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RESEARCH ARTICLE

Exploring the silent epidemic: investigating the hidden burden of normal weight obesity in type 2 Diabetes Mellitus in India - a cross-sectional study

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Abstract

Objective This study aimed to determine the prevalence of Normal Weight Obesity (NWO) and evaluate its association with cardiometabolic risk factors among patients with Type 2 Diabetes Mellitus (T2DM) in Gujarat, India.

Methods This cross-sectional study included 432 adults with T2DM attending a Non-Communicable Disease clinic. Anthropometric measurements, body composition analysis using bioelectrical impedance, and clinical parameters were assessed. NWO was defined as normal BMI (18.5–24.9 kg/m^2) with high body fat percentage (≥ 25% for men, ≥ 32% for women). Cardiometabolic risk factors, including blood glucose, blood pressure, and lipid profile, were evaluated. Statistical analyses included descriptive statistics, correlation analysis, and multivariate logistic regression.

Results The prevalence of NWO was 33% among the study population. Significant discordance was observed between BMI classification and body fat percentage, with 91% of males and 51.8% of females with normal BMI having obese levels of body fat. Individuals with NWO demonstrated higher cardiometabolic risk profiles compared to non-obese counterparts, including elevated random blood glucose levels (290 ± 110 mg/dL vs. 180 ± 80 mg/dL, $p < 0.001$), higher systolic (148.8 ± 25.4 mmHg vs. 122.5 ± 19.5 mmHg, $p < 0.001$) and diastolic blood pressure (98.5 ± 55.6 mmHg vs. 78.6 ± 36.6 mmHg, $p < 0.001$), and increased prevalence of hypertension (61% vs. 15%, $p < 0.001$). A moderate positive correlation was found between body fat percentage and random blood sugar levels ($r = 0.504$, $p < 0.001$). Multivariate analysis identified age, duration of diabetes, blood glucose levels, and blood pressure as independent factors associated with NWO.

Conclusion The high prevalence of NWO and its significant association with adverse cardiometabolic risk factors in T2DM patients underscores the limitations of using BMI alone for obesity assessment. These findings highlight the need for incorporating body composition analysis in routine clinical practice to improve risk stratification and management strategies in T2DM patients, particularly in the Asian Indian population.

Keywords Type-2 diabetes, Obesity, Normal weight obesity, BMI, Body fat percentage

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Introduction

Type 2 Diabetes Mellitus (T_2DM) is a metabolic disorder characterized by insulin resistance and impaired glucose regulation. It is a global health concern, with an increasing prevalence worldwide. Traditionally, obesity has been considered a major risk factor for the development of T_2DM. However, there is growing recognition of a distinct phenotype known as "Normal Weight Obesity" (NWO) or "metabolically obese, normal weight" (MONW) individuals, who exhibit normal body weight but have a disproportionately higher amount of body fat and a metabolic profile similar to that of obese individuals.

The pandemic Diabetes Mellitus is a growing concern, especially in low-income and middle-income countries, which contribute to nearly 75% of the disease burden [1]. Indian patients with T_2DM constitute 1 in 6 adults with T_2DM globally, with marked differences in prevalence across the states [2, 3]. The younger age of onset and faster progression from pre-diabetes to diabetes among Indians increases the disease burden [4]. With a 10.4% age-adjusted comparative prevalence of T_2DM, India accounted for the highest mortality in the Southeast Asian region, with 1,010,262 deaths due to T_2DM and its complications in 2019 [2, 5]. The age-standardized disability-adjusted life year rate for T_2DM increased in India by 39.6% {95% uncertainty interval (UI) 32.1–46.7%} from 1990 to 2016 [5]. Notably, of patients who died due to T_2DM in India in 2016, 42.6% (95% UI 41.6–43.9%) were younger than 70 years. Nearly half (47.3%) of the patients diagnosed with diabetes had not been diagnosed previously [6]. Although the prevalence of T_2DM remains higher in the economically advanced states of India, it has surged rapidly in the less-developed states. Rapid epidemiological transition with an aging population, compounded by modifiable risk factors such as an unhealthy diet, sedentary lifestyle, tobacco use, and obesity, is an important driver of the T_2DM epidemic in India. Among these, obesity is one of the most pivotal and dominant risk factors; the prevalence of overweight in India markedly increased from 9.0% in 1990 to 20.4% in 2016 [5].

The implications of NWO in individuals with T_2DM are substantial. Despite having a normal weight, NWO individuals experience a higher cardiovascular risk compared to their metabolically healthy counterparts with similar BMI. They are more likely to develop hypertension, dyslipidemia, and other metabolic complications associated with T_2DM. Moreover, NWO individuals may exhibit a suboptimal response to standard diabetes therapies, leading to poorer glycaemic control and increased risk of diabetic complications. Therefore, recognizing and addressing NWO in individuals with T_2DM is crucial for optimizing their treatment and reducing long-term health risks.

Understanding the underlying factors contributing to NWO in T_2DM is essential for effective management and prevention strategies. Factors such as genetic predisposition, hormonal imbalances, and lifestyle factors, including sedentary behavior and unhealthy dietary patterns, may contribute to the development of NWO.

So, this present study aimed to find the prevalence of Normal weight obesity and to evaluate the body fat (BF) % across various BMI categories in patients with T_2DM.

Methodology

Study Design and setting

This cross-sectional study was conducted among patients with Type 2 Diabetes Mellitus (T2DM) attending the Non-Communicable Disease (NCD) clinic at a tertiary care hospital in Gujarat, India, from March to April 2023.

Study Population and Sampling

The sample size was calculated using the formula: ZP(1-P)/d2, where Z is the Z statistic for a 95% confidence level (3.84), P is the expected prevalence of Normal Weight Obesity among T2DM patients (74%), and d is the precision level (4%). This yielded a sample size of 424. [7] All diabetic patients visiting the NCD clinic during the study period were included in the study (Fig. 1).

Eligibility criteria

Patients aged at least 18 years, attending follow-up, known to have diabetes irrespective of the disease duration or diabetic treatment, who came to the NCD clinic and consented to the study were included. Patients who did not consent to participate in the study, and those with known risks that modulated the results of Sarcopenia assessment, such as critically ill patients, pregnant women, those with a history of stroke, carpal tunnel syndrome, severe hip or knee osteoarthritis, dysarthria or dysphasia, hearing difficulties, use of walking aid, physical disabilities that affect hand-grip and/or walking and use of electronic implants such as a pacemaker, were excluded [8].

Data collection and data variables

The data collection process was conducted at the NCD clinic by trained research assistants. After obtaining written informed consent, participants completed a structured questionnaire capturing demographic information including age, sex, duration of diabetes, and current antidiabetic medication use. Anthropometric measurements were performed using standardized protocols. Weight was measured to the nearest 0.1 kg using a calibrated digital scale, with participants in light clothing and without shoes. Height was recorded to the nearest 0.1 cm using a

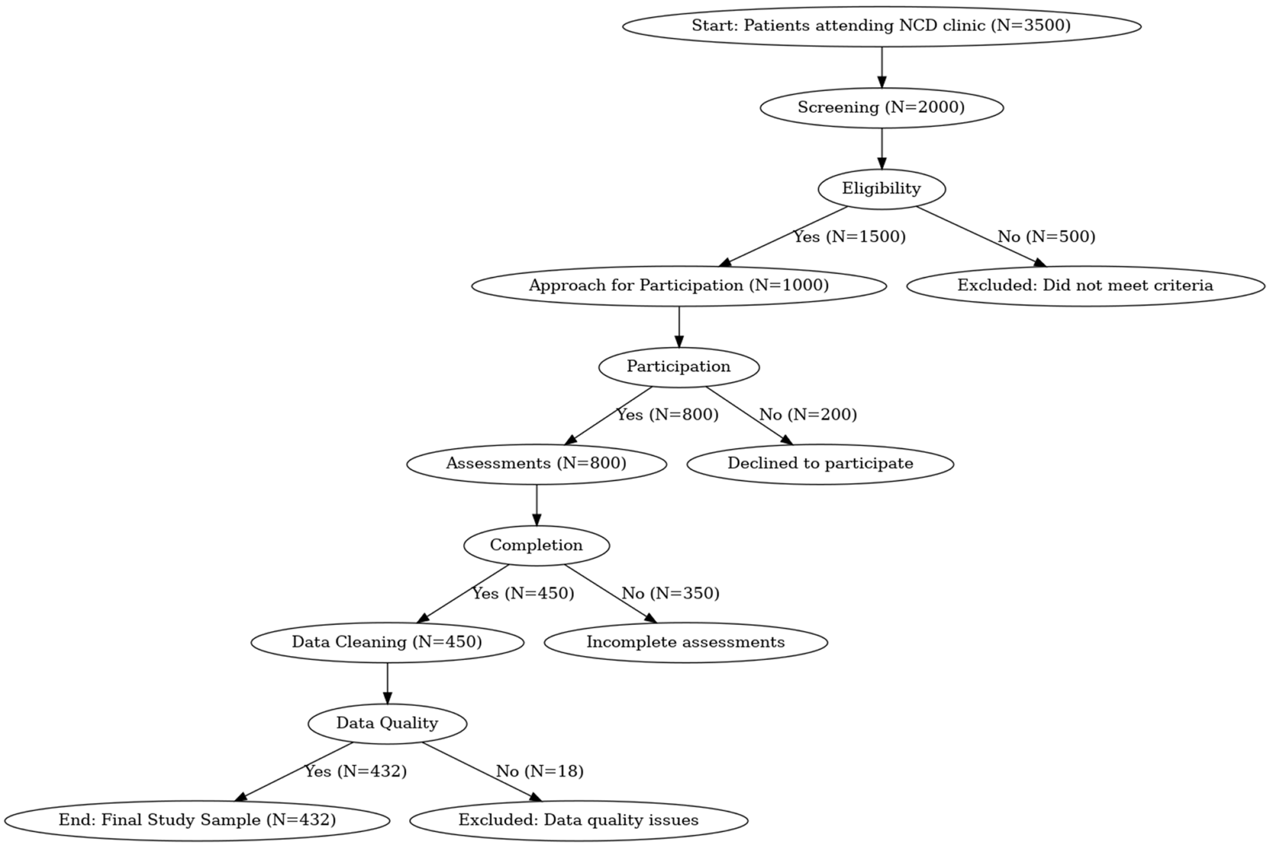

Fig. 1 Flow chart shows the Participant's recruitment process

stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared. Waist circumference was measured at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest, while hip circumference was measured around the widest portion of the buttocks, both to the nearest 0.1 cm. Body composition analysis was conducted using the Omron HBF-702T Bio-impedance Analyzer, which provided measurements of total body fat percentage and visceral fat level. Clinical parameters were also assessed, with random blood sugar (RBS) measured via a finger-prick blood sample using a glucometer, and blood pressure recorded using a calibrated digital sphygmomanometer after 5 min of rest, with the average of two readings being recorded. All data were immediately documented on standardized forms and checked for completeness and accuracy before the participant left the clinic. Asian cut-off values for defining obesity were used in this study. Table 1 summarizes the operational definitions of the parameters used.

Ethical consideration

Written informed consent was taken from the participants in their vernacular language. All the participants were given instructions about the study before the start of the study. Good clinical care was performed. Ethical approval from the institute (Shri M P Shah Government Medical College, Jamnagar, Gujarat, India) was obtained before the start of the study. (REF:07/01/2023).

Statistical analysis

Data analysis was performed using SPSS version 26. Descriptive statistics were employed to summarize the study population characteristics, with categorical variables presented as frequency distributions and proportions, and continuous variables as mean ± standard deviation (SD). To explore relationships between variables, Pearson correlation coefficients (r) were calculated. Comparisons of means across different obesity strata were conducted using one-way ANOVA, while chi-square tests were utilized for comparing proportions. To identify factors associated with Normal Weight Obesity (NWO), multivariate logistic regression analysis was performed. The strength of associations was expressed as adjusted odds ratios with 95% confidence intervals. Subgroup analyses stratified by gender were conducted for anthropometric variables and bio-impedance indices to understand the effect of gender on these parameters. Throughout the analysis, a p-value < 0.05 was considered statistically significant. To ensure data quality, all analyses were independently verified by two researchers, and

Table 1 Operational definitions

Variables	Classification
Normal Weight Obesity (NWO)	BMI 18.5–24.9 kg/m^2 with high BF% (≥ 25% for men, ≥ 32% for women)
Non-obese (NO)	BMI 18.5–24.9 kg/m^2 with normal BF%
Obese (OB)	BMI ≥ 25 kg/m^2
Body fat percentage. % [9]	
Male	Essential fat: 2—5
	Athletes: 6—13
	Fitness: 14—17
	Acceptable: 18—24
	Obese: ≥25
Female	Essential fat: 10—13
	Athletes: 14—20
	Fitness: 21—24
	Acceptable: 25–31
	Obese: ≥32
BMI, Kg/m^2 [10, 11]	
	Underweight < 18.5
	Normal:18.5–22.9
	Obverweight > 23
	At Risk:23-24.9
	Obese: ≥25
	Class-1:25-29.9
	Class-2:>30

Table 2 Socio-demographic characteristics of patients

Variables	Frequency (%)
Age, in years	
30–39	56 (13.0)
40–49	64 (15.0)
50–59	76 (17.5)
60 and above	236 (54.5)
Gender	
Male	238 (55.0)
Female	194 (45.0)

any discrepancies were resolved through discussion and consensus.

Results

About 236 (54.5%) patients were above 60 years and the mean age of patients was 55.9±14 years. 238 (55%) subjects were males and 194(45%) were female (Table 2).

Table 3 presents a comprehensive overview of the anthropometric, bio-impedance, and clinical characteristics of the study population, stratified by gender and presented as a total. The study included 432 participants, with 238 males and 194 females. The mean BMI for the entire population was 24.0±4.1 kg/m^2, indicating an overall normal weight status, with no significant difference between males and females (p=0.621). However, the body fat percentage showed a significant difference between genders (p<0.001), with males having a higher mean (38.9±11.0%) compared to females (34.0±11.05%). This discrepancy between BMI and body fat percentage highlights the potential limitation of using BMI alone to assess obesity. The distribution of BMI categories also differed significantly between genders (p=0.002), with a higher proportion of females in the normal BMI category (56.7% vs. 40.0% in males) and a higher proportion of males in the overweight category (27.7% vs. 9.2% in females). Regarding diabetes-related measures, males had significantly higher random blood sugar levels compared to females (304.0±127.7 mg/dL vs. 217.0±127.0 mg/dL, p<0.001). The duration of diabetes and ongoing anti-diabetic therapy also showed significant differences between genders (p=0.037 and p<0.001 respectively), with a higher proportion of females on anti-diabetic therapy (94.3% vs. 81.9% in males). These findings underscore the importance of gender-specific considerations in the assessment and management of obesity and diabetes.

The sex-stratified analysis revealed cases of NWO (BMI within the normal range and a high BF %) as shown in Table 4.

Table 4 provides a detailed comparison of body fat percentage across different BMI categories, separately for males and females. This table reveals a striking disparity between BMI classification and body fat percentage, particularly evident in the normal BMI category. Among males with a normal BMI (n=96), a staggering 91% had obese levels of body fat (≥25%). Similarly, for females with a normal BMI (n=110), 51.8% had obese levels of body fat (≥32%). This phenomenon, known as normal weight obesity, was prevalent across all BMI categories.

Table 3 Anthropometric, Bio-impedance, and clinical characteristics of the Study Population

Variables	Males (*N*=238)	Females (*N*=194)	Total (*N*=432)	*p*-value
Anthropometric measures				
BMI (kg/m^2)	23.9±4.17	24.1±4.0	24.0±4.1	0.621
Waist circumference (cm)	100.0±12.0	98.9±12.1	98.0±12.0	0.345
Hip circumference (cm)	105.9±13.0	110.5±12.0	107.0±12.9	0.001*
Bio-impedance measures				
Body fat percentage (%)	38.9±11.0	34.0±11.05	30.0±11.0	<0.001*
Visceral fat percentage (%)	9.6±5.85	8.1±5.9	9.1±5.9	0.008*
BMI category				0.002*
Underweight	11 (4.6)	2 (1.0)	13 (3.0)	
Normal	96 (40.0)	110 (56.7)	206 (47.6)	
Overweight	66 (27.7)	18 (9.2)	84 (19.4)	
Obese	65 (27.3)	64 (32.9)	129 (30.0)	
Diabetes-related measures				
Random blood sugar level	304.0±127.7	217.0±127.0	203.0±127.0	<0.001*
Duration of diabetes (%)				0.037*
<5 years	50 (21.0)	39 (20.1)	89 (20.6)	
5–10 years	127 (53.4)	123 (63.4)	250 (57.8)	
>10 years	61 (25.6)	32 (16.5)	93 (21.5)	
On-going anti-diabetic therapy n (%)				<0.001*
Yes	195 (81.9)	183 (94.3)	378 (87.5)	
No	43 (18.0)	11 (5.7)	54 (12.5)	

BMI – Body Mass Index, $p<0.05$*-significant, $p<0.001$-highly significant

Even in the underweight BMI category, all males (100%) and half of the females (50%) had obese levels of body fat. In the overweight BMI category, 91% of males and 27.7% of females had obese body fat levels. These findings were statistically significant for both males and females ($p<0.001$), indicating a consistent pattern of discordance between BMI and body fat percentage across genders. This discrepancy highlights the potential inadequacy of BMI alone in identifying adiposity and associated health risks, especially in this diabetic population. It underscores the importance of incorporating body composition measurements, such as body fat percentage, in clinical assessments to more accurately identify individuals at risk of obesity-related complications, even among those with seemingly normal or low BMI.

Correlation analysis between BMI and BF%.

The correlation between BMI and BF% demonstrates a weak positive relationship in the study. (r=0.203, P=0.043)

Correlation Analysis Between BF% and Blood Sugar Levels.

A statistically significant, moderate positive correlation r=0.504, $P<0.001$** between BF% and Random Blood Sugar (RBS) was seen in overall participants, as seen in Fig. 2.

Table 5 shows that the proportion of participants with hypertension in the normal-weight obese group was significantly higher than that in the non-obese group. [Proportion with hypertension–NO (15%), NWO (61%), OB (51%)]. This was also reflected in the mean systolic (p-value=0.001) and diastolic (p-value=0.001) blood pressure values, which were higher in the NWO group than in the non-obese and obese group. Similarly, the mean random blood sugar value (p-value<0.001) was also higher in the Normal-weight obesity group than in the non-obese and obese groups, as evidenced in Table 5.

Table 6 presents the results of a multivariate logistic regression analysis, examining factors associated with Normal Weight Obesity (NWO) among patients with Type 2 Diabetes Mellitus. This analysis adjusts for multiple variables simultaneously, providing a more comprehensive understanding of the independent effects of each factor on the likelihood of NWO. The results are expressed as adjusted odds ratios (AOR) with corresponding 95% confidence intervals (CI) and p-values,

Table 4 Comparison of Body Fat % with body Mass Index Category

BMI category	Essential fat	Athletes	Fitness	Acceptable	Obese	*p*-value
Males (*N*=238)	(2–5%) (*N*=0)	(6–13%) (*N*=0)	(14–17%) (*N*=6)	(18–24%) (*N*=12)	(≥25%) (*N*=220)	<0.001**
Underweight (*n*=11)	0	0	0	0	11 (100%)	
Normal (*n*=96)	0	0	3 (3.1%)	6 (6.25%)	87 (91%)	
Overweight (*n*=66)	0	0	0	6 (9%)	60 (91%)	
Obese (*n*=65)	0	0	3 (5%)	0	62 (95%)	
Females (*N*=194)	(10–13%) (*N*=0)	(14–20%) (*N*=17)	(21–24%) (*N*=16)	(25–31%) (*N*=51)	(≥32%) (*N*=110)	<0.001**
Underweight (*n*=2)	0	0	0	1 (50%)	1 (50%)	
Normal (*n*=110)	0	10 (9%)	13 (11.8%)	30 (27%)	57 (51.8%)	
Overweight (*n*=18)	0	3 (16.6%)	0	10 (55.5%)	5 (27.7%)	
Obese (*n*=64)	0	4 (6.25%)	3 (4.6%)	10 (15.6%)	47 (73%)	

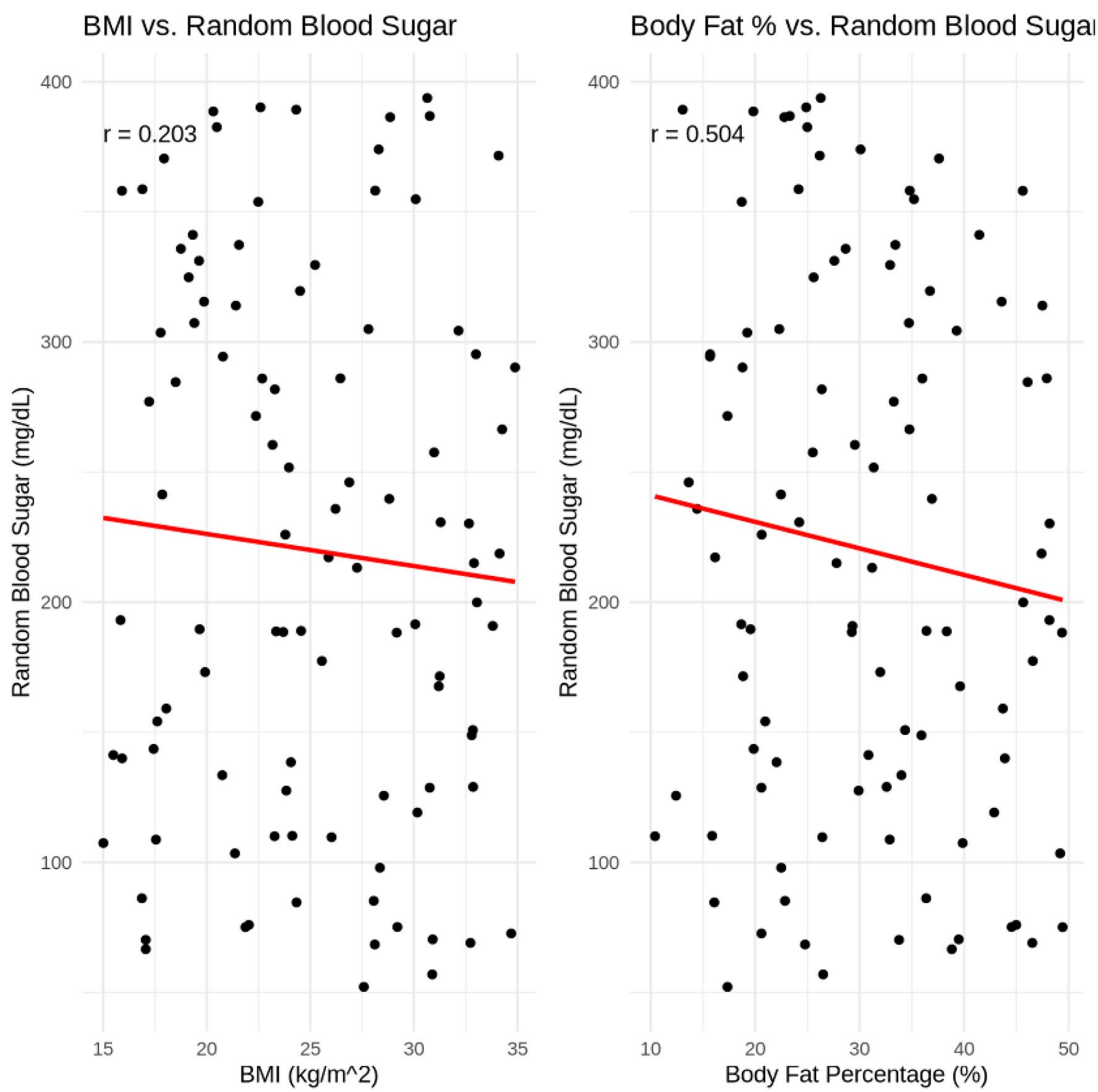

Fig. 2 shows the Correlation between BMI Vs. Random Blood Sugar levels and BF% vs. random Blood Sugar levels

Table 5 Comparison of Random Blood Sugar and blood pressure measurements among the different groups of obesity (NWO and obese group)

Variables	Non-obese (NO) *n* (%) (*n* = 159)	Normal weight obese n (%) (NWO)(*n* = 144)	Obese (OB) n (%) (*n* = 129)	*P*-value
Mean random plasma glucose mg/dl (SD)	180 ± 80	290 ± 110	260 ± 90	0.001*
Mean systolic blood pressure mm of Hg (SD)	122.5 ± 19.5	148.8 ± 25.4	136.5 ± 19.9	0.001*
Mean diastolic blood pressure, mm of Hg (SD)	78.6 ± 36.6	98.5 ± 55.6	88.4 ± 44.6	0.001*
Hypertension, n (%)	24(15)	88(61)	66(51)	0.001(NO Vs NWO) * 0.001(NO Vs OB) * 0.09(NWO Vs OB) *
Pre-Hypertension, n (%)	66(41)	54(37)	52(40)	0.49(NO Vs NWO) 0.83(NO Vs OB) 0.63(NWO Vs OB)
No-Hypertension, n (%)	69(43)	2(1.4)	11(8.5)	0.001(NO Vs NWO) * 0.04(NO Vs OB) * 0.001(NWO Vs OB) *

SD-Standard Deviation, $p < 0.05$-significant, $P < 0.001$-Highly Significant

Table 6 Multivariate Logistic Regression Analysis for Factors Associated with Normal Weight obesity

Variables	Adjusted Odds Ratio	95% CI	*p*-value
Age (years)			
30–39	1.00 (Reference)	-	-
40–49	1.32	0.87–2.01	0.192
50–59	1.68	1.12–2.52	0.012*
60 and above	2.15	1.45–3.18	< 0.001*
Gender			
Male	1.00 (Reference)	-	-
Female	0.76	0.54–1.07	0.115
Duration of diabetes			
< 5 years	1.00 (Reference)	-	-
5–10 years	1.45	0.98–2.15	0.064
> 10 years	1.87	1.21–2.89	0.005*
Random blood sugar level (per 10 mg/dL increase)	1.03	1.01–1.05	0.002*
Systolic blood pressure (per 10 mmHg increase)	1.18	1.09–1.28	< 0.001*
Diastolic blood pressure (per 10 mmHg increase)	1.22	1.11–1.34	< 0.001*

*Statistically significant ($p<0.05$) CI: Confidence Interval

allowing for interpretation of both the magnitude and statistical significance of associations.

Age emerged as a significant factor, with older age groups showing progressively higher odds of NWO compared to the reference group of 30–39 years. Notably, individuals aged 60 and above had the highest odds (AOR: 2.15, 95% CI: 1.45–3.18, $p<0.001$), suggesting that the risk of NWO increases substantially with age. Gender, however, did not show a statistically significant association with NWO (Female AOR: 0.76, 95% CI: 0.54–1.07, $p=0.115$), indicating that after adjusting for other factors, the likelihood of NWO was similar between males and females.

The duration of diabetes also played a role, with those having diabetes for over 10 years showing significantly higher odds of NWO compared to those with less than 5 years duration (AOR: 1.87, 95% CI: 1.21–2.89, $p=0.005$). This suggests that longer exposure to diabetes may increase the risk of developing NWO. Importantly, both random blood sugar levels and blood pressure measurements were associated with increased odds of NWO. For every 10 mg/dL increase in random blood sugar, the odds of NWO increased by 3% (AOR: 1.03, 95% CI: 1.01–1.05, $p=0.002$). Similarly, for every 10 mmHg increase in systolic and diastolic blood pressure, the odds of NWO increased by 18% (AOR: 1.18, 95% CI: 1.09–1.28, $p<0.001$) and 22% (AOR: 1.22, 95% CI: 1.11–1.34, $p<0.001$) respectively.

These findings highlight the complex interplay of demographic, clinical, and metabolic factors in the development of NWO among diabetic patients. The strong associations with age, diabetes duration, blood sugar levels, and blood pressure underscore the importance of comprehensive assessment and management of these factors in diabetic care, particularly in identifying and addressing NWO. This analysis provides valuable insights for clinicians and researchers, emphasizing the need for a multifaceted approach to understanding and managing NWO in the context of Type 2 Diabetes Mellitus.

Discussion

This study provides valuable insights into the prevalence of Normal Weight Obesity (NWO) and its association with cardiometabolic risk factors among patients with Type 2 Diabetes Mellitus (T2DM) in Gujarat, India. The findings highlight the limitations of using Body Mass Index (BMI) alone as a measure of obesity and underscore the importance of assessing body composition, particularly body fat percentage, in clinical practice.

Prevalence of Normal Weight Obesity.

Our study revealed a high prevalence of NWO (33%) among T2DM patients, which aligns with recent studies in different populations. For instance, Kapoor et al. reported a prevalence of 32% among Indian adults with high diabetes risk [12], while Zhang et al. found a prevalence of 29.9% among Chinese university students [13]. Similar findings emerge from studies in Malaysia (19.8%) [14] and Korea (19.3%) [15]. The similar prevalence in our study supports the growing recognition of NWO as a significant concern, particularly in Asian populations. Several factors might contribute to this prevalence -**Body fat distribution**: Asians tend to have a higher percentage of body fat stored viscerally (around organs) compared to subcutaneously (under the skin) [16]. Visceral fat is more metabolically active and linked to insulin resistance, a hallmark of T2DM, even in individuals with a normal BMI, **Muscle composition**: Muscle mass plays a crucial role in glucose metabolism. Studies suggest Asians may have a lower muscle mass to body fat ratio compared to other ethnicities [17]. This can further contribute to insulin resistance despite a normal BMI. **Genetic predisposition**: Genetic variants influencing fat distribution and insulin sensitivity might be more prevalent in certain Asian populations, increasing NWO risk for T2DM [18].

Body composition and BMI discordance

A striking finding of our study was the significant discordance between BMI classification and body fat percentage. Among individuals with normal BMI, 91% of males and 51.8% of females had obese levels of body fat. This misclassification was observed across all BMI categories, highlighting the potential inadequacy of BMI in identifying adiposity. Previous research by Amirabdollahian and Haghighatdoost (2018) similarly found that BMI underestimated obesity prevalence by 50% compared to body fat percentage measurements [19]. Similar findings have been reported in other studies: Visaria et al. (2023) found that among over 9,700 adults, only 47% with obesity based on body fat percentage were correctly classified as obese by BMI [20]. A previous study also demonstrated a significant underestimation of body fat percentage by BMI in athletes [21]. **Potential Reasons for Misclassification: Muscle mass**: BMI solely considers weight and height, not differentiating between muscle and fat mass. Individuals with high muscle mass, like athletes, can have a normal BMI despite a high body fat percentage due to their denser muscle composition. **Sex differences**: Men tend to store more fat subcutaneously (under the skin), while women store more fat viscerally (around organs). Visceral fat is more metabolically active and linked to health risks, even in individuals with a normal BMI. **Ethnicity**: Body fat distribution can vary by ethnicity. Asians, for example, tend to have a higher percentage of visceral fat compared to other ethnicities, potentially leading to NWO (normal weight obesity) and misclassification by BMI.

Cardiometabolic risk factors

Our results demonstrate that individuals with NWO have a higher cardiometabolic risk profile compared to their non-obese counterparts. The NWO group had significantly higher mean random blood glucose levels, systolic and diastolic blood pressure, and a higher prevalence of hypertension compared to the non-obese group. These findings are consistent with a recent meta-analysis by Xu et al. (2021), which found that NWO was associated with a 39% increased risk of developing T2DM [22].

Interestingly, our study found that the NWO group had even higher mean blood glucose and blood pressure levels than the overtly obese group. This unexpected finding suggests that NWO individuals may be at particularly high risk for cardiometabolic complications, possibly due to delayed diagnosis and intervention. A recent study by García-Hermoso et al. (2020) similarly reported that NWO was associated with poorer cardiometabolic profiles in children and adolescents [23].

Correlation analysis

The correlation analysis revealed a moderate positive correlation between body fat percentage and random blood sugar levels ($r=0.504$, $p<0.001$), while no significant correlation was found between BMI and random blood sugar levels. This further emphasizes the importance of body fat assessment in predicting glycemic control in T2DM patients. These findings align with a recent study by Correa-Rodríguez et al. (2020), which found stronger associations between body fat percentage and cardiometabolic risk factors compared to BMI [24].

Multivariate analysis

The multivariate logistic regression analysis identified several factors independently associated with NWO, including age, duration of diabetes, random blood sugar levels, and blood pressure. The strong association with age (AOR: 2.15 for age≥60 years) suggests that the risk of NWO increases with advancing age, possibly due to age-related changes in body composition. This is consistent with findings from Batsis et al. (2019), who reported an increase in NWO prevalence with age in older adults [25]. The potential reasons behind these associations: **Age**: As individuals age, muscle mass tends to decrease while fat mass increases. This shift in body composition can contribute to NWO, even with a normal BMI [26]. **Duration of diabetes**: Longer durations of T2DM can lead to progressive insulin resistance and impaired glucose metabolism. This may promote fat storage even in individuals with normal weight [27]. **Random blood sugar levels**: Elevated random blood sugar levels, a marker for poor glycemic control, could be indicative of increased fat storage and NWO risk [28]. **Blood pressure**: Hypertension (high blood pressure) is often linked to insulin resistance and metabolic dysfunction, potentially contributing to NWO development. [29]

Clinical implications

The high prevalence of NWO and its association with adverse cardiometabolic risk factors in our study population has important clinical implications. It suggests that relying solely on BMI for obesity assessment may lead to the underdiagnosis of high-risk individuals, particularly in the Asian Indian population. A recent review by Iacobini et al. (2019) emphasized the need for incorporating body composition analysis in clinical practice to improve risk stratification and personalized treatment strategies [30].

It is important here to acknowledge some limitations of this study and the comparability of the findings with previous research. Variations in study design, sample size, participant characteristics, and measurement techniques for RBS and BF% may contribute to differences in reported correlation coefficients. Additionally, the specific population and demographic factors can influence the strength of the correlation.

Some potential limitations of the study that could be discussed

Sample Size: One limitation of the study is the relatively small sample size. A larger sample size could provide more robust and generalizable results. Factors such as geographical location, cultural differences, and healthcare practices may limit the generalizability of the findings to other populations or regions. The small sample size may limit the statistical power and the ability to detect smaller, yet potentially significant, correlations between RBS and BF%.

Cross-Sectional Design: The study design was cross-sectional, capturing data at a single point in time. As a result, it is not possible to establish a causal relationship between RBS and BF%. Longitudinal studies are needed to determine the temporal association and to better understand the directionality of the relationship.

Measurement Methods: It is important to consider the specific measurement techniques employed in the study and their potential limitations or sources of error.

Confounding Factors: The study may not have accounted for certain confounding factors that could influence the relationship between RBS and BF%. Variables such as physical activity levels, dietary habits and medication use, could have influenced the results but were not adequately addressed or controlled for in the analysis.

It is essential to acknowledge these limitations as they provide insights into the potential impact on the interpretation and generalizability of the study findings. By addressing these limitations, future research can build upon the existing knowledge and provide a more comprehensive understanding of the relationship between RBS and BF% in individuals with diabetes.

In summary, this study emphasizes the high prevalence of NWO and the positive correlation between RBS and BF% in individuals with T_2DM. These findings underscore the importance of considering body composition and glycaemic control together in the management of diabetes, and they provide a foundation for future research and interventions aimed at optimizing metabolic health in this population.

Conclusion

The present study highlights the critical importance of recognizing and addressing NWO in the management of T2DM. By adopting a more nuanced approach to obesity assessment that includes body composition analysis, healthcare providers can better identify and manage cardiometabolic risk in this vulnerable population, potentially leading to improved outcomes and reduced complication rates in T2DM.

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Author contributions

Dr Yogesh M - Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Data Curation, Writing, Project Administration and Funding. Mansi Mody - Conceptualization, Methodology, Validation, Formal Analysis, Investigation, Data Curation, Writing, Visualization and Supervision. Dr Naresh Makwana – Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation, Data Curation, Writing and Funding. Samyak Shah - Conceptualization, Methodology, Validation, Investigation, Writing, and visualization. Jenish Patel - Conceptualization, Methodology, Validation, Investigation, Data Curation, Writing and Project Administration.

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Data availability

The datasets during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval from the institute (Shri M P Shah Government Medical College, Jamnagar, Gujarat, India) was obtained before the start of the study. (REF:07/01/2023).

Consent for publication

Written informed consent was taken from the participants in their vernacular language. All the participants were given instructions about the study before the start of the study. Good clinical care was performed.

Competing interests

The authors declare that they have no competing interests.

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