Original article

Prevalence and risk factors of metabolic syndrome in obese and non-obese South Indian adults: A population-based cross-sectional study

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Abstract. *Background and aim:* Metabolic syndrome (MetS), a cluster of risk factors associated with various noncommunicable diseases, has traditionally been linked to obesity. However, recent studies have demonstrated high MetS prevalence among non-obese individuals, with evidence suggesting distinct patterns of lifestyle risk factors between obese and non-obese populations. This study aims to estimate the prevalence of MetS in non-obese individuals and investigate the independent associations between lifestyle risk factors and MetS in both obese and non-obese populations. *Methods:* A total of 443 participants were recruited, comprising 177 non-obese and 266 obese individuals in this study. Data were collected on family history, physical activity levels, smoking status, alcohol consumption patterns, and dietary intake of fruits and vegetables. Obesity was classified according to Asia-Pacific criteria, with non-obese defined as (BMI <25 Kg/m²). *Results:* MetS affected 58.91% of all study participants, with a substantial 40.7% occurrence, even among those who were not obese. The presence of Type 2 diabetes mellitus (T2DM) demonstrated a strong correlation with MetS, regardless of whether individuals were classified as obese or non-obese. Among obese participants, a history of cardiovascular disease (CVD) showed a significant association with MetS, while in non-obese participants, sex and family history of T2DM were significantly associated with MetS. *Conclusions:* Our study population showed a notable prevalence of MetS, extending significantly beyond just those participants with obesity. This suggests the need for MetS screening in both obese and non-obese populations to ensure timely detection and management of MetS. (www.actabiomedica.it)

Key words: metabolic syndrome, risk factors, prevalence, obesity, non-obese adults, cross-sectional studies, epidemiology, south India

Introduction

Metabolic syndrome (MetS) is characterized by a constellation of interrelated physiological, biochemical, clinical, and metabolic factors that elevate an individual's susceptibility to cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), and specific types of cancer (1,2). The global prevalence of MetS has reached concerning levels, affecting approximately 41.8% of Americans in 2017-18 and 20-30% across various regions (1,3,4). In India, meta-analyses of hospital-based studies have reported MetS prevalence as high as 47% (5). This burden is expected to increase, as evidenced by a recent meta-analysis showing a 22.30% prevalence of T2DM in South Asia and rising T2DM rates in lower-income nations, where approximately 80% of individuals with T2DM develop MetS (6–8). Moreover, according to the World Health Organization (WHO), developing nations account for the majority of deaths due to noncommunicable diseases (9). While obesity is traditionally considered a primary component of MetS (1), emerging evidence highlights a significant prevalence among non-obese individuals. Studies across India demonstrate this phenomenon: community-based research in rural West Bengal identified MetS in 12.8% of individuals with normal waist circumference and 15.1% in the Chennai Urban area among body mass index (BMI) less than 25 kg/m^2. In comparison, research among obstructive sleep apnea (OSA) patients in central India found MetS in 35% of individuals with a BMI below 25 kg/m^2 (10–12) Similarly, some international observations, including studies from Malaysia and Poland, report MetS prevalence of 17.7% and 17.27%, respectively, among non-obese populations (13,14). The rising prevalence of MetS in non-obese populations may be attributed to the adoption of Western dietary patterns and sedentary lifestyles, compounded by genetic predisposition to diabetes and CVD (15). Of particular concern is that Asian populations demonstrate elevated cardiovascular risk even at normal BMI values (16,17). Further, Studies have shown that metabolically unhealthy individuals with normal BMI are more prone to develop T2DM and CVD (18,19). Moreover, economic implications are substantial, with noncommunicable disease expenditure in India projected to increase 2.5-fold by 2051, surpassing spending on communicable diseases (20). A range of modifiable lifestyle factors has been associated with elevated MetS risk. These encompass tobacco use, patterns of alcohol intake, sedentary behaviours, suboptimal nutritional practices, and insufficient consumption of plant-based foods, particularly fruits, and vegetables (21–24). Interestingly, Malaysian (13) studies found no significant differences in MetS prevalence among non-obese individuals based on these lifestyle factors. However, Japanese research demonstrated that these modifiable risk factors conferred an elevated MetS risk in non-obese than in obese (25). Furthermore, geographical location, ethnicity, and socioeconomic status influence MetS outcomes (5). There is a lack of research that has examined the independent effects of these modifiable risk factors on obese and non-obese adults in the coastal Karnataka population. Despite extensive epidemiological research on MetS across Indian populations, there remains a critical knowledge gap regarding its prevalence and risk determinants among non-obese individuals. This deficit is particularly pronounced in coastal Karnataka populations, where the interplay between lifestyle factors and MetS development across BMI categories remains poorly understood. Furthermore, while obesity is widely recognized to elevate the risk for MetS, the burden and distinct risk profile of MetS among non-obese individuals in this region have not been comprehensively evaluated. This study aims to determine the prevalence of MetS and identify associated lifestyle risk factors across obese and non-obese adult populations in coastal Karnataka.

Materials and Methods

Study design and population

This observational study was conducted in two hospital settings, one tertiary and another secondary care hospital in Manipal and Udupi, India. This study was conducted in outdoor patients from August 2022 to October 2024, and 443 participants were recruited. We included 20-60-year-olds, both genders, and who provided informed consent; participants were excluded if they had any known CVD, renal and liver insufficiency, tumors, pregnant women, and thyroid disorders.

Data collection

Demographic and clinical parameters

Participants' age, sex, height, weight, and waist circumference (WC) were noted by a qualified health practitioner in the study setting after obtaining consent from the participants. BMI was calculated using individual height and weight. The blood pressure measurement was done twice for each participant after 10 minutes of rest. All the measurements were performed using a standard calibrated machine. Obesity was defined using Asia-Pacific cut-off values: BMI ≥ 25 kg/m² was classified as obese, and BMI < 25 kg/m² as non-obese (26).

The measurement of WC utilized a tape measure with no elastic properties. Measurements were taken at two anatomical locations: between the lowest costal margin and superior iliac crest at the lateral aspects, as well as at the level of the umbilicus. Measurements were taken while the subject was wearing light clothing (27).

Assessment of self-reported health behaviours

Family history

The family history of diabetes, hypertension, and cardiovascular diseases was noted as Yes and No, and the presence and absence of disease were assessed using self-reports by participants.

Behavioural risk factors

Smoking status was assessed using a dichotomous question (Yes/No) ("Do you currently smoke any tobacco products?"). Assessment of physical activity levels was conducted through the administration of the WHO Global Physical Activity Questionnaire (GPAQ), with participants classified as active or inactive based on metabolic equivalent (MET)-minutes per week (active: >600 MET-minutes per week) (28). Dietary patterns were assessed by asking participants about their vegetarian or non-vegetarian food consumption. Alcohol consumption was classified into three distinct categories: individuals with no alcohol intake, those consuming within moderate limits (defined as fewer than 14 weekly for males and fewer than 7 for females), and heavy consumers, whose intake exceeded these gender-specific thresholds (29). Daily fruit and vegetable consumption was assessed with a yes/no question (Yes: minimum 5 portions of fruits and vegetables) (27).

Laboratory parameters

The biochemical components of metabolic syndrome, which include high-density lipoprotein-cholesterol (HDL-C), triglyceride, fasting plasma glucose (FPG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), were evaluated using an automated machine (Cobas 800 series, Roach Diagnostic) after 10-12 hours of fasting. The lab adheres to internal and external quality.

Ethical statements

The institutional ethics committee of Kasturba Hospital and Medical College, Manipal, approved the study (IEC number 143/2022). All study participants provided signed documentation of informed consent prior to enrolment.

Definition of MetS

Modified NCEP ATP III (2005) (30)
≥ 3 following criteria:

1. WC Male (≥90cm), Female (≥80cm)
2. HDL-C Male (<40 mg/dL), Female (<50 mg/dL)
3. FPG ≥100 mg/dL
4. Triglyceride ≥150 mg/dL
5. Blood pressure ≥130/85 mmHg

Sample size calculation

The minimum required sample size calculation incorporated the following parameters: a significance level (α) of 0.05, an expected prevalence of 50% derived from an initial pilot investigation with 30 participants in a hospital-based setting, and a margin of error of 5% (d). Based on these parameters, the sample size was determined using the formula:

$$n = \left(Z_1 - \frac{\alpha}{2}\right)^2 \left(\frac{(p)(1-p)}{d^2}\right) \text{i.e.,}$$

$$n = (1.96)^2 \left(\frac{(0.50)(1-0.50)}{(0.05)^2}\right) = 385$$

Considering a drop-out of 10%, we have a minimum requirement of 427 participants.

A total of 458 participants were recruited initially, and after removing a participant with incomplete information and thyroid disorders, we finally included 443 participants in our study.

Statistical analysis

A comparison of obese and non-obese groups was made using either the independent sample t-test or the Chi-square test. Multiple logistic regression analysis (Force entry method) was performed considering the presence or absence of MetS as dependent variables and demographic and behavioral factors as exploratory variables. A reference independent attribute was coded as (0) for females in sex, 20-40 years age group, 'No' for family history, food habits, T2DM, and behavioral risk factors. A P-value <.05 is considered statistically significant. Statistical analysis was conducted using Jamovi Software (V 2.3.28).

Results

General characteristics

The characteristics of subjects, such as family history, biochemical parameters, and lifestyle risk factors, are shown in Table 1. Out of 443 subjects, 177 (40%) (114 male and 63 female) were non-obese, and 266 (60%) (179 male and 87 female) were obese. The median age was 50[10] in non-obese and 48[15] in obese. There was no significant difference in family history, food habits, and lifestyle risk factors among the obese and non-obese groups. HDL-C components of MetS were significantly reduced in the obese group (P<0.001). Furthermore, the ratio of TC/HDL-C also shows a statistically significant difference (P<0.001). Moreover, the presence of MetS was significantly raised among obese. The overall prevalence of MetS was 58.91% of our study population. According to Asian-Pacific criteria for BMI, MetS was present in 71.1% of obese participants and 40.7% of non-obese participants.

Sex-specific prevalence of metabolic syndrome components

Table 2 presents the prevalence of the components of MetS. The most prevalent MetS component in males was raised FPG (70%), and reduced HDL-C (43%) was less prevalent. In contrast, WC (66.7%) in females was the most prevalent, and triglyceride (32.7%) was the least prevalent. MetS affected 57.8% of male participants and 44.4% of female participants.

Factors associated with the MetS outcome

Table 3 presents the data findings from multivariate logistic regression analyses. In this analysis, the mutual effect of the independent variable was controlled. As shown in the table, the presence of T2DM had a positive association with MetS in both with and without obesity. Increased likelihood of developing MetS, as indicated by elevated odds ratios (ORs), were found in males compared to females in non-obese participants (OR:2.01, 95% CI:1.05-3.86, P=0.03) and family history of diabetes (OR:2.61, 95% CI:1.41-4.84, P=0.002). In obese individuals, a higher OR of getting MetS was observed in those having a family history of CVDs (OR:4.84,95% CI:1.43-16.34, P=0.002). The ORs for MetS were consistently higher in obese individuals compared with non-obese individuals across various lifestyle risk factors: current smoking (OR of 2.28 with obesity and OR of 1.18 without obesity), heavy alcohol consumption (OR of 1.99 with obesity and OR of 1.12 without obesity), physical inactivity (OR of 0.74 with obesity and OR of 1.07 without obesity), and insufficient fruits and vegetables intake (OR of 1.26 with obesity and OR of 0.63 without obesity).

Discussion

Our analysis revealed that MetS affected 58.91% of the study participants, indicating a substantial presence of this condition in the examined population. There was a significantly high prevalence of MetS in obese (71.05%) compared to non-obese (40.68%). Regarding gender, males had more prevalence (63.1%) than females (50.7%). The most prevalent component

Table 1. Subject characteristics.

Variables	All (n=443)	Non-obese (n=177)	Obese (n=266)	*P*
Sex				
Men	293 (66)	114 (64)	179 (67)	0.53[b]
Women	150 (34)	63 (36)	87 (33)	
Age	49[13]	50[10]	48[15]	0.72[a]
20-40 years	102 (23)	40 (23)	62 (23)	
41-60 years	341 (77)	137 (77)	204 (77)	0.86[b]
Body mass index (Kg/m^2)	25.7[5.4]	23.1[2.8]	27.9[4.5]	<0.001[a]
Waist circumference (cm)	89.3±10.7	81.8±6.62	94.9±9.73	<0.001[a]
Family history of diabetes				
Yes	220 (50)	81 (46)	139 (52)	0.18[b]
No	223 (50)	96 (54)	127 (48)	
Family history of hypertension				
Yes	228 (51)	86 (49)	142 (53)	0.32[b]
No	215 (49)	91 (51)	124 (47)	
Family history of CVD				
Yes	57 (13)	23 (13)	34 (13)	0.95[b]
No	386 (87)	154 (87)	232 (87)	
Food habits				
Veg	101 (23)	42 (24)	59 (22)	0.70[b]
Non-veg	342 (77)	135 (76)	207 (78)	
Diabetes				
Yes	192 (43)	70 (40)	122 (46)	0.19[b]
No	251 (57)	107 (60)	144 (54)	
Physical activity				
Yes	192 (43)	78 (44)	114 (43)	0.80[b]
No	251 (57)	99 (56)	152 (57)	
Smoking				
Yes	34 (8)	9 (5)	25 (9)	0.09[b]
No	409 (92)	168 (95)	241 (91)	
Alcohol consumption				
No	334 (75)	137 (77)	197 (74)	0.38[b]
Moderate	63 (14)	26 (15)	37 (14)	
High	46 (11)	14 (8)	32 (12)	
Daily Fruit and vegetable consumption				
Yes	165 (37)	58 (33)	107 (40)	0.11[b]
No	278 (63)	119 (67)	159 (60)	
Systolic blood pressure (mmHg)	130[20]	130[20]	130[20]	0.16[a]

Table 1 (*Continued*)

Variables	All (n=443)	Non-obese (n=177)	Obese (n=266)	*P*
Diastolic blood pressure (mmHg)	80[10]	80[7.75]	80[10]	0.11[a]
Fasting Plasma glucose (mg/dL)	108[41.8]	106[32.3]	109[47.8]	0.002[a]
Triglyceride (mg/dL)	140[77.8]	136[69.3]	140[81.5]	0.02[a]
High-density lipoprotein cholesterol (mg/dL)	44[14.8]	46[16.3]	43[14.8]	<0.001[a]
Low-density lipoprotein cholesterol (mg/dL)	126±39	122±36.9	129±40.3	0.11[a]
Total cholesterol (mg/dL)	194±40.9	191±40.9	196±40.8	0.32[a]
TC/HDL	4.10[1.7]	4[1.8]	4.5[1.6]	<0.001[a]
Metabolic syndrome components				
<3	182 (41)	105 (59)	77 (29)	<0.001[b]
≥3	261 (59)	72 (41)	189 (71)	

a=t-test, **b**=chai-square test. [a]Data are presented as mean±standard deviation, median with [IQR], [b]Data are presented as numbers (percentages). *Abbreviations:* CVD: cardiovascular disease; TC: total cholesterol; HDL: high-density lipoprotein cholesterol.

of MetS in females was WC; in males, it was FPG. The biochemical component of MetS showed significant differences between the groups. T2DM showed a significant correlation with MetS, regardless of whether individuals were obese or not. The presence of T2DM was associated with the presence of MetS in both obese and non-obese groups. Among individuals without obesity, being male and having a family history of diabetes demonstrated significant associations with MetS development. However, obese, only the presence of CVD was significantly associated with the presence of MetS. Furthermore, our findings show that alcohol consumption, insufficient consumption of fruits and vegetables, and smoking were linked to higher odds ratios of MetS in obese individuals. However, lack of physical activity showed an increased odds ratio of MetS in non-obese individuals. The high prevalence of MetS observed in our study aligns with findings from comparable settings across India. However, notable variations exist in the literature. A study conducted in neighbouring states reported a substantially higher prevalence of 76%, likely attributable to their exclusive urban study population compared to our mixed rural-urban (31). Similarly, Subramani et al. study from the Gwalior region (32), using identical MetS diagnostic criteria, documented a prevalence of 72.7%. A comprehensive meta-analysis by Krishnamurthy et al. reported MetS prevalence rates up to 47% in hospital-based studies, suggesting that urbanization and associated lifestyle changes may be significant contributing factors (5). Our findings regarding the relationship between obesity and MetS are consistent with existing literature. Latha P S et al. study in rural South India demonstrated a strong association between obesity and increased MetS risk (33). This pattern was further corroborated by Negi P C et al., who reported elevated MetS prevalence among obese employees in Northern India (34). The prevalence of MetS among non-obese individuals in our study parallels findings from a hospital-based study in the Philippines that employed identical diagnostic criteria (35). However, a study done in Chennai using Asia-Pacific cut-off for BMI found a prevalence of MetS among non-obese of 15.1%; this lower prevalence than our study might be the study setting that they used in community-based than the hospital-based used in our study (12). Our findings regarding MetS prevalence among females aligned with research conducted in Mysore by K. Karl et al., who

Table 2. Prevalence of individual risk factors of MetS based on gender.

SN	Components of MetS	Definition	Men(n=293) n (%)	Women(n=150) n (%)	Total(n=443) n (%)
1	Central obesity Men Women	 ≥90cm ≥80cm	 163(55.6) -	 - 100(66.7)	 263(59.4)
2	Raised Blood pressure	≥130/85 mmHg	180(61.4)	76(50.7)	256(57.8)
3	Raised FPG	≥100 mg/dL	205(70)	96(64)	301(67.9)
4	Raised TG	≥150 mg/dL	141(48.1)	49(32.7)	190(42.9)
5	Reduce HDL-C Men Women	 <40mg/dL <50mg/dL	 126(43) -	 - 76(50.7)	 202(45.6)
6	MetS Prevalence	≥ The above three criteria	185(63.1)	76(50.7)	261(58.9)

Abbreviations: FPG: fasting plasma glucose, TG: triglyceride, HDL-C: high-density lipoprotein-cholesterol, MetS: metabolic syndrome, n: number. Data are presented as numbers (percentages).

Table 3. Risk factors associated with the presence of MetS (Logistic regression analysis).

Attributes		Non-obese			Obese		
		OR	95% CI	*P*	OR	95% CI	*P*
Sex	Women Men	0.49 2.01	1.05-3.86	0.03	0.68 1.48	0.85-2.57	0.17
Age (Years)	20-40 41-60	0.84 1.19	0.57-2.45	0.64	0.81 1.23	0.66-2.27	0.51
Family history of diabetes	No Yes	0.38 2.61	1.41-4.84	<0.002	0.63 1.58	0.93-2.70	0.09
Family history of hypertension	No Yes	0.62 1.60	0.88-2.93	0.12	0.69 1.45	0.85-2.48	0.17
Family history of CVD	No Yes	1.08 0.93	0.38-2.28	0.87	0.21 4.84	1.43-16.34	0.002
Food habits	Veg Non-Veg	1.45 0.69	0.34-1.38	0.297	1.79 0.56	0.28-1.12	0.09
Physical activity	Yes No	0.93 1.07	0.59-1.96	0.82	1.35 0.74	0.43-1.27	0.27
Alcohol consumption	No Moderate Heavy	0.89 1.09 1.12	0.48-2.56 0.37-3.40	0.96 0.96	0.50 1.43 1.99	0.64-3.21 0.78-5.08	0.25 0.25
Smoking	No Yes	0.85 1.18	0.30-4.54	0.81	0.44 2.28	0.76-6.88	0.11
Daily Fruit and vegetable consumption	Yes No	1.59 0.63	0.33-1.19	0.15	0.79 1.26	0.73-2.15	0.40
Type 2 diabetes mellitus	No Yes	0.21 4.77	2.49-9.13	<0.001	0.23 4.41	2.40-8.12	<0.001

Abbreviations: CVDs: cardiovascular diseases. OR: odds ratio, CI: confidence interval; veg: vegetarian; Non-veg: non-vegetarian, Multiple logistic regression analysis (force entry method) was conducted, taking present and absence of MetS as dependent variables and age, sex, family history of disease, and lifestyle risk factors for MetS as attributed variables for both groups.

reported that 47.1% of their female participants met the diagnostic criteria for MetS using a similar definition of MetS (36). However, WC was the most prevalent component in females in our study, whereas low HDL-C was the most common component in their study. Furthermore, the study by Subramani et al. (32) shows a very high prevalence in both males (75%) and females (84.5%) compared to our findings. The high prevalence of WC in females and high prevalence of blood pressure in males was found in a study done in the Malaysian population (13). This study found a high prevalence of FPG in males compared to females (13). Furthermore, the high prevalence of MetS in males compared to females was demonstrated by a previous study by A. Pouria et al. done in a cohort of 3495 participants (37)and by Vatakencherry et al. study done in a hospital setting in Kerala (31). Conversely, Subramani et al. (32) shows a high prevalence of MetS in females compared to males in Central India. Similarly, a study done in the Chinese population also showed a high prevalence among females compared to males (38). The difference in the prevalence of MetS in males and females from different studies might be due to population diversity, lifestyle, cultural aspects, and diagnostic criteria used to define MetS (38).

The significant difference in the biochemical component of MetS in obese compared to non-obese in our population might be due to the high prevalence of MetS among obese, which might have influenced the high level of HDL-C, FPG, TC/HDL-C, and triglyceride in obese compared to non-obese. Further, K Ayako et al. (25) in the Japanese population show results similar to those of our study on obese and non-obese populations. Further, obesity can influence lipid metabolism through various pathways, including insulin resistance, free fatty acids, adipokines, and vitamin D (39,40).

The presence of diabetes as a risk factor for MetS was similar to the study by Krishna et al., which shows that T2DM is highly associated with MetS, which is similar to our analysis (41). Male sex was found to develop MetS compared to females in non-obese, which was supported by a prior study done in the Japanese adult population (25). While the Japanese study reported higher odds of MetS among current smokers and individuals with low fruit and vegetable intake and alcohol consumption in the non-obese group, our findings differed. Notably, our results align with Negi P.C. et al.'s study, which found no significant association between lifestyle risk factors (smoking, dietary habits, alcohol consumption, and physical inactivity) and MetS outcomes (33). To the best of our knowledge, this is the first study evaluating the prevalence of MetS in obese and non-obese populations in this coastal Karnataka region of India. Further, this study evaluates the lifestyle as well as family history of obese and non-obese for the outcome of MetS. This study shows a significant prevalence of MetS, with a high prevalence in the obese and non-obese populations. Our study is not without limitations; firstly, this is a hospital-based study, which might be the reason for the high prevalence of MetS. Secondly, a smaller sample size for logistic regression might have influenced the outcome of the analysis for the presence of MetS. Further, this observational study will affect the establishment of causal relationships between cause and effect.

Conclusion

Our study revealed a high prevalence of MetS, with significant occurrences among non-obese individuals even when using Asia-Pacific BMI cut-off values. T2DM was strongly linked with MetS in both without obesity and with obesity. Among obese individuals, smoking, insufficient fruit and vegetable intake, and alcohol consumption were associated with higher odds of developing MetS. At the same time, physical inactivity was the primary risk factor in non-obese individuals. These findings underscore the necessity for healthcare authorities to monitor MetS risk factors carefully, particularly in non-obese populations who might otherwise escape routine metabolic screening.

Ethical Approval: This study was conducted following the Helsinki Declaration Principles. The Institutional Ethics Committee of Kasturba Medical College and Kasturba Hospital, Manipal, approved the study, and consent was taken from each participant (numbered, IEC: 143/2022).

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity

interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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