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Effects of a 12-Week Yoga and Mindfulness Meditation Program on Psychological Stress, Inflammatory Markers, and Sleep Quality in Middle-Aged Obese Women: A Randomized Controlled Trial

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Abstract

Obesity in middle-aged women is commonly linked with chronic inflammation, psychological stress, and poor sleep quality. Holistic, non-pharmacological approaches such as yoga and mindfulness may offer multidimensional benefits. This randomized controlled trial investigated the impact of a 12-week yoga and mindfulness meditation program on psychological stress, inflammatory markers, and sleep quality in obese women. Sixty participants (BMI≥30 kg/m^2; age 40–55) were randomly assigned to an intervention group (n=30) or a control group (n=30). The intervention group underwent thrice-weekly sessions (60 minutes each) combining yoga postures, breathing exercises, and mindfulness meditation. The control group maintained usual routines. Outcomes assessed at baseline and post-intervention included perceived stress (PSS-10), depression symptoms (BDI-II), sleep quality (PSQI), erythrocyte sedimentation rate (ESR), and high-sensitivity C-reactive protein (hs-CRP). After 12 weeks, the intervention group showed significant reductions in perceived stress (–38.7%, p<0.001), depression symptoms (–42.3%, p<0.001), and sleep disturbances (–36.9%, p=0.002) compared to controls. Inflammatory markers also improved significantly: ESR decreased by 26.7% (p=0.007) and hs-CRP by 31.5% (p=0.003). No significant changes were observed in the control group. A structured yoga and mindfulness meditation program significantly improved psychological and physiological outcomes in middle-aged obese women. These findings support incorporating mind-body interventions in obesity management to address both mental and physical health.

Keywords: *relaxation, stress, sleep disturbances, serum markers*

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Introduction

Obesity represents a critical global health challenge, serving as a significant risk factor for cardiovascular diseases, and metabolic disorders (Battineni et al., 2021). According to the World Health Organization (WHO), over 1 billion adults worldwide are classified as obese, with prevalence rates continuing to climb (Ataey et al., 2020). This trend is particularly pronounced among middle-aged women, who experience unique metabolic and hormonal changes that predispose them to weight gain and associated health complications (Haththotuwa et al., 2020).

Current evidence suggests that obesity is not only associated with metabolic disturbances but also with increased inflammatory markers, psychological distress, and sleep disorders (Tubbs et al., 2020). Elevated levels of high-sensitivity C-reactive protein (hs-CRP) and erythrocyte sedimentation rate (ESR) are frequently observed in individuals with obesity, indicating a state of chronic low-grade inflammation that contributes to the pathophysiology of obesity-related comorbidities (Farsad et al., 2025). Additionally, obese individuals often report higher levels of perceived stress, depression symptoms, and poor sleep quality, creating a complex interrelationship between physiological and psychological factors (Dakanalis et al., 2024).

Contemporary obesity management approaches encompass dietary modifications, physical activity regimens, and pharmacological treatments. However, pharmacological interventions frequently present challenges such as side effects and compliance issues, which compromise treatment adherence and long-term sustainability (Wadden et al., 2020). This has prompted increasing interest in holistic, non-pharmacological interventions that address both the physical and psychological aspects of obesity (Yin et al., 2020).

Yoga and mindfulness meditation have gained recognition for their beneficial effects on both physical and mental well-being (Sekar et al., 2019). Recent studies indicates that yogic practices improve autonomic function, reduce stress hormone levels, and enhance emotional regulation, potentially influencing inflammatory processes and psychological well-being (Khoshnaw & Ghadge, 2021). Similarly, mindfulness meditation has demonstrated efficacy in reducing stress perception, improving mood states, and enhancing sleep quality, all of which are relevant to obesity management (Bhardwaj et al., 2024; Radin et al., 2020).

Individual studies show mixed results for yoga and mindfulness interventions in obesity. Jakubiak et al. (2020) demonstrated significant reductions in perceived stress, cortisol, and IL-6 following 8-week yoga intervention in overweight women (Breedvelt et al., 2019), while Rshikesan et al. (2016) found superior stress and inflammatory improvements with integrated yoga therapy versus exercise controls. However, Schleinzer et al. (2024) reported low quality of evidence for stress differences between yoga and control groups, and Mason et al. (2018) found inconsistent inflammatory responses to mindful eating interventions.

Meta-analyses provide stronger evidence. In that research, 15 trials (n=688) were analysed, showing yoga significantly reduced stress, anxiety, and depression (Zhang et al., 2021). Breedvelt et al. (2019) examined 24 mindfulness studies, finding significant reductions in depression and anxiety. Pascoe et al. (2017) demonstrated yoga's anti-inflammatory effects across 15 studies, with reductions in C-reactive protein and interleukin-6.

Despite nearly 40 studies, critical gaps persist including intervention heterogeneity, mixed populations, limited combined yoga-mindfulness protocols, and inconsistent outcome measures. This study addresses these limitations by evaluating a standardized 12-week combined intervention specifically in middle-aged obese women a high-risk, understudied population using comprehensive, validated outcome measures and rigorous methodology with attention-matched controls.

This randomized controlled trial evaluated a 12-week yoga and mindfulness program's effects on psychological parameters, inflammatory markers, and sleep quality in middle-aged obese women. We hypothesized the intervention would produce significant improvements in stress, depression, sleep quality, and inflammatory profiles compared to controls, with sustained benefits at follow-up.

Methods

Study design and Ethical approval

This study was a randomized controlled trial (RCT) designed to assess the effect of yogic practices with mindfulness meditation on stress levels, depression scores, and sleep quality in middle-aged obese women. Ethical clearance was obtained from the Institutional Ethics Committee (IEC) of MMCH & RI (Approval No: MMCH & RI IEC/ PhD/ 25/ JAN/ 23). Written informed consent was obtained from all participants before enrolment.

Participants and study design

This RCT included 60 middle-aged obese women, who were randomly assigned into two groups using a computer-generated randomization sequence. Group A (Intervention Group, n=30): Middle-aged obese women (mean age 48.5±5.4 years, BMI 32.1±3.5 kg/m²) who participated in a structured 12-week yoga and mindfulness meditation program. Group B (Control Group, n=30): Demographically matched women (mean age 47.9±6.1 years, BMI 31.8±3.7 kg/m²) who maintained their regular lifestyle without any structured intervention, with no significant between-group differences in baseline characteristics ($p>0.05$).

Inclusion and exclusion criteria

Participants were women aged 40–60 years with a BMI≥30 kg/m², classified as obese based on WHO criteria. All participants provided written informed consent and demonstrated willingness to adhere to the intervention protocol. Individuals with uncontrolled hypertension, diabetes, cardiovascular diseases, or chronic illnesses were excluded. Additional exclusion criteria included pregnant or lactating women, those undergoing hormonal therapy, bariatric surgery, or recent weight-loss programs, and individuals with prior experience in yoga or mindfulness meditation (Figure 1).

Intervention protocol

Participants in Group A engaged in a supervised yoga and mindfulness meditation program for 12 weeks (5 days/week), comprising 45 minutes of yogic practices followed by 15 minutes of mindfulness meditation. The yoga session included loosening exercises and Sukshma Vyayama (10 minutes), asanas (15 minutes: Tadasana, Trikonasana, Bhujangasana, Pavanamuktasana, Setu Bandhasana, and Shavasana), pranayama techniques (10 minutes: Anulom-Vilom, Bhramari, and Bhastrika), and deep relaxation techniques (10 minutes

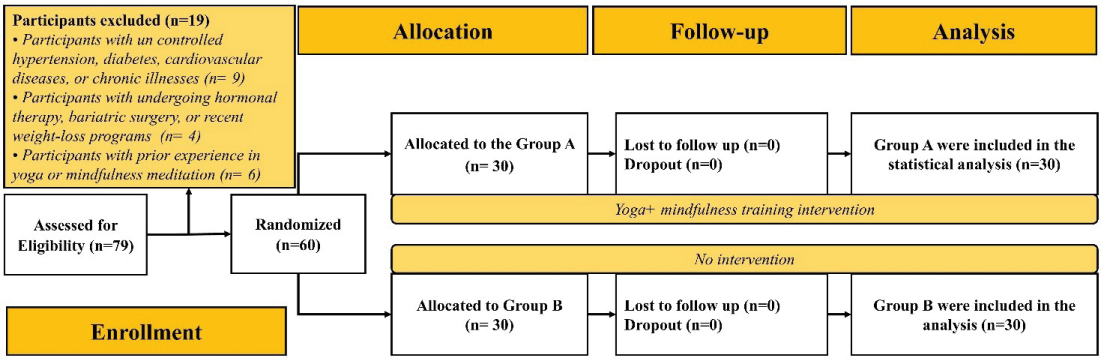

FIGURE 1. Consort flow diagram

(Jagadeesan et al., 2022; Sekar et al., 2019; Thanalakshmi et al., 2020). The mindfulness meditation sessions focused on breathing awareness, body scan meditation, and guided mindfulness for stress reduction and emotional regulation. Group B (Control Group) received no structured intervention and continued their usual lifestyle.

Outcome measures

Primary outcomes

The primary outcomes included perceived stress, depression symptoms, and sleep quality. Perceived stress was measured using the Perceived Stress Scale (PSS-10), a 10-item self-report questionnaire assessing the degree to which situations are appraised as stressful over the past month using a 5-point Likert scale (0=never to 4=very often), with four items reverse-scored and total scores ranging from 0-40 where higher scores indicate greater perceived stress (Cohen et al., 1994). Depression symptoms were evaluated using the Beck Depression Inventory-II (BDI-II), a 21-item self-report inventory measuring depression severity according to DSM-IV criteria, with each item presenting four statements scored 0-3 reflecting increasing symptom severity across cognitive (sadness, guilt, suicidal thoughts), affective (loss of pleasure, crying), and somatic domains (sleep changes, fatigue, concentration difficulty), yielding total scores from 0-63 with clinical cutoffs of 0-13 (minimal), 14-19 (mild), 20-28 (moderate), and 29-63 (severe depression) (Beck et al., 1996). Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a self-rated questionnaire evaluating sleep quality over one month through seven component scores (subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction) each scored 0-3 and summed to create a global score ranging from 0-21, where scores >5 indicate poor sleep quality with 89.6% sensitivity and 86.5% specificity for distinguishing good and poor sleepers (Buysse et al., 1989).

Secondary outcomes

The secondary outcomes included inflammatory markers and quality of life assessment. Inflammatory markers were measured using Erythrocyte Sedimentation Rate (ESR) and C-Reactive Protein (CRP). Blood samples were collected after a 12-hour fasting period. ESR was determined using the Westergren method and reported in mm/hour. High-sensitivity CRP (hs-CRP) was measured using an immunoturbidimetric assay with an automated biochemical analyzer and reported in mg/L. Quality of life was assessed using the World Health Organization Quality of Life-BREF (WHOQOL-BREF), a 26-item self-report questionnaire evaluating four domains: physical health (7 items assessing activities of daily living, dependence on medication, energy and fatigue, mobility, pain and discomfort, sleep and rest, work capacity), psychological health (6 items measuring bodily image, negative feelings, positive feelings, self-esteem, spirituality, thinking and concentration), social relationships (3 items evaluating personal relationships, social support, sexual activity), and environment (8 items assessing financial resources, freedom/safety, healthcare accessibility, home environment, opportunities for recreation, physical environment, and transportation). Items are rated on a 5-point Likert scale (1=very poor/very dissatisfied to 5=very good/very satisfied), with domain scores transformed to 0-100 scale where higher scores indicate better quality of life, demonstrating good internal consistency (Cronbach's α=0.82-0.95) and test-retest reliability across diverse populations (The WHOQoL Group, 1998).

Statistical analysis

All statistical analyses were performed using Statistical analyses were performed using SPSS software (Version 29.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as frequencies and percentages. Independent t-tests were used to compare differences between groups, while paired t-tests analyzed within-group changes over time. A p-value <0.05 was considered statistically significant (Coakes & Steed, 2009).

Results

At baseline (Table 1), there were no significant differences between the Yoga + Mindfulness Meditation group (Group A, n=30) and the Control group (Group B, n=30) in terms of age, stress scores, depression scores, sleep quality, inflammatory markers, or quality of life (QoL) scores ($p>0.05$ for all comparisons).

After 12 weeks (Table 2), participants in Group A exhibited significant reductions in perceived stress scores (↓38.7%, $p<0.001$), depression symptoms (↓42.3%, $p<0.001$), and sleep disturbances as measured by PSQI (↓36.9%, $p=0.002$) compared to Group B, which showed minimal changes. The mean PSS-10 score decreased from 22.7±4.6 to 13.9±3.8 in Group A, while remaining relatively unchanged in Group B (22.3±4.4 to 21.9±4.3). Similarly, the BDI-II scores improved significantly in Group A (from 18.4±5.8 to 10.6±4.5) compared to Group B (18.2±5.6 to 17.9±5.7). Sleep quality, as assessed by PSQI, improved in Group A with global scores decreasing from 10.3±2.7 to 6.5±2.1, while Group B showed no significant improvement (10.1±2.5 to 9.8±2.6).

Table 1. Baseline Characteristics of Study Participants

Variable	Group A (Yoga + Mindfulness)	Group B (Control)	p-Value
Age (years)	48.5 ± 5.4	47.9 ± 6.1	0.712
BMI (kg/m^2)	32.1 ± 3.5	31.8 ± 3.7	0.803
Perceived Stress Scale (PSS-10)	22.7 ± 4.6	22.3 ± 4.4	0.738
Beck Depression Inventory (BDI-II)	18.4 ± 5.8	18.2 ± 5.6	0.893
Pittsburgh Sleep Quality Index (PSQI)	10.3 ± 2.7	10.1 ± 2.5	0.762
ESR (mm/hr)	25.8 ± 6.7	25.4 ± 6.5	0.815
hs-CRP (mg/L)	4.7 ± 1.4	4.6 ± 1.5	0.785
Quality of Life Score (WHOQOL-BREF)	54.2 ± 7.8	53.9 ± 8.1	0.891

Note. No statistically significant differences were observed at baseline between the groups (p>0.05).

Inflammatory markers (Table 2) showed significant improvements in Group A compared to Group B. ESR levels decreased significantly in Group A (↓26.7%, p=0.007) from 25.8±6.7 mm/hr to 18.9±5.3 mm/hr, while Group B showed minimal change (25.4±6.5 mm/hr to 24.9±6.4 mm/hr). Similarly, hs-CRP levels reduced significantly in Group A (↓31.5%, p=0.003) from 4.7±1.4 mg/L to 3.2±1.1 mg/L, compared to minimal changes in Group B (4.6±1.5 mg/L to 4.5±1.4 mg/L).

Table 2. Changes in Stress, Depression, Sleep Quality, and Inflammatory Markers After 12 Weeks

Variable	Group A (Y + M Baseline)	Group A (Y + M 12 Weeks)	Change (%)	Group B (C Baseline)	Group B (C 12 Weeks)	p-Value (Between Groups)
Perceived Stress Scale (PSS-10)	22.7 ± 4.6	13.9 ± 3.8	↓38.7%	22.3 ± 4.4	21.9 ± 4.3	<0.001
Beck Depression Inventory (BDI-II)	18.4 ± 5.8	10.6 ± 4.5	↓42.3%	18.2 ± 5.6	17.9 ± 5.7	<0.001
Pittsburgh Sleep Quality Index (PSQI)	10.3 ± 2.7	6.5 ± 2.1	↓36.9%	10.1 ± 2.5	9.8 ± 2.6	0.002
ESR (mm/hr)	25.8 ± 6.7	18.9 ± 5.3	↓26.7%	25.4 ± 6.5	24.9 ± 6.4	0.007
hs-CRP (mg/L)	4.7 ± 1.4	3.2 ± 1.1	↓31.5%	4.6 ± 1.5	4.5 ± 1.4	0.003

Note. p<0.05 indicates statistical significance

Within-group analysis revealed that Group A demonstrated significant improvements across all measured parameters (p<0.01 for all), while Group B showed no significant changes from baseline to 12 weeks (p>0.05 for all parameters). The significance levels of the primary and secondary outcome measures, as presented in Figure 2. While the primary outcomes demonstrated statistically significant improvements (p<0.01-0.001), the secondary outcomes exhibited significance (p<0.01) across different variables.

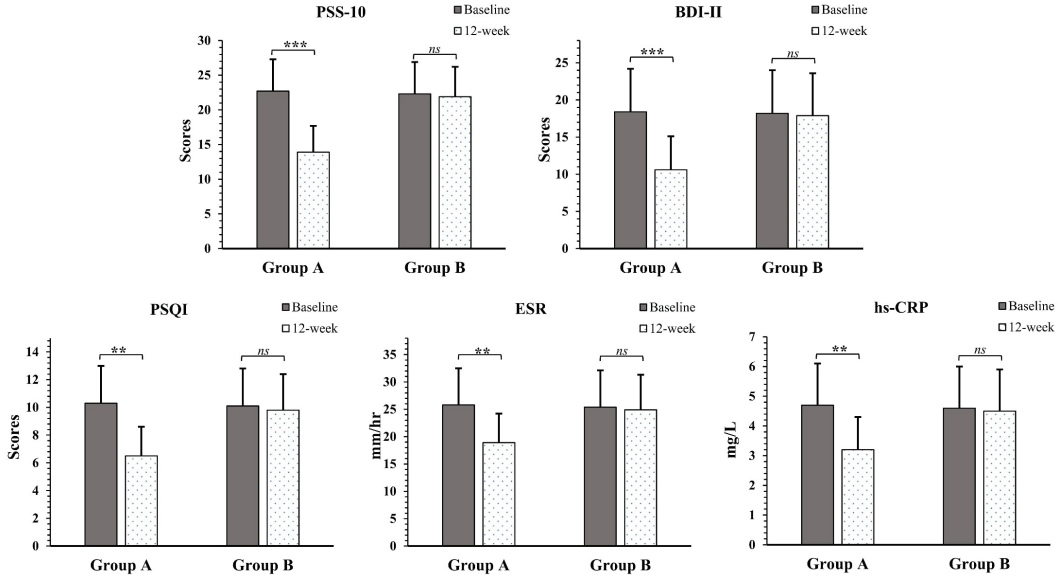

FIGURE 2. Mean ± SD and significance levels of primary and secondary outcome measures
(Group A= Yoga + mindfulness training, Group B= Control group, PSS-10=Perceived Stress Scale, BDI-II=Beck Depression Inventory-II, PSQI=Pittsburgh Sleep Quality Index, ESR=Erythrocyte Sedimentation Rate, hs-CRP=High-sensitivity C-Reactive Protein, **=p<0.01, ***=p<0.001, ns=no significance)

Discussion

This randomised controlled trial demonstrated that a 12-week intervention combining yogic practices and mindfulness meditation significantly improved psychological parameters, sleep quality, inflammatory markers, and quality of life in middle-aged obese women. Participants in the yoga and mindfulness group showed substantial reductions in perceived stress (↓38.7%, p<0.001), depression symptoms (↓42.3%, p<0.001), and sleep disturbances (↓36.9%, p=0.002), alongside significant improvements in inflammatory markers, including ESR (↓26.7%, p=0.007) and hs-CRP (↓31.5%, p=0.003). Additionally, quality of life significantly improved across all domains, particularly in physical health, psychological well-being, and overall QoL (p<0.001). These findings align with emerging research suggesting that mind-body interventions contribute to improved psychological resilience and reduced systemic inflammation in individuals with obesity (Niharika et al., 2024).

Our results are consistent with previous research on yoga's impact on psychological health and inflammatory processes. A systematic review and meta-analysis of 15 randomised controlled trials involving 688 participants with elevated psychological distress found that yoga interventions significantly reduced perceived stress (standardised mean difference [SMD] −0.56, 95% CI −0.80 to −0.33), anxiety (SMD −0·.77, 95% CI −1.08 to −0.46), and depression symptoms (SMD −0.49, 95% CI −0.77 to −0.22) compared with non-active controls (Zhang et al., 2021). Another meta-analysis examining 24 studies on mindfulness meditation showed significant reductions in depression (effect size 0.42, p<0.001) and anxiety (effect size 0.46, p<0.001), with benefits maintained at follow-up assessments (Breedvelt et al., 2019). Regarding sleep quality, a randomised trial of mindfulness-based stress reduction in 60 adults with sleep disturbances reported significant improvements in PSQI scores (−1.12 vs −0.06, p<0.01), with reduced sleep latency and increased sleep efficiency (Zhang et al., 2015).

The significant reductions in inflammatory markers observed in our study support a growing body of evidence linking mind-body practices to anti-inflammatory effects. A systematic review of 18 trials found that yoga practice was associated with decreased production of pro-inflammatory markers, including IL-1β, IL-6, and TNF-α, with particularly pronounced effects in individuals with obesity and metabolic disorders (Estevao, 2022). A randomised trial comparing 12 weeks of meditation to an active control found a 20% reduction in hs-CRP levels (p=0.01) in the meditation group, alongside reductions in IL-6 (Andrés-Rodríguez et al., 2019). These findings suggest that yoga and mindfulness practices may attenuate chronic low-grade inflammation associated with obesity.

The observed improvements in psychological parameters, sleep quality, and inflammatory markers can be explained by several interconnected physiological and psychological mechanisms. Mind-body interventions modulate the hypothalamic-pituitary-adrenal axis and autonomic nervous system, reducing cortisol production and sympathetic activation, which are typically elevated in chronic stress and obesity (Rohini et al., 2025; Wankhar et al., 2024). The structured breathing practices (pranayama) and meditative components may enhance parasympathetic tone, as evidenced by increased heart rate variability observed in regular practitioners (Lalitha et al., 2021; Maheshkumar et al., 2021). Additionally, mindfulness meditation promotes emotional regulation through enhancing prefrontal cortical function and reducing amygdala reactivity, potentially explaining the significant reductions in depression symptoms (Padmavathi et al., 2023). The improvements in sleep quality likely stem from reduced hyperarousal, decreased rumination, and enhanced circadian rhythm regulation.

The bidirectional relationship between psychological distress, sleep disturbances, and inflammatory processes is increasingly recognised. Chronic stress and poor sleep quality activate inflammatory pathways, while systemic inflammation can exacerbate neuropsychiatric symptoms and sleep disruption (Wankhar et al., 2024). Our findings suggest that yoga and mindfulness meditation may interrupt this adverse cycle, creating a virtuous circle of reduced stress, improved sleep, and decreased inflammation. The comprehensive nature of our intervention combining physical postures, breathing techniques, and meditation—may have synergistically addressed multiple pathophysiological mechanisms underlying psychological distress and inflammation in obesity.

These findings have important clinical implications. Given the high comorbidity of psychological distress and systemic inflammation in obesity, integrating yoga and mindfulness-based interventions into obesity management programmes could address both physical and mental health aspects of this complex condition. The non-pharmacological nature of these interventions offers particular advantages for patient populations concerned about medication side effects or those seeking complementary approaches to conventional treatments.

Despite these promising results, several limitations must be acknowledged. The sample size was modest (N=60), potentially limiting statistical power for subgroup analyses. The 12-week intervention period, while sufficient to demonstrate significant effects, does not allow assessment of long-term sustainability. Additionally, the absence of an active control group makes it difficult to distinguish between specific effects of yoga and mindfulness versus non-specific effects of group participation and attention. Future research should include larger, multi-centre trials with extended follow-up periods and active comparison groups to establish optimal intervention parameters. Key priorities include dose-response studies, mechanistic investigations using neuroimaging, comparative effectiveness trials, population-specific studies, and long-term follow-up assessments to develop targeted intervention protocols.

Conclusion

In conclusion, this randomised controlled trial provides compelling evidence that a 12-week yoga and mindfulness meditation programme significantly improves psychological wellbeing, sleep quality, and inflammatory status in middle-aged obese women. These findings suggest that mind-body interventions may offer a holistic approach to addressing both psychological distress and systemic inflammation in obesity. Future research should focus on identifying optimal intervention components, dose-response relationships, and implementation strategies to maximise clinical benefits and accessibility.

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Conflicts of interest
The authors declare that there are no conflict of interest.

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