection policies.

## 8. Source of Funding

None.

## 9. Conflict of Interest

None.

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