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Exploration of factors influencing self-management of Metabolic Syndrome among individuals living in urban slum settings of Delhi, India

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Abstract

Metabolic Syndrome is a growing threat globally, particularly among socioeconomically disadvantaged individuals in urban poor settings. Despite this, there is a scarcity of research to understand determinants influencing self-management behaviors among individuals in these settings. Study was conducted from September 2022 to January 2023, with the aim of investigating socio-cultural, behavioral, and environmental determinants of MetS self-management among adults in urban poor settings of Delhi. Study adopted a mixed-methods approach, and included 120 Participants having MetS. Qualitative data based on HBM model were collected through in-depth interviews and subjected to thematic and sentiment analyses. The quantitative data included demographics, clinical parameters, and lifestyle behaviours, and were subjected to descriptive statistical analyses. Participants demonstrated poor control of blood pressure (147/86 mmHg ± 21/14), and blood glucose (238 mg/dL ± 92), with limited awareness and self-management of MetS. Self-management barriers included time constraint, household responsibilities, finances, and socio-cultural norms. Despite participants' access to mobile phones, low digital and health literacy prevented effective use of technology. However, majority participants perceived MetS as risk to health, and expressed interest towards adopting healthy behaviors. The findings emphasized the need for contextually tailored, affordable, and behaviorally grounded interventions to enhance self-management among socio-economically disadvantaged urban populations.

Background

Metabolic Syndrome (MetS) has been identified as a cluster of risk factors, including conditions such as obesity, elevated blood pressure, and distorted lipid and glucose metabolism [1]. This syndrome poses a heavy burden on both individual health and health care systems, making it a global public health concern [2]. The pathogenesis of MetS is under debate, but studies have suggested chronic inflammation as one of the underlying mechanisms for its development [3]. A recent study found that a Mediterranean lifestyle was associated with a lower frequency of MetS and reduced all-cause mortality in Spain, indicating the need for lifestyle modifications as preventive measures [4]. The South Asian modified specific NCEP criteria are more accurate in determining the prevalence of MetS among Indians [5]. Studies have shown that in India, the prevalence of MetS is higher in urban areas compared to rural areas and increases with higher socioeconomic status [6].

A study reported that the prevalence of MetS in northern India is more than 40%, with a significantly higher prevalence in females [7]. The Chennai Urban Rural Epidemiology Study (CURES) reported MetS prevalence rates of 26%, 18%, and 23% according to the IDF, NCEP, and WHO criteria, respectively [8]. A large multicenter study in India involving 19,973 subjects reported 27% prevalence of MetS with NCEP criteria, which increased to 35% with SAM-NCEP criteria [9]. In urban Chennai, the prevalence of MetS was 41% (36% in men and 47% in women) using waist circumference > 90 cm in men, and > 85 cm in women, as criteria for abdominal obesity [10]. Another study indicated an alarming rise in the prevalence of MetS in rural areas, which will eventually be reflected in increased morbidity and mortality from heart disease [11].

Although metabolic syndrome poses a significant public health challenge across the entire country, the people residing in the urban slums demand specific attention due to unique socioeconomic, environmental, and healthcare disparities. These challenges add to the existing risk factors such as poor nutrition, lack of physical activity, and high stress levels and worsens the condition. Limited education, poverty, and living conditions make them even more susceptible to MetS, resulting in poor health outcomes.

Public health and health promotion interventions based on social and behavioral science theories are more effective than those lacking a theoretical base [12]. The Health Belief Model (HBM) is one of the most widely applied theories, consisting of six constructs, namely, risk susceptibility, risk severity, benefits to action, barriers to action, self-efficacy, and cues to action, that help to understand the association of behavioral and environmental factors with decision-making about disease self-management. This further helps to investigate the issues that cannot be effectively explained by quantitative analysis. HBM has proven to be applicable across a wide range of cultural settings and health topics [13, 14]. A scoping review identified that HBM has good predictive ability for COVID-19-related behavior [15]. The model has been widely used to explain findings in cross-sectional studies of MetS [16], and to explore factors causing individuals to neglect specific health recommendations [17], with beneficial aspects for program development [18, 19].

The present study used the HBM to explore the role of socio-cultural, environmental, and behavioral factors affecting the self-management practices of MetS among individuals living in urban slum settings of Delhi, India. Understanding these factors will help develop better intervention plans that are tailored to individual needs.

Methods

Study design

The study adopted a mixed-method design that involved both qualitative and quantitative methods to explore both the lived experiences of the individuals with MetS, and the estimates on associated risk factors. Mixed-method approach provided a comprehensive understanding of the determinants, as compared to any of these methods alone. The aim was to explore the influence of socio-cultural, environmental, and behavioral determinants such as unhealthy diet, physical activity, stress, and sleep levels, on self-management practices among individuals with MetS living in urban slum settings. The emphasis was given on the qualitative data that captured insights on perceptions, beliefs, and barriers, which was further followed and supported by the estimates of prevalence and associations of risk factors, through the quantitative data. This study adheres to the GRAMMS (Good Reporting of A Mixed Methods Study) guidelines [20], and the completed GRAMMS checklist is provided as a supplementary file.

Study area

The study was conducted in different zones of Delhi, including North, East, South, and West, to ensure the diverse representation.

Inclusion and exclusion criteria

Inclusion criteria: The participants were included if they were: (a) Adults aged 18 years and above, gave informed consent, had metabolic syndrome based on JIS criteria 2009 [21], owned an Android phone, and were willing to use technology. Exclusion criteria included individuals less than 18 years of age, those with terminal illness, impaired cognition, and a coexisting illness documented in the medical record, or self-reported conditions associated with systemic inflammation (e.g., rheumatoid arthritis, acute systemic infection), who were pregnant or lactating, and were involved in other clinical trials or protocols related to metabolic syndrome.

Defining Metabolic Syndrome (MetS). MetS is a cluster of biochemical and physiological abnormalities associated with cardiovascular disease and diabetes [22]. The 2009 Joint Interim Statement (JIS) diagnostic criteria for metabolic syndrome (MetS) define MetS as the presence of at least three out of the following five risk factors: central obesity, high triglycerides, low HDL cholesterol, high blood pressure, and elevated fasting glucose [23].

Data collection

Data were collected from 120 participants across the urban slum settings of Delhi, from 13 September 2022 to 17 March 2023. Both qualitative and quantitative data were gathered on individuals who met the defined inclusion criteria. There were 120 In-depth interviews conducted with 30 participants each from four zones of Delhi (North, East, South, and West), generating key themes around socio-cultural, behavioral, and environmental factors influencing the self-management of MetS among individuals living in urban slum settings. Further, quantitative data on select tools was taken to support findings from qualitative data.

Quantitative data were gathered on the following variables.

Socio-demographic characteristics. Information was recorded on age, gender, marital status, educational qualification, occupation, and monthly household income (INR).

Clinical assessments. Anthropometric measurements (height, weight, waist circumference) were gathered. In addition, blood pressure levels were recorded by using a digital sphygmomanometer, and random blood glucose levels were recorded using a glucometer.

Familiarity with the use of technology. Data was recorded about the use of mobile phones and the ability of the participants to read and send text messages, along with access to the internet.

MetS-related knowledge, attitude, and practices. This was assessed using a series of questions about individuals' existing MetS related knowledge, and their attitudes and practices towards self-management.

24-hour dietary recall. A 24-hour dietary recall was conducted to ascertain the dietary intake of the enrolled participants. The nutrient consumption within the last 24 hours was computed for macro and micronutrients, viz. energy, protein, carbohydrates, total fiber, fat, total saturated fatty acids (TSFA), total monounsaturated fatty acids (TMUFA), total polyunsaturated fatty acids (TPUFA), retinol, and vitamin E [24]. The nutrients were shortlisted based on their role in preventing and treating patients with metabolic syndrome as per the existing evidence. Further, the composition of consumed fat was analyzed in terms of total saturated fatty acids (TSFA), total monounsaturated fatty acids (TMUFA), and total polyunsaturated fatty acids (TPUFA). Vitamin A and E intake were considered due to their antioxidant properties and role in maintaining mitochondrial functions and structure [25]. Moreover, a comparison of the nutrient intake of the male and female populations was made to gather insights about the gender-wise differences [26].

Physical activity. This was assessed using the Global Physical Activity Questionnaire (GPAQ). MET-minutes (Metabolic Equivalent of Task) were calculated using the formula: Total MET-minutes = (Minutes per day × MET value) × Days per week. The following WHO-recommended MET values were used: vigorous-intensity activity (8 MET-minutes/minute), moderate-intensity activity (4 MET-minutes/minute), and walking (3 MET-minutes/minute). Based on total MET-minutes, physical activity levels were classified as low (<600 MET-minutes/week), moderate (600-2999 MET-minutes/week), or high (≥3000 MET-minutes/week) [27].

Perceived Stress Scale (PSS). The Perceived Stress Scale (PSS) is the most widely used psychological instrument originally developed for measuring the perceived stress [28]. It is a measure of the degree to which situations are appraised as stressful. The PSS is a 10-item test that rates the frequency of stress-related experiences on a five-point scale from 0 (Never) to 4 (Very Often). To calculate the total score, responses to four positively worded items (questions 4, 5, 7, and 8) are reverse scored (e.g., a response of 0 becomes 4, 1 becomes 3, and so on). After reversing these items, all scores are summed to produce the total PSS score, with higher totals indicating greater perceived stress. The total score ranges from 0 to 40, and individuals were categorized into various stress categories of low stress (score of 0-13), moderate stress (score of 14-26), and high stress (score of 27-40).

Pittsburgh Sleep Quality Index (PSQI). The Pittsburgh Sleep Quality Index (PSQI) is a standardized self-rated questionnaire to assess sleep quality and disturbances over a 1-month time interval [29]. It has been designed to evaluate seven components, namely, subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component is scored from 0 to 3, where 0 indicates no difficulty and 3 indicates severe difficulty. The scores for the seven components are then summed up to yield a global PSQI score

ranging from 0 to 21. A global score greater than 5 indicates poor sleep quality, while a score of 5 or less suggests good sleep quality. Higher scores reflect more severe sleep problems.

Morisky Medication Adherence Scale-4 (MMAS-4). MMAS is a brief, four-item questionnaire to assess a patient's adherence to the medications prescribed by their doctor [30, 31]. It is very simple and quick to administer and has been designed to focus on the common reasons that result in non-adherence. Each question has an option to answer with "yes" or "no," and the responses are finally scored to classify adherence into categories, namely, typically high (0), medium (1–2), or low (3–4). The permission to use MMAS-4 has been obtained, and the license has been secured from the copyright holder.

Data analysis

For the quantitative data, descriptive analysis was performed using univariate statistics to report means and standard deviations for the continuous variables, and frequency distributions for the categorical variables. The qualitative data underwent thematic analysis using inductive reasoning guided by the Health Belief Model (HBM) framework. Key themes such as perceived susceptibility to health risks, barriers hindering access to care, and self-efficacy in managing health emerged organically from participant narratives. These themes were systematically triangulated with quantitative findings to deepen the interpretation and findings of the participant-reported experiences and measurable behavioral patterns. Statistical significance thresholds were set at $p<0.05$, with 95% confidence intervals reported where applicable, ensuring methodological rigor in interpreting study results.

Sentiment analysis. The analysis was performed by using a 7-step methodology. At the first step, thematic quotes were retrieved from open-ended survey questions and data captured during the interview, ensuring alignment with the study objectives. The raw quotes were then pre-processed by cleaning the text to eliminate the punctuations, special characters, etc., followed by sentiment analysis using Valence Aware Dictionary and sEntiment Reasoner (VADER) tool [32], which helps in providing a compound score to assess the sentiment polarity. Then, each score was categorized as positive, negative, or neutral. The individual frequency of each of the categories was calculated to highlight the most frequently used topics, based on which the word cloud was generated, where the size is directly proportional to the frequency or importance of the term reference.

Integration of the methods

Integration occurred at several stages with qualitative and quantitative methods designed in parallel under the Health Belief Model (HBM) to ensure a common conceptual framework. The standardized tools for primary risk factors for MetS were used to assess patterns for stress, sleep quality, physical activity, diet, and medication adherence. Integration primarily occurred at the analysis and interpretation phases. Qualitative findings were triangulated with quantitative results from clinical, behavioral, and lifestyle indicators. Further, Sentiment Analysis provided quantitative metrics to the qualitative data. The integration of qualitative and quantitative findings was undertaken by a multidisciplinary team of public health researchers, establishing a process of rigorous and balanced interpretations of both data.

Results

Participant characteristics

The participants' socio-demographic characteristics have been presented in Table 1. A total of 120 participants were enrolled in the study, from the North, East, South, and West zones of Delhi. Seventy percent of the participants were females (n = 84), and over 82% (n = 98) were more than 40 years of age. Nearly 32% (n = 38) had never been to school. Nearly half of the participants of the (48%, n = 57) had a monthly household family income below 19,515 INR. Seventy-one percent of the participants (n = 85) had reported some form of employment.

Table 1. Socio-demographic characteristics of the sample population.

Participant characteristics	Mean (SD) / Frequency n (%)
Gender (N = 120)	
Male	36 (30%)
Female	84 (70%)
Age (N = 120)	
Mean age	51 (10)
20-40 years	22 (18%)
Above 40 years	98 (82%)
Educational level (N = 120)	
No schooling	38 (32%)
Attended school	82 (68%)
Employment status (N = 120)	
Employed	85 (71%)
Unemployed	35 (29%)

Health status of the participants

The health status of the participants has been summarized in Table 2. The mean BMI was 29.7 kg/m² (SD = 4), and the mean waist circumference was 105 cm (SD = 10). Ninety-five percent of the study participants were overweight to obese (n = 114). Mean blood pressure was 147/86 mmHg (SD = 21/14) and mean blood glucose level was 238 mg/dL (SD = 92), with 58% of participants reporting blood glucose >200 mg/dL. Most diabetic individuals (91%; n = 74) were on medications.

Table 2. Anthropometric, clinical characteristics of participants.

Participant characteristics	Mean (SD) / Frequency n (%)
Anthropometric assessments	
Mean Weight, Kg	70 (SD = 12)
Mean Waist Circumference, cm	105 (SD = 10)
Mean Body Mass Index, kg/m^2	29.7 (SD = 4)
BMI Classification	
Normal BMI (18-24.9), kg/m^2	6 (5%)
Overweight (25-29.9), kg/m^2	66 (55%)
Obese (≥30), kg/m^2	48 (40%)
Clinical Assessment	
Mean Systolic and Diastolic Blood Pressure (mmHg)	147/86 (SD = 21/14)
Mean Blood Glucose (mg/dL)	238 (SD = 92)
Earlier diagnosed with diabetes	
Yes	81 (68%)
No	39 (32%)
Management of Diabetes	
Medication management	74 (91%) of those diagnosed
Earlier diagnosed with hypertension	
Yes	65 (54%)
No	53 (44%)
Don’t know	2 (2%)

Familiarity with technology and preference towards receiving MetS related information

An assessment of participants' familiarity with technology has been presented in Table 3. Eighty-one percent (n = 97) of the study participants used their mobiles. More than half of them (60%; n = 72) had access to the internet. Further, majority of them did not have knowledge on how to send a text message (85%; n = 102) or read a text message (62%; n = 75). Ninety-two percent of them were not using any prior mobile app to self-manage their health condition.

Nearly 98% (n = 118) of them perceived it useful to get more information related to self-management of MetS. Health topics perceived as useful by the study participants included MetS related dietary information (71%; n = 85), stress reduction (52%; n = 62), physical activity (63%; n = 77), weight management (55%; n = 66), and sleep (10%; n = 12). Video message (39%; n = 47), followed by phone call (29%; n = 35), SMS (27%; n = 32), and WhatsApp (10%; n = 12) were the preferred modes of receiving health messages. Weekly (64%; n = 77), daily (19%; n = 23), and twice a week (13%; n = 15) were the preferred frequencies of receiving the messages to self-manage MetS.

Table 3. Technology use assessment for self-management.

Variables assessed	Frequency n (%)
Frequency of mobile phone usage	97 (81%)
Access to the internet	72 (60%)
Ability to send text messages	18 (15%)
Ability to read text messages	45 (38%)
Frequency of using a mobile app to manage a health condition	10 (8%)
Desire for additional information on self-management	118 (98%)
Ability to implement the advice received	17 (74%)
Preferred method to receive information (multiple answers)	
• Phone call	35 (29%)
• SMS	32 (27%)
• Video message	47 (39%)
• WhatsApp message	12 (10%)
Preferred health topics (multiple answers)	
• Healthy diet	85 (70.8%)
• Physical activity	77 (63%)
• Weight management	66 (55%)
• Stress reduction	62 (52%)
• Sleep	29 (23%)

Knowledge, Attitudes, and Practices related to MetS & Self-management

The awareness related to MetS has been presented in Table 4. Awareness of Metabolic Syndrome was extremely low, with only 3% having heard the term, but no one could define it. The most common perceived health risks of MetS were identified as stress (43%; n = 51), unhealthy diet (21%; n = 25), genetic predisposition (11%; n = 13), and lack of physical activity (9%; n = 11). More than half of the study participants (58%; n = 70) had received some health education, and of those who had, doctors (91%; n = 63) were the most common source. Nearly half of these study participants (56%; n = 39) adhered to the recommendations given, and the most common advice was related to dietary modifications (75%; n = 51). Inability to do physical activity, food avoidance, and inadequate time and resources were the self-reported challenges in adhering to the suggested recommendations. More than half of the study participants (59%; n = 69) reported no change in the treatment over a period. Most of the participants reported never checking their cholesterol (83%, n = 93), and regular monitoring of weight, blood glucose, and blood pressure was also reported to be inconsistent.

Fifty-seven percent (n = 68) of the study participants reported self-management of MetS at home along with ongoing treatment. Healthy eating, ayurvedic treatment, and walking were the common reported self-management practices. Twenty-eight percent reported challenges in undergoing self-management practices. The factors that influenced self-management practices related to MetS included physical activity changes (29%; n = 33), dietary changes (25%; n = 29), stress (20%; n = 23), medication (17%; n = 20), and sleep (9%; n = 10).

Table 4. Awareness, perceptions, and health education related to MetS.

Variables assessed	Frequency n (%) / Mean ± SD
Awareness of MetS	
Heard of the term "Metabolic Syndrome"	3 (3%)
Able to define Metabolic Syndrome	0 (0%)
Perceived Health Risks of MetS	
Stress	51 (43%)
Unhealthy diet	25 (21%)
Genetic predisposition	13 (11%)
Lack of physical activity	11 (9%)
Health education received	
Received any health education	70 (58%)
Source of health education: Doctor	63 (91%), of those educated
Adherence to Recommendations	
Followed the recommendations given	39 (56%) of those educated
Changes in treatment over time	
Yes	44 (38%)
No	69 (59%)
Not sure	3 (3%)
Frequency of blood pressure testing	
Daily	1 (0.9%)
Twice a week	10 (8.7%)
Weekly	16 (13.9%)
Monthly	39 (33.9%)
3 - 6 Months	20 (17.4%)
Twice a year	3 (2.6%)
Once in a year	10 (8.7%)
Never	16 (13.9%)
Frequency of blood glucose testing	
Daily	0.0%
Twice a week	6 (5.2%)
Weekly	7 (6.0%)
Monthly	45 (38.8%)
3 - 6 Months	24 (20.7%)
Twice a year	1 (0.9%)
Once in a year	13 (11.2%)
Never	20 (17.2%)
Frequency of cholesterol testing	
Daily	0.0%
Twice a week	0.0%
Weekly	0.0%
Monthly	1 (0.9%)
3 - 6 Months	5 (4.5%)

Twice a year	1 (0.9%)
Once in a year	12 (10.7%)
Never	93 (83.0%)
Frequency of weight monitoring	
Daily	0.0%
Twice a week	3 (2.6%)
Weekly	5 (4.3%)
Monthly	21 (18.1%)
3 - 6 Months	24 (20.7%)
Twice a year	3 (2.6%)
Once in a year	12 (10.3%)
Never	48 (41.4%)
Alcohol consumption and smoking among the participants	
Alcohol consumption	
Yes	17 (14%)
No	102 (86%)
Frequency of alcohol consumption	
Daily	4 (23.5%)
Weekly	3 (17.7%)
Monthly	6 (35.3%)
Occasionally	4 (23.5%)
Smoking status	
Yes	14 (13%)
No	95 (87%)
Frequency of smoking	
Daily	12 (86%)
Occasionally	2 (14%)
Number of cigarettes/bidis smoked daily (Mean)	4.6 (3.7)

Diet and physical activity pattern analysis

Dietary patterns among individuals living with MetS. Dietary habits and consumption patterns among the participants have been presented in Table 5. Most common consumption of dairy products was reported either once a day (35%; n = 42) or weekly (25%; n = 30). Milk (82%; n = 75), yogurt (46%; n = 42), Paneer (42%; n = 39), butter/ghee (18%; n = 17), or butter milk (18%; n = 17) were the most consumed dairy products. Nearly 22% (n = 26) of the study participants reported adding additional salt to their food, as compared to 9% (n = 11) who reported adding additional sugar. The majority (74%; n = 89) of the participants responded that they do not end meals with a sweet. Further, it was reported that more than half of the study participants (63%; n = 76) consumed food outside, with 29% reporting twice a month, followed by 25% monthly, and 24% once a week. Despite the above dietary patterns, more than half of them (72%; n = 86) expressed that the changes in their dietary practices would have a positive effect on their health. Nearly a quarter of study participants (23%; n = 28) had made changes to their grocery shopping to enhance the self-management of MetS.

Table 5. Dietary habits and consumption patterns among participants.

Consumption of dairy products (N = 120)	Frequency n (%)
>once a day	10 (8%)
Never	3 (3%)
once/day	42 (35%)
Rarely	19 (16%)
Twice a week	16 (13%)
Weekly	30 (25%)
Types of Dairy Products Consumed	
Milk	75 (82%)
Yogurt	42 (46%)
Paneer	39 (42%)
Butter/Ghee	17 (18%)
Buttermilk	17 (18%)
Additional salt to the meals (N = 120)	
No	94 (78%)
Yes	26 (22%)
Additional sugar to beverages (N = 119)	
No	108 (91%)
Yes	11 (9%)
Ending meal with sweet (N = 120)	
Always	4 (3%)
Never	89 (74%)
Rarely	4 (3%)
Sometimes	21 (18%)
Very often	2 (2%)
Consumption of food outside (n = 120)	
No	44 (37%)
Yes	76 (63%)
Frequency of consuming food outside (n = 76)	
Daily	3 (4%)
Monthly	19 (25%)
More than 3 times a week	1 (1%)
Occasionally (once in 3 months)	7 (9%)
Once a week	18 (24%)
Thrice a week	2 (3%)
Twice a month	22 (29%)
Twice a week	4 (5%)

Dietary pattern from 24-hour Dietary Recall. Findings from the 24-hour Dietary Recall have been presented in Table 6. The mean intake of macronutrients such as energy, protein, carbohydrates, and fats was 1370.0±513.0 kcal/d, 47.1±15.0 g/d, 193.7±68.8 g/d, and 42.0±20.5 g/d, respectively. The percentage contributions to energy from protein, carbohydrate, and fat were 13.8%, 56.6%, and 27.6%, respectively. The percentage intake lies between 15%-20%, with a minimum recorded for TMUFA (14.8%), followed by TPUFA (15.2%), and highest for TSFA (18.5%). 70% consumed vitamin A (603.4±644.6 mcg/d). The vitamin E intake was found to be low among the population, with merely 20% of the RDA.

Table 6. Nutrient intake of the participants as per 24-hours dietary recall.

Nutrients	Total			Male				Female			
	Mean	SD	% Consumption	Mean	SD	RDA	% Consumption	Mean	SD	RDA	% Consumption
Energy (kcal/d)	1370.2	421.5	76.5	1569.3	471.2	2110.0	74.4	1284.8	369.5	1660.0	77.4
Protein (g/d)	47.1	15.0	97.2	54.1	13.6	54.0	100.1	44.1	14.6	46.0	95.9
Carbohydrate (g/d)	193.7	68.8	78.6	223.6	72.8	290.1	77.1	181.0	63.2	228.3	79.3
Total Fibre (g/d)	29.2	11.8	108.1	33.5	14.3	32.0	104.6	27.4	10.1	25.0	109.6
Fat (g/d)	42.0	20.5	84.7	46.7	26.0	58.6	79.6	40.1	17.4	46.1	86.9
Total Saturated fatty acids (TSFA) (g/d)	3.5	4.9	18.5	2.5	2.3	23.0	10.8	3.9	5.6	18.0	21.8
Total Monounsaturated fatty acids (TMUFA) (g/d)	2.8	4.4	14.8	2.1	2.2	23.0	9.0	3.1	5.0	18.0	17.3
Total Polyunsaturated fatty acids (TPUFA) (g/d)	2.9	2.6	15.2	3.0	2.0	23.0	13.0	2.9	2.9	18.0	16.2
Vitamin A (µg/d)	603.4	644.6	69.3	449.5	310.7	1000.0	45.0	669.3	735.0	840.0	79.7
Vitamin E (µg/d)	1.5	1.2	20.0	1.5	0.8	7.5	19.7	1.5	1.3	7.5	20.2

Physical activity patterns among individuals living with MetS. The physical activity related behavioral patterns among participants are summarized in Table 7. More than half of the study participants (52%; n = 62) were engaged in some form of physical activity, with the majority of them (85%; n = 52) reporting daily physical activity. More than half of the study participants (62%; n = 74) reported that they would not do any aerobic exercise even after a diagnosis of MetS. Physical activity was also assessed by utilizing the Global Physical Activity Questionnaire (Figure 1). More than half of the study participants (n = 70; 59%) were classified in the low activity category (<600 MET-min/week), with only 14% (n = 17) falling under moderate activity (600–2999 MET-min/week) and 26% (n = 31) as high activity (≥3000 MET-min/week), based on WHO-recommended MET thresholds.

Table 7. Physical activity-related behavioral patterns among participants.

Variables assessed	Frequency n (%)
Engaged in physical activity (n = 120)	
Yes	62 (52%)
No	58 (48%)
Frequency of engaging in physical activity (n = 61)	
1-3times/week	6 (10%)
4-6times/week	2 (3%)
Everyday	52 (85%)
Once a month	1 (2%)
Usage of the app for physical activity	
Yes	1 (1%)
No	119 (99%)
Likelihood of carrying out aerobic exercises if diagnosed (n = 120)	
Likely	41 (34%)
Unlikely	74 (62%)
Very likely	5 (4%)

Perceived Stress Scale (PSS)

The distribution of the level of stress is presented in Figure 2. Nearly half of the study participants (51%; n = 61) reported experiencing moderate stress, followed by 47% of participants experiencing low stress (n = 57).

Morisky Medication Adherence Scale-4 (MMAS-4)

The frequency distribution of the MMAS-4 scale has been presented in Table 8. Based on the MMAS-4 scores, more than half of the participants (55%; n = 66) showed low adherence to their medication, while 44 (37%) had moderate, and only 9 (8%) had high adherence. This indicates that many individuals in the study are not consistently following their prescribed treatment. The low level of adherence was self-reported due to factors such as forgetting to take medicines, stopping when feeling better or worse, or a lack of understanding about the importance of regular medication.

Table 8. Frequency distribution of the MMAS-4 scale.

Adherence Status	Score	Frequency (%) N = 119
Low	3-4	66 (55)
Medium	1-2	44 (37)
High	0	9 (8)

Pittsburgh Sleep Quality Index (PSQI)

Distribution of Pittsburgh Sleep Quality Index (PSQI) scores among participants is presented in Table 9. Sixty percent of the study participants rated their subjective sleep quality to be fair, while 15% of individuals rated it as very good. Around one-fourth of the individuals rated their sleep quality as “fairly bad” or “very bad”. About 30% of individuals had a sleep latency of 16 to 60 minutes. 20% had sleep latency between 31-60, or more than 60 minutes. Eighteen percent had a sleep latency of less than or equal to 15 minutes. Around one-fourth of the individuals had a sleep duration of more than 7 hours. Around 30% of the individuals had a sleep duration of either 6 to 7 hours or between 5 to 6 hours. However, a small percentage of study participants had a sleep duration of less than 5 hours. Ninety-seven percent of the study participants had <65% sleep efficiency. More than half of the study participants (58%; n = 55) reported sleep disturbances less than once a week, while 32% (n = 30) reported them once or twice a week. The majority of the individuals reported not using sleep medications. Around 66% reported some kind of daytime dysfunctions and reduced enthusiasm over the last month, due to sleep disturbances and inadequate sleep.

Table 9. Distribution of Pittsburgh Sleep Quality Index (PSQI) scores among participants.

Components of PSQI	Score of PSQI				
	0	**1**	**2**	**3**	**Total**
	n (%)				
Subjective Sleep Quality	**Very Good**	**Fairly good**	**Fairly bad**	**Very bad**	
	14 (16%)	57 (60%)	11 (12%)	12 (12%)	94 (100%)
Sleep Latency	**≤15minutes**	**16-30 minutes**	**16-60 minutes**	**≥31 minutes**	
	16(18%)	29 (32%)	27 (30%)	18(20%)	90(100%)
Sleep Duration	**>7hours**	**6-7 hours**	**5-6hours**	**<5 hours**	
	26 (28%)	28 (30%)	29 (32%)	9(10%)	92(100%)
Habitual Sleep Efficiency	>85%	75-84%	65-74%	<65%	
		3 (3%)	-	88(97%)	91(100)
Sleep Disturbance	**Not during the past month**	**Less than once a week**	**Once or twice a week**	**Three or more times a week**	
	2(2%)	55 (58%)	30 (32%)	7(8%)	94(100%)
Use of sleeping medications	**Not during the past month**	**Less than once a week**	**Once or twice a week**	**Three or more times a week**	
	86(92%)	5 (5%)	2 (2%)	1(1%)	94(100%)
Daytime dysfunctions, over the last month	**No problem at all**	**Only a very slight problem (less than once a week)**	**Somewhat of a problem (once or twice a week)**	**A very big problem (once or more than thrice)**	
	32(34%)	26 (28%)	28 (30%)	8(8%)	94(100%)

Health Belief Model (HBM) analysis of MetS self-management

HBM offered a structured lens to interpret the socio-cultural, behavioral, and environmental factors that influence self-management of MetS among individuals living in urban slum settings of Delhi. By integrating qualitative interviews with quantitative survey data, participant experiences were mapped across the six HBM constructs.

A thematic matrix presented in Table 10 summarizes the main HBM-based themes, their sub-themes, and participant perspectives and interpretations. It was found that the perceived susceptibility included stress, genetic predisposition, and lifestyle habits, while perceived severity reflected concerns about worsening health and comorbidities. These qualitative insights were supported by quantitative findings, such as 50% of participants reporting moderate stress, 66% reporting uncontrolled diabetes, and 83% never having checked their cholesterol. Perceived barriers included lack of time, physical ailments, unhealthy diets, economic hardship, and cultural restrictions like veiling among women, reflected in only 52% reporting regular physical activity. Thematic clustering and sentiment analysis highlighted the individualized and multifactorial nature of these challenges. Perceived severity and susceptibility were marked by anxiety about deteriorating health and lack of regular monitoring, reinforcing the psychological burden of MetS.

In contrast, perceived benefits and self-efficacy emerged in proactive behaviors such as dietary modification and exercise, though these were often inconsistent due to competing demands. Quantitatively, 57% reported dietary changes, 48% engaged in regular exercise, but only 29% demonstrated good medication adherence. Cues to action were evident in the near-universal desire for more information and health education, particularly on stress reduction and lifestyle modification. Despite limited awareness of MetS as a disease, 98% expressed interest in learning more, highlighting the potential for targeted interventions. Overall, self-management of MetS in this setting was found to be shaped by a complex interplay of personal, socio-cultural, and systemic factors.

Table 10. HBM-based thematic analysis of participant perceptions and behaviors related to MetS.

HBM-based Themes	Axial Coding	Supporting sub-themes (Open Coding)	Participants' perspective and Interpretation
Perceived Susceptibility	Perceived MetS risk	Genetic predisposition, Stress, Lack of Sleep, Dietary choices, Alcohol/tobacco consumption, Comorbidities, Sedentary behavior/inactivity	Perceived risk was shaped by stress, poor sleep, family history, and unhealthy behaviors such as "*I feel stressed and crave food*." Sedentary lifestyles and past tobacco or alcohol use were also recognized as increasing susceptibility.
Perceived Severity	Perceived MetS impact	Tiredness and lethargy, Fear of worse health, Food restrictions, deteriorating health, Medication side effects, Worsening Economic conditions, Comorbidities	Many participants expressed anxiety about worsening health and comorbidities, often without regular monitoring: "*I fear my condition worsening.*" A lack of awareness about MetS as a cluster of conditions contributed to uncertainty and fear.
Perceived Barriers	Challenges in MetS self-management	Time constraints, Physical hindrance, Unhealthy dietary choices, outside food, Lack of Sleep, Medicine distrust, Failing to Medication adherence, Medicine side-effects, Inactive lifestyle, Family Environment, Family economic status	Participants described a range of barriers to effective MetS self-management, including physical limitations, economic hardship, and cultural restrictions. For women, mobility was often constrained by social norms: "*Because of veil, I can't go for walks*" Economic constraints and stress-induced eating were also prevalent: "*Sometimes I feel so angry, thus, I crave to eat something tasty from outside*" Family responsibilities and medication side effects further complicated adherence, and some discontinued medication after feeling better, reflecting gaps in chronic disease understanding.
Perceived Benefits	Perceived MetS management benefits	Dietary modification improves health, maintaining a routine improves health, maintaining a routine improves health, Physical activities improve MetS condition, Medicine compliance helps MetS condition, Economic benefits, better productivity	Participants identified benefits to self-management such as dietary changes and medication adherence: "*Avoiding outside food has helped me save money and feel better.*" These perceived benefits motivated some to sustain healthy practices.
Self-efficacy	Perceived MetS Self-management	Self-monitoring, Medicine adherence and compliance, Timely diagnosis, Walking, Exercise, and Yoga, Controlled diet, restricting sugar & salt intake, Quitting outside food Habits, Quitting alcohol and smoking	Confidence in managing MetS varied. Some described consistent engagement in healthy behaviors: "*I use yoga and control food.*" However, most reported only moderate medication adherence, indicating a need for additional support.
Cue to Action	Perceived MetS Knowledge	Unawareness of MetS syndrome	While few participants recognized the term "Metabolic Syndrome," nearly all acknowledged health risks and expressed a desire for more information: "*I want to learn how to manage this better*". This strong motivation presents an opportunity for targeted education and intervention.
	Determination to improve MetS health	Curiosity to know about MetS self-management, Determination to follow the diet plan, and activities cues	

Sentiment distribution across Health Belief Model (HBM) constructs

Figure 3 presents the sentiment analysis of participant quotes mapped to key HBM themes. Most self-management-related quotes were neutral, reflecting a pragmatic approach to daily health behaviors. Quotes coded under perceived susceptibility were predominantly neutral, followed by negative, indicating that risk awareness often coexisted with concern or anxiety. For perceived barriers, neutral sentiment was most common, but a significant proportion of quotes were negative, highlighting the emotional burden and frustration associated with obstacles to MetS management. These sentiment patterns underscore the importance of supportive interventions that address not only informational gaps but also the psychological challenges faced by participants.

Discussion

Our study aimed to examine the self-management practices of Metabolic Syndrome (MetS) among the urban slum population of Delhi, guided by the HBM. These findings provide insights into the design and development of interventions to enhance self-management of MetS.

Results of our study showed that the majority of the study participants were overweight to obese, with elevated blood pressure and high blood glucose levels. Yet, the participants reported inconsistent self-monitoring of their weight, blood glucose, blood pressure, and cholesterol levels. Nearly a quarter of the study participants do not undergo a regular medical checkup. This could be attributed to the stress, lack of time and space, and financial constraints, as demonstrated from the qualitative data. The lack of consistent disease monitoring could lead to late diagnosis, poor disease management, and worsened health outcomes, highlighting the importance of self-monitoring in designing the intervention for urban slum population.

Results of our study showed that a good number of individuals in urban slum settings used mobile phones regularly; however, the literacy levels related to sending or reading a text message were low. Despite these limitations, the majority of the individuals agreed that receiving health information related to self-management of MetS would be very useful. This is an important finding to take into consideration when designing and developing digital health interventions to enhance MetS related self-management, especially among populations living in urban slum settings. Else, there is a risk of introducing a digital gap among individuals with high or poor technology literacy.

The analysis of 24-hour dietary recall data reveals that participants were generally sufficiently supplied with macronutrients-energy, proteins, carbohydrates, and fats. When compared to the recommended dietary allowances (RDA) of the Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN), the average percent consumption was found to be more than three-quarters of the RDA for all the macronutrients. Further, micronutrient intake presented a mixed pattern, with sufficient intake of vitamin A, while intake of vitamin E was overwhelmingly low, suggesting a deficiency in antioxidant nutrient consumption. A substantial difference among different genders was noticed in terms of fat profile and vitamin A intake, where female participants reported almost twice the consumption of SFA and MUFA compared to male participants. Further, vitamin E intake was about 35% higher in females. However, this finding cannot be generalized due to disproportionate gender distribution. While there is a basic awareness of the importance of diet and exercise in managing MetS, the adoption of healthier behaviors is limited. Time constraints, financial limitations, stress, and family preferences for unhealthy food were the barriers to self-management, as reported by the participants. Physical inactivity was often caused due to household responsibilities, joint pain, cultural norms, limited space, and perceptions that daily labor or commuting sufficed as exercise. These factors highlight the need for behavior-change interventions that address environmental and cultural barriers, while encouraging sustainable dietary and physical activity practices.

Poor sleep quality and stress management, as indicated by our findings, can have significant implications for physical and mental health, exacerbating conditions such as hypertension, diabetes, and depression [33], which are prevalent in low-income urban populations. These findings underscore the need for tailored interventions focusing on stress reduction, improving sleep quality, and addressing environmental and psychological factors affecting stress and sleep.

Results of our study revealed that participants had limited awareness of Metabolic Syndrome. Doctors were the primary source of health information, and diet-related health information was the most common advice that the participants received. More than half of the study participants reported no change in their treatment to manage their health condition, indicating limited access to healthcare, low motivation, and limited awareness. This suggests a need for a comprehensive multifactorial behavior change intervention to alleviate the risk burden of MetS by including educational modules related to contributing risk factors. Regular screening programs and comprehensive patient education are crucial steps to enhance self-management of MetS. Further, addressing socio-economic and environmental barriers, health literacy, and understanding the use of technology among urban slum populations is imperative to improving the overall health status of this population.

The perceived severity of MetS among participants was high, driven by worsening health conditions, food restrictions, medication side effects, poor economic conditions, and the presence of comorbidities. The high prevalence of uncontrolled diabetes and hypertension among participants points to a substantial burden of disease, compounded by a lack of awareness and regular health check-ups. This lack of awareness contributes to anxiety and fear about their health conditions, suggesting the need for increased health education and regular screening programs in these communities. Addressing susceptibility factors such as stress and sleep disturbance could potentially reduce the burden of MetS in this population. Study findings suggest that participants are aware of the positive impacts of healthy behaviors, which can be leveraged in designing interventions that promote sustainable self-management practices. Self-efficacy among participants was demonstrated through various self-management activities, including self-monitoring, medication adherence, engaging in physical activities, and dietary modifications. Low to moderate medication adherence indicated by the Morisky Adherence Scale underscores the need for strategies to enhance adherence. Awareness and education about MetS emerged as crucial cues to action for self-management. While most participants were unfamiliar with the term "Metabolic Syndrome," they recognized the health risks associated with high blood pressure, high blood glucose, and obesity. This awareness can be leveraged to provide a foundation for educating the community about MetS, and promoting proactive health behaviors.

There are a few limitations in this study that are worthwhile to mention. The findings are based on the self-reported information, which is subject to recall bias and social desirability bias, particularly in reporting dietary patterns, stress, and medication adherence. The sample was drawn from urban slum settings of Delhi; therefore, the findings may not be generalizable to other socioeconomic contexts.

In a few cases, qualitative narratives shaped the interpretation of quantitative results. For example, during interviews, participants usually associated poor dietary habits with stress and financial constraints, which may have given overemphasis on “stress” as an explanatory factor for the high rates of overweight (29.2%) and hypertension (41.7%). In another instance, the quantitative survey demonstrated that the majority of the participants consumed vegetables every day may have limited the development of more nuanced qualitative insights regarding dietary nutritional adequacy and cultural perceptions of diet.

Despite these limitations, the mixed methods approach provided a richer and more holistic understanding of the self-management of MetS, which would not have been possible through a single method alone.

Conclusions

This study highlights the valuable insights into the complex interplay between individual behaviors, environmental factors, and the pervasive influence of socio-cultural dynamics on the management of Metabolic Syndrome (MetS) among the urban slum population living in Delhi. The results demonstrate the need to include a multifaceted approach to design and developing targeted public health interventions based on socio-economic, behavioral, environmental and cultural context of the community to enhance the self-management of MetS among individuals living in urban slum settings of Delhi. Further, understanding the perceived contributors to MetS from a socio-economic lens highlights the interconnectedness of lifestyle

factors and their impact on health. Addressing these barriers through targeted interventions such as patient education, reminder systems, and support services could improve adherence and, consequently, health outcomes in this population.

Declarations

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Authors' Contribution

AJ conceptualized the study, designed the methodology, and wrote the original draft. SA and UA contributed to the conceptualization and provided critical review and insights. AG and BR reviewed the draft and provided additional insights. BM contributed to the project administration and supervision. MG reviewed the manuscripts and made final edits. AK and SS contributed to data curation and investigation.

Conflict of Interest

The authors have no financial or non-financial conflict of interests for disclosure.

Ethics and consent

The study is approved by the Indian Council of Medical Research – National Institute of Child Health & Development Research (formerly known as National Institute of Pathology) Institutional Human Ethics Committee in January 2022 with approval No. NIP-IEC/29-12-2021/05/01R1. The study adheres to the ethical principles outlined in the Declaration of Helsinki.

Written informed consent was available both in English and Hindi, and was obtained from each selected participant. Data confidentiality and anonymity of study participants were ensured.

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Data Availability Statement

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

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Figures

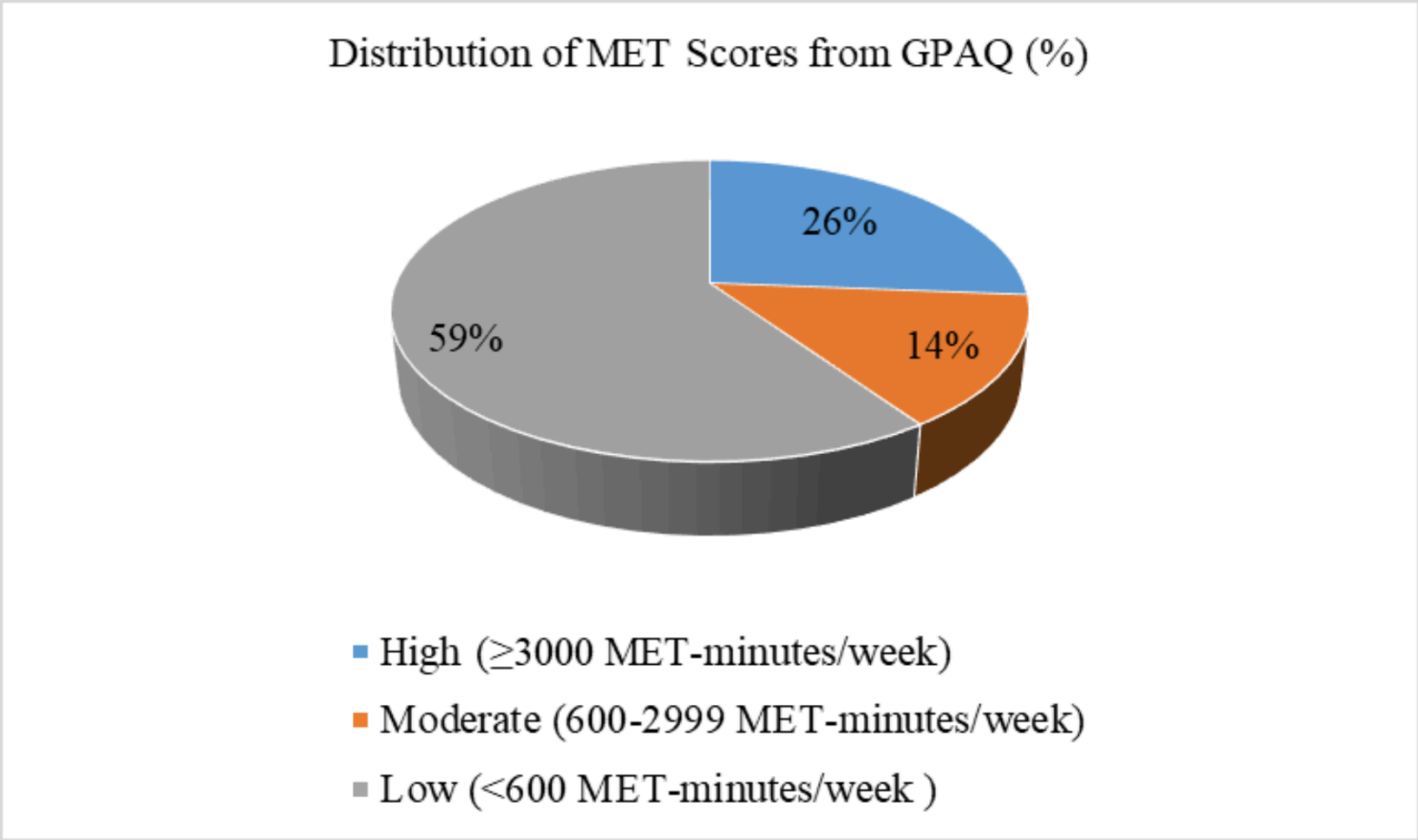


Figure 1

Frequency distribution of MET scores from Global Physical Activity Questionnaire

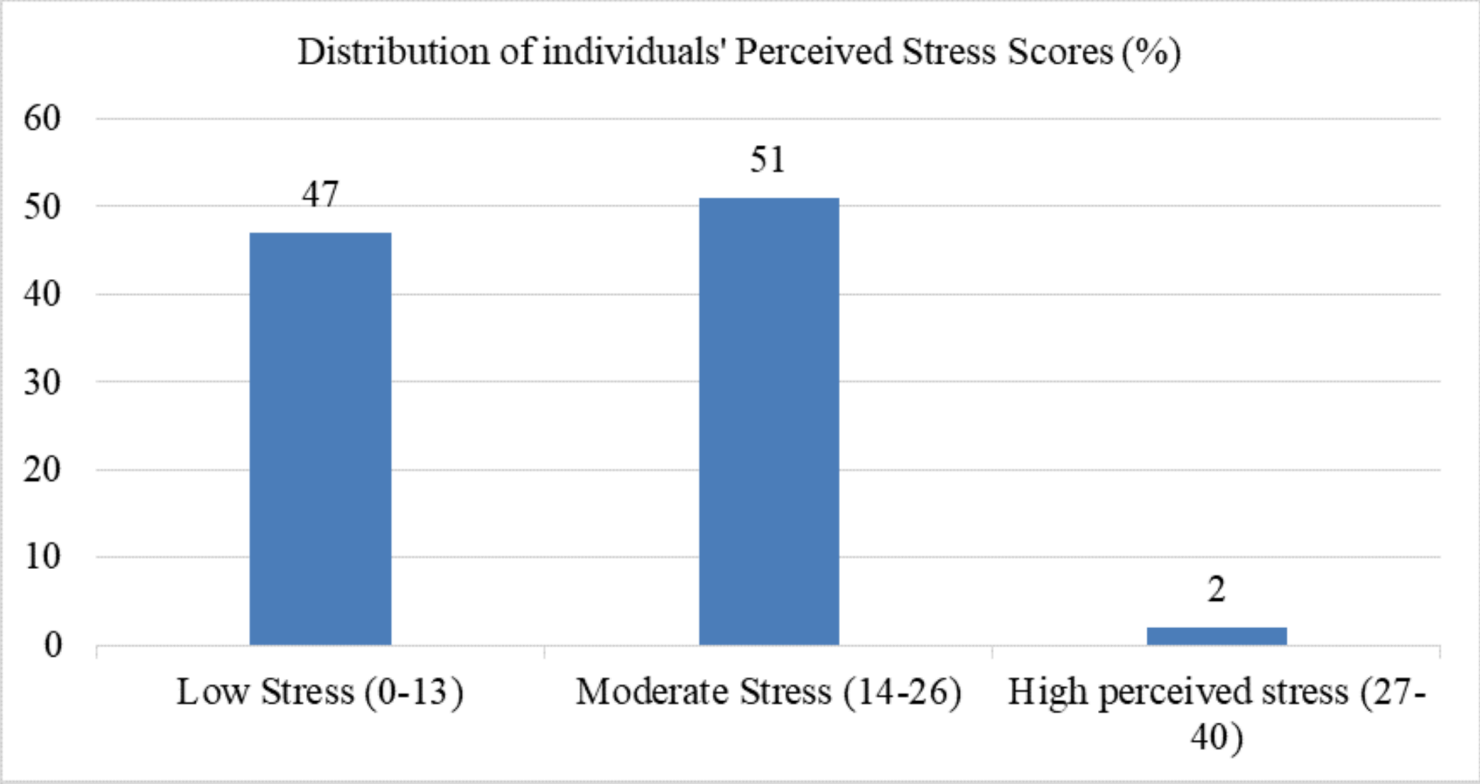


Figure 2

Frequency distribution of perceived stress levels based on PSS Scores

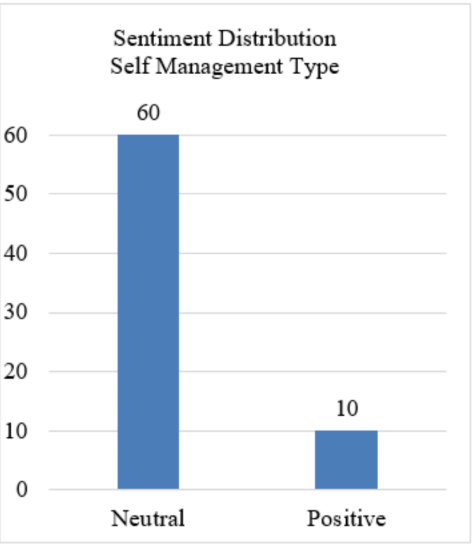


Fig 2. (**a**) Sentiment distribution of the self-management type among the respondents

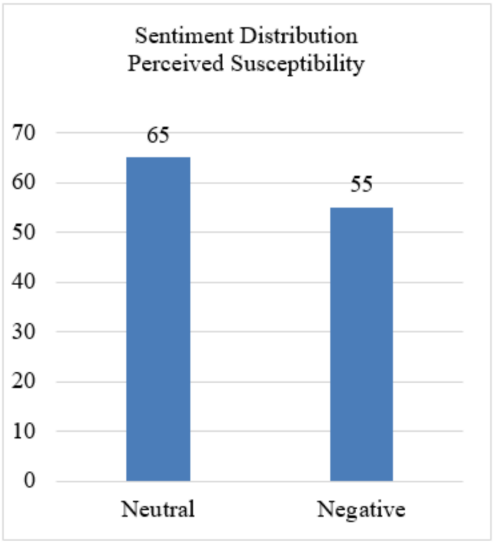


Fig 2. (b) Sentiment distribution of the perceived susceptibility type among the respondents

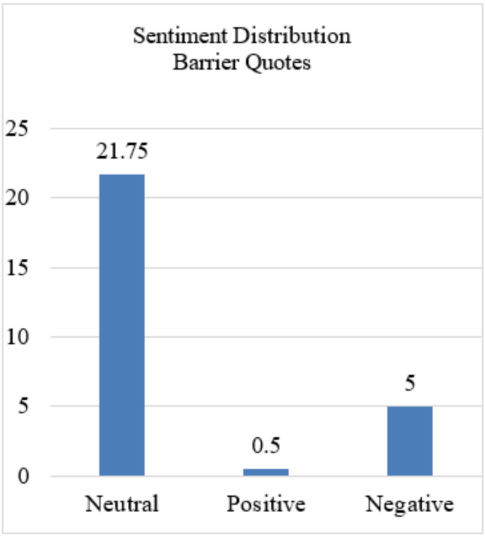


Fig 2. (c) Sentiment distribution of the barrier quote type among the respondents

Figure 3

Sentiment distribution for MetS related Self-Management, susceptibility, and barriers quotes