Journal of Associated Medical Sciences 2024; 57(3): 90-97

JAMS
Journal of Associated Medical Sciences

Scopus Indexed & Thai-Journal Citation Index Centre (TCI)

Journal of Associated Medical Sciences

Journal homepage: https://www.tci-thaijo.org/index.php/bulletinAMS/index



Association between sensory processing patterns and stress among community-dwelling people with metabolic syndrome

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ARTICLE INFO

Article history:
Received 16 May 2024
Accepted as revised 3 July 2024
Available online 7 July 2024

Keywords:
Sensory processing patterns, stress, metabolic syndrome, sensory preferences, sensory arousals.

ABSTRACT

Background: Stress is a risk factor for metabolic syndrome (MetS). High and low sensory stimulation can trigger high stress, but no research exists on the relationship between sensory processing patterns and stress among people with MetS.

Objective: This study examined the association between sensory processing patterns and stress.

Materials and methods: A total of 117 people with MetS in the Nam Phrea subdistrict, Hang-Dong District, Chiang-Mai Province, Thailand, aged 35-85, completed the Thai Sensory Patterns Assessment-Adult Version (TSPA) and the Thai Stress Test (TST-24). Demographic and metabolic variable information was gathered. Descriptive statistics were used to summarize the demographic characteristics and stress. Spearman's correlation and regression analysis examined the associations between the sensory processing patterns in each sensory modality and stress scores.

Results: A total stress score was significantly correlated with preferences in visual and auditory senses, as well as with arousal levels in visual and smell-taste senses (r =-0.397, -0.199, -0.358, 0.268, and p<0.05). Regression analysis revealed that stress can be predicted by preferences and arousal levels in visual and smell-taste senses (R^2 =0.156, 0.039, 0.174, and 0.050, respectively; p<0.05).

Conclusion: The results suggest that sensory processing patterns might associated with stress, which is a predictor of MetS. Health professionals can utilize acquired knowledge to implement sensory-based interventions for individuals with MetS to address their stress issues.

Introduction

Metabolic syndrome (MetS) is defined as a cluster of metabolic abnormalities, such as insulin resistance, visceral obesity, hypertension, and dyslipidemia.[1] Over the last decades, MetS has been considered a worldwide epidemic because of its increased prevalence in the general population, estimated at 25% of the world population[2, 3] and 20–27% of Thai adults.[4] Individuals with MetS have a greater risk of developing cardiovascular disease (CVD) in the next 5-10 years than those without MetS.[5] Thus, identifying and understanding the risk factors for MetS are important for both early screening and providing early intervention to prevent the increasing severity of MetS.

Recently, evidence has revealed psychological and behavioral risks for MetS, including unhealthy eating,[6] a sedentary lifestyle,[7,8] and stress.[9,10] Recent treatments have also focused directly on addressing these risks, but most treatments are not successful enough to minimize the

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doi: 10.12982/JAMS.2024.051
E-ISSN: 2539-6056

severe progression of MetS. Thus, a deeper understanding of these behavioral and psychological risks is necessary for understanding the mechanisms underlying unhealthy behaviors and emotions linked to the development of MetS.

Sensory Processing Patterns refer to how the brain receives, organizes, and responds to sensory information obtained from the environment in daily life.[11] These patterns are a crucial aspect of how individuals interact with the world around us, affect how they perceive and react to various stimuli, and shape human emotions and behaviors in healthy and unhealthy ways.[11,12] Importantly, sensory processing patterns influence an individual's ability to handle external and internal stimuli, which can impact their stress levels.[13] For instance, individuals with high arousal or sensitivity to sensory stimuli may experience higher stress levels due to their heightened sensitivity to stimuli, making it difficult for them to tolerate certain environments.[13] Conversely, those with low arousal or sensitivity to sensory stimuli may become stressed from the need to exert more effort to seek out sufficient stimuli to feel engaged.[11] Therefore, understanding an individual's sensory processing pattern is essential for developing effective strategies to manage stress.[13]

Moreover, evidence highlights the role of sensory processing patterns in many risks of MetS, especially stress.[14-18] Previous research has shown that people with sensory sensitivity is related to high stress.[18-20] and increased cortisol levels.[21] This is because individuals in this group are quicker to detect and react to specific sensory stimuli than those with typical sensory processing, making them more susceptible to feeling overwhelmed and stressed. The physiological response to stress, sustained over an extended period, can trigger metabolic abnormalities through the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axes, ultimately leading to the development of MetS.[10] Moreover, behavioral responses to stress are also associated with MetS, such as increased food consumption and reduced physical activity.[22] Therefore, investigating sensory processing patterns as determining stress factors among individuals with MetS is imperative for targeted interventions that consider sensory aspects in managing stress and, subsequently, the severity of MetS.

However, there is no research regarding the relationship between sensory processing patterns in specific modalities and stress among people with MetS. Specifying what sensory processing patterns predict stress in a particular sense is important for tailoring sensory-based interventions to support both physical and mental well-being to minimize the progression of MetS. Therefore, the aim of this study was to examine the relationships between sensory processing patterns in specific modalities and stress among community-dwelling people with MetS.

Materials and methods

This study used a correlational research design and received ethics approval from the Research Ethics Committee of the Faculty of Associated Medical Sciences, Chiang Mai University (No. AMSEC-65EX-071).

Participants

This study recruited 117 people with MetS (42 males and 75 females) aged 35 to 85 years (mean = 54.31±10.77) from the Nam Phrae subdistrict health promotion hospital, Hang-Dong District, Chiang-Mai province, Thailand. The inclusion criteria encompassed the presence of three metabolic risk factors, as delineated by the Harmonized Criteria for MetS,[1] which included elevated fasting blood glucose (FPG) levels ≥100 mg/dL, elevated blood pressure (BP) ≥130/85 mmHg, and waist circumference (WC) exceeding >90 cm (for males) and >80 cm (for females). The exclusion criteria were the presence of serious mental illness, sensory impairment, chronic diseases (e.g., thyroid, respiratory, liver, kidney, and cardiovascular diseases), or cognitive impairments screened by the Mental State Examination Thai 10 (MSET-10).[23]

Data collection materials

Demographic questionnaire

This questionnaire was used to gather data, including age, gender, education level, career status, and marital status.

Measures of metabolic risk factors

Capillary fasting blood glucose (CFBG) was measured by a nurse in the early morning (between 7:00 and 8:00 am) following a 12-hour fasting period. Blood pressure (BP) was assessed using an automatic sphygmomanometer with the participant seated following a 10-minute resting period. The mean of the two measurements was used to calculate the estimated blood pressure. Waist circumference (WC) was measured with a nonelastic circumference measuring tape. At the same time, the individual stood, rounded to the nearest 0.1 cm, and taken midway between the lowest rib and the iliac crest.

The Thai Sensory Patterns Assessment-Adult Version (TSPA)

The self-reported TSPA-adult version comprises 60 items divided into two parts: sensory preferences (35 items) and sensory arousals (25 items); each is divided into six categories based on sensory modalities. As confirmed by factor analysis, these include visual, auditory, smell and taste, tactile, proprioceptive, and vestibular senses. This questionnaire uses a 5-point Likert scale, in which participants rate how frequently they respond to sensory events in daily life.

In part of sensory preferences, there are 35 items for assessing the type of sensory stimulus that tends to make individuals feel affirmed, comfortable, and pleasurable. The items are divided into 6 categories, including visual (4 items), auditory (5 items), smell and taste (9 items), tactile (4 items), proprioceptive (8 items), and vestibular (5 items) senses. An example of sensory preference is: "I like eating sweets or smelling food." Participants responded to each item using a 5-point Likert scale: 1 = never, 2 = seldom, 3 = occasionally, 4 = frequently, 5 = always.

In part of sensory arousal, there are 25 items for assessing the alertness of the nervous system, which is affected by sensory input in daily life. The items are

also divided into 6 categories, including visual (3 items), auditory (6 items), smell and taste (3 items), tactile (3 items), proprioceptive (3 items), and vestibular (7 items) senses. An example item for sensory arousal is: "I can eat food that has a strong or pungent smell." Participants responded to each item using a 5-point Likert scale. The scale for items indicating high arousal was: 1 = never, 2 = seldom, 3 = occasionally, 4 = frequently, 5 = always. The scale was reversed for items indicating low arousal: 5 = never, 4 = seldom, 3 = occasionally, 2 = frequently, 1 = always.

The scores for each sensory modality in both two parts are aggregated and reported as a percentage, indicating low (below 25%), moderate (25-75%), or high (above 75%) sensory preferences or levels of sensory arousal. The TSPA has acceptable validity (IOC = 0.60 to 1.00 in parts 1 and 2) and reliability (ICC = 0.93, 0.77, Cronbach's alpha = 0.89, and 0.62 in parts 1 and 2).[24]

Thai Stress Test (TST-24)

The self-reported TST-24 consists of 24 items to assess both positive and negative psychological reactions to daily life events, and each item is rated on a 3-point scale from 1 to 3 (never = 0, sometimes = 1, and often = 3). The items were divided into negative (items 1-12) and positive (items 13-24) feelings, each of which were separately summed, with both having a possible range of 0 to 36 (higher scores indicating greater stress). The scores were then compared to a matrix table to obtain an index score, classifying the individual's stress into four levels (excellent mental health, normal mental health, mild anxiety, and stress). The Cronbach's alpha for the total test was 0.84, and the sprit half reliability coefficient for the total test was 0.88.[25]

Procedure

After obtaining approval from the Research Ethics Committee, the participants were recruited from the Nam Phrae subdistrict health promotion hospital from January 1st, 2023, to April 30th, 2023. Purposive sampling was employed for recruited participants. Initially, a physician screens individuals with MetS during the annual health checkup and screening for metabolic diseases, and then village health volunteers establish initial contact with eligible participants. A total of 145 individuals who met the diagnostic criteria for MetS were invited to participate in the study through advertisements via posted flyers and word-of-mouth done by the village health volunteers. Those who expressed interest in participating in this study directly contacted the researcher or the village health volunteers via phone. An assessor used the MSET-10 and asked them to complete a demographic questionnaire to ensure that they met the inclusion criteria. Finally, the 117 participants who met the inclusion criteria and agreed to participate in the study were asked to sign an informed consent form and then complete the questionnaire for gathering data on TSPA and TST-24.

Data analysis

The data was analyzed utilizing SPSS version 20 (SPAA Inc., USA) and STATA. Descriptive statistics were used to analyze demographic information, metabolic risk variables (CFBG, SBP, DBP, and WC), and stress scores. The Kolmogorov- Smirnov test was used to determine the normality of the distribution of variables. The test revealed that the sensory processing patterns and stress data did not follow a normal distribution. Therefore, the Spearman correlation test was employed to determine the relationships between sensory processing patterns in each specific modality and stress. Nonparametric regression or Kernel regression methods were used to determine whether stress can be predicted by sensory patterns in specific sensory modalities. The significance was set at the 0.05 level or below.

Results

Demographic characteristics

The general sample characteristics and metabolic risks are presented in Table 1. The participants were between 35 and 84 years old. Most participants were female (64.1%). Most participants have completed primary school (51.3%) and were married (65.8%). The means of the metabolic risk variables were as follows: capillary fasting blood glucose (CFPG) was 115.61 mg/dL, systolic blood pressure (SBP) was 135.06 mmHg, diastolic blood pressure (DBP) was 86.88 mmHg, and wrist circumference (WC) was 91.36 cm.

Table 1. Demographical characteristics and metabolic risk variables in people with MetS (N=117).

Variables	N (%)
Gender	
Male	42 (35.9)
Female	75 (64.1)
Education Levels	
Under primary school	17 (14.5)
Primary school	60 (51.3)
High school	32 (27.4)
Bachelor's degree	8 (6.8)
Postgraduate	0 (0)
Marriage status	
Single	18 (15.4)
Married	77 (65.8)
Divorced	9 (7.7)
Widowed	13 (11.1)
Age	
35-44 years	19 (16.2)
45-64 years	72 (61.6)
65 year and over	26 (22.2)
mean ± Std. Deviation	54.31±10.77
Metabolic risk variables	**Mean±SD**
Metabolic risks	
CFPG (mg/dL)	115.61±18.17
SBP (mmHg)	135.06±6.56
DBP (mmHg)	86.88±3.30
WC (cm)	91.36±9.37

Note: CFPG: capillary fasting blood glucose, SBP: systolic blood pressure, DBP: diastolic blood pressure, WC: wrist circumferences.

Stress

The stress scores are presented in Table 2. The mean negative stress score exceeded the mean positive (mean = 8.77 and 6.31, respectively). Additionally, most participants had low-stress levels (43.60%), as shown in Table 2.

Table 2. Stress scores and stress levels of people with MetS (N=117).

Variables	Minimum	Maximum	Mean	SD
Positive stress scores	0	24	6.31	4.93
Negative stress scores	0	36	8.77	7.34
Total stress scores	0	43	15.09	9.24
Stress levels n (%)				
Level 1: Good mental health	8 (6.80)			
Level 2: Normal	25 (21.40)			
Level 3: Low stress	51 (43.60)			
Level 4: High stress	33 (28.20)			

Correlation between sensory patterns and stress

As presented in Table 3, negative stress scores were negatively correlated with preferences in visual (r=-0.297, *p*=0.001) and auditory senses (r=-0.213, *p*=0.021), as well as with arousal levels in visual (r=-0.373, *p*=0.000), auditory (r=-0.244, *p*=0.008), and proprioceptive senses (r=-0.229, *p*=0.013). This indicates that individuals who do not prefer visual or auditory sensory inputs or had low arousal levels in visual, auditory, or proprioceptive senses were likelier to report experiencing negative stress.

Table 3. Correlations between sensory patterns and stress (N=117).

Sensory patterns	Negative stress score		Positive stress score		Total stress score	
	r	*p* value	r	*p* value	r	*p* value
P-visual	-0.297	**0.001***	-0.319	**0.000***	-0.397	**0.000***
P-auditory	-0.213	**0.021***	-0.140	0.133	-0.199	**0.031***
P-smell and taste	0.017	0.856	-0.233	**0.011***	-0.168	0.071
P-tactile	0.143	0.125	-0.103	0.271	0.009	0.921
P-vestibular	0.110	0.237	0.118	0.204	0.173	0.062
P-proprioceptive	0.117	0.208	-0.078	0.406	-0.016	0.868
A-visual	-0.373	**0.000***	-0.257	**0.005***	-0.358	**0.000***
A-auditory	-0.244	**0.008***	0.035	0.705	-0.085	0.360
A-smell and taste	0.164	0.078	0.260	**0.005***	0.268	**0.003***
A-tactile	0.145	0.119	-0.113	0.152	-0.036	0.701
A-vestibular	0.168	0.069	-0.195	**0.035***	-0.076	0.418
A-proprioceptive	-0.229	**0.013***	-0.004	0.969	-0.109	0.243

Note: P: preferences, A: arousal, p values were calculated using the Spearman correlation test, p≤0.05.*

A positive stress score was negatively correlated with preferences in visual (r=-0.319, *p*=0.000) and smell-taste senses (r=-0.233, *p*=0.011) and with arousal levels in visual (r=-0.257, *p*=0.005) and vestibular senses (r=-0.195, *p*=0.035), except for arousal levels in smell-taste senses, which showed a positive correlation (r=0.260, *p*=0.005). This indicates that individuals who do not prefer visual or smell-taste sensory inputs or had low arousal levels in visual or vestibular senses were likelier to report experiencing positive stress. However, individuals with high arousal levels in the smell-taste sense were more likely to report experiencing positive stress.

The total stress scores were negatively correlated with preferences for the visual (r=-0.397, *p*=0.000) and auditory senses (r=-0.199, *p*=0.031) and with arousal levels in the visual sense (r=-0.358, *p*=0.000). In contrast, they were positively correlated with arousal levels in the smell-taste senses (r=0.268, *p*=0.003). This indicates that individuals who do not prefer visual or auditory sensory inputs or who have low arousal levels in a visual sense were more likely to report experiencing stress. However, individuals with high arousal levels in the smell-taste sense were also more likely to report experiencing stress.

Predicting stress by sensory patterns

As presented in Table 4, the Kernel regression analysis revealed that both preferences and arousal levels in visual and smell-taste senses were significant predictors of stress (R^2=0.156, 0.039, 0.174, 0.050; *p*=<0.001, 0.040, <0.001, 0.026, respectively), as well as preference in vestibular sense (R^2=0.044; *p*=0.016). However, the R^2 values or the coefficient of determination, which indicate the proportion of the variance in stress that can be explained by sensory pattern predictors, were relatively low (ranging from 0.039-0.174). This means that the sensory processing patterns could predict 3.9%-17.4% of the variability in the stress (dependent variable). This suggests that these predictors could explain or predict a smaller portion of the variation in stress levels.

Table 4. Sensory patterns predictors of total stress score (N=117).

Dependent variable	Predictor variables	Coefficient	Bootstrap estimate of SE	R^2	*p* value
Total stress scores	P-visual	-0.221	0.043	0.156	**<0.001***
	P-auditory	-0.101	0.065	0.097	0.118
	P-smell and taste	-0.152	0.074	0.039	**0.040***
	P-tactile	-0.001	0.115	0.071	0.993
	P-vestibular	0.176	0.073	0.044	**0.016***
	P-proprioceptive	0.012	0.067	0.002	0.859
	A-visual	-0.177	0.040	0.174	**<0.001***
	A-auditory	-0.094	0.088	0.030	0.289
	A-smell and taste	0.112	0.050	0.050	**0.026***
	A-tactile	-0.016	0.059	0.041	0.784
	A-vestibular	-0.023	0.059	0.015	0.693
	A-proprioceptive	0.060	0.123	0.083	0.627

Note: P: preferences, A: arousal, p values were calculated the kernel regression analysis, p ≤ 0.05.*

Discussion

The main findings of the present study are that sensory processing patterns, both in terms of sensory preferences and levels of sensory arousal, are associated with stress among people with MetS.

Relationship between levels of sensory arousal and stress sensory processing patterns

The findings showed that levels of sensory arousal in smell-taste senses were positively correlated with stress. This means that individuals who more quickly register smell-taste stimuli were likelier to report experiencing higher stress levels. This finding aligns with previous studies on the relationship between sensory sensitivity (high levels of sensory arousal) and high stress,[18-20, 26,27] but prior studies were often performed only in healthy adults. This study has shown that higher sensory arousals are also associated with higher stress in adults with MetS. Furthermore, while most previous studies did not clearly establish whether specific sensory modalities were related to stress, this finding demonstrated that higher stress was associated with higher arousal levels, especially in smell and taste. The link between the senses of smell and taste and the emotional system is well established. The olfactory and gustatory system is closely linked to the limbic system in the brain, which plays a crucial role in processing emotions and memories.[28,29] Therefore, individuals with high arousal to smell and taste stimuli are more prone to feeling overwhelmed, especially in environments with strong or unpleasant stimuli.

Moreover, the findings also showed that stress was negatively correlated with arousal levels in the visual sense. This means that lower arousal levels in response to visual stimuli were associated with higher stress levels, or, in other words, individuals who experience low arousal from visual stimuli tend to report high stress. This finding is consistent with earlier studies, which have shown that a problem in noticing or detecting sensory input, especially a low registration, is also related to stress.[18] However, this study specified specific senses associated with greater stress levels, including lower sensory arousals in visual, auditory, vestibular, and proprioceptive senses. According to Cox and Mackay,[30] stress is a human perception resulting from comparing a person's ability to cope with environmental demands. People with low arousal levels in the abovementioned senses might put extra effort or pressure on themselves to avoid threats or dangers in everyday situations, causing them stress. Furthermore, because the abovementioned sensory modalities are involved in human survival, a lack of sensory awareness might contribute to feelings of insecurity, ultimately leading to increased stress responses.

Therefore, the finding suggested that both under and over-sensory stimulation from certain stimuli can trigger stress.

Associations between low sensory preference and high stress

The new aspects highlighted in this study, which also expand upon previous studies by including an assessment of sensory preferences in specific modalities, have shown that stress was negatively correlated with preferences for visual, auditory, and smell-taste senses. This means that individuals with lower preferences for or do not prefer visual, auditory, and smell-taste stimuli in their daily lives are more likely to report experiencing higher stress levels. Generally, each person has different sensory experiences and develops individualized memories across their life span.[11] The memories make every person unique in the sense they prefer or do not prefer. Exposure to unpleasant sensory stimuli makes people more likely to become overwhelmed and have heightened stress responses.[31,32] Previous studies showed that unpleasant odor stimuli can cause stress,[33,34] while pleasant sensory stimuli promote healing and relaxation in mammals.[33] Therefore, when providing intervention to deal with stress, an individual's sensory preferences should be considered, especially visual, auditory, and smell-taste senses.

Although the correlations between sensory processing patterns and stress were found at low to medium levels (R-values ranged from -0.397 to 0.268), they still highlight the importance of understanding individuals' sensory processing patterns in managing stress. According to the findings, under-stimulation, over-stimulation, and unpleasant stimulation from certain sensory modalities, particularly visual, auditory, and smell-taste stimuli, could contribute to stress levels. Therefore, health professionals should incorporate sensory processing assessments into their evaluation and treatment processes to understand how individuals respond to sensory stimuli. By identifying whether an individual is more sensitive (high arousal) or less sensitive (low arousal) to these stimuli, health professionals can tailor interventions to either minimize sensory overload or provide necessary sensory stimulation. This personalized approach can help individuals manage stress levels and improve overall well-being.

Predicting stress by sensory processing patterns

The findings highlighted the possibility of using sensory processing patterns as predictors of stress, specifically low preferences for visual and smell-taste senses, low arousal levels in the visual sense, and high arousal levels in the smell-taste sense. Based on these findings, people with those sensory patterns are at high risk of suffering from chronic stress triggered by sensory stimuli in daily life. Neuroendocrine hormones released during stress may cause increased activation of the SAM and HPA axes, altering metabolic abnormalities and increasing the severity of MetS.[10] People in those groups should receive sensory-based interventions that consider their sensory needs to modulate high-stress levels triggered by those sensory stimuli in daily life in order to prevent serious mental health problems related to the development of chronic diseases.

However, the findings showed that the coefficient of determination (R^2), which indicates the proportion of the variance in the dependent variable (stress) that is predictable from the predictors (sensory processing

patterns) in a regression model, was relatively low (R^2 values ranged from 0.039 to 0.174). This means that the sensory processing pattern variables could predict 3.9% to 17.4% of the variability in the stress variable. This finding suggests that while sensory preferences and arousal levels in visual, auditory, smell-taste, and vestibular senses were significant predictors of stress, other factors not examined in this study and not included in the current regression model might play substantial roles in influencing the stress experiences of participants. The factors could consist of individual factors or environmental influences.[35] Furthermore, the stress responses may also be influenced by the dynamic nature of sensory experiences and their interaction with individual perceptions, coping mechanisms, and socio-economical and situational contexts.[13,29,35] Therefore, future research could explore these factors in greater depth to provide a more comprehensive understanding of how sensory processing patterns impact stress responses across different populations and contexts. Additionally, investigations into multifaceted factors contributing to stress experiences beyond sensory modalities alone are needed.

The finding showed an association between sensory processing patterns and stress. However, it is important to note that implementing sensory-based interventions should be personalized due to individual differences in sensory processing patterns.[11] Therefore, health professionals should collaborate with patients to specify whether sensory stimuli can trigger a stress response. This information can help therapists suggest sensory environments, coping strategies, activities, or routines that can support sensory needs and address stress in daily life while being appropriate with what the individual truly wants or needs to do to support physical and mental health.

Limitations

A small sample size could limit the generalizability of the findings, which may not represent the larger population. Furthermore, relying on self-reported participant data introduces subjectivity and potential reporting bias. Future research should consider using a larger and more diverse sample to increase the robustness and applicability of the findings. In addition, incorporating multiple data collection methods, such as objective assessments based on biochemical testing for stress hormones (e.g., salivary cortisol testing or blood cortisol testing), could also provide more comprehensive and validated results.

Conclusion

The results of this study indicated that sensory processing patterns, especially preferences and arousal levels in the visual and smell-taste senses, were associated with and potentially predictors of stress. The findings may assist health professionals in tailoring sensory-based environments, strategies, and interventions to support stress reduction and minimize MetS progression.

Conflict of interest

The authors declare no conflict of interest.

Funding

This research was supported by the Faculty of Associated Medical Sciences, Chiang Mai University, under Grant AMS-2023.

Acknowledgements

This research was supplied by the Department of Occupational Therapy, Faculty of Associated Medical Sciences, Chiang Mai University.

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