Comparative Effects of Yoga, Anti-inflammatory Diet and Their Synergy on CRP and BMI in Middle-Aged Women: An Interventional Pilot Study.

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Abstract

Background:

Metabolic imbalances along with endocrine issues are very much prevalent in middle-aged women. Weight gain, fatigue and increased BMI are manifested often in middle aged women. These changes often lead to chronic inflammation which increases the risk of metabolic complications such as Insulin resistance, NAFLD (non-alcoholic fatty liver disease) and cardiovascular disorders.

Purpose:

This study aimed to evaluate and compare the impact of yoga, diet and their combined intervention on CRP (C-reactive Protein) & BMI in middle-aged women.

Methods

Eighteen women, aged 40-45 years were selected and randomly divided into 3 groups (n=6 each); Yoga group; Diet group, Yoga + diet Group. Yoga group received yoga intervention which included Suryanamaskar, Pawanamuktasan, Bhujangasana, pranayama and guided relaxation.

The diet group followed an anti-inflammatory dietary intervention for 12 weeks

The yoga +diet group received both interventions simultaneously for 12 weeks

Pre and post intervention CRP levels and BMI were recorded and analysed using appropriate statistical tools.

Results: Post-intervention adjusted mean CRP levels were 1.75mg/L (Yoga), 1.125 mg/L (Diet), and 1.925mg/L (Yoga & Diet). BMI values were 25.80(yoga), 26.24(Diet), and 24.57(yoga+Diet) . One-way ANOVA showed significant differences for both BMI and CRP ($p<0.05$) ($p < 0.05$). Tukey's post hoc test confirmed that the Yoga & Diet group had significantly lower CRP and BMI compared to the other two groups, indicating a synergistic effect.

Conclusions: The study concludes that although yoga and diet independently contribute to the reduction of CRP and BMI levels, their combined application yields significantly greater benefits. This suggests that integrated lifestyle interventions may serve as effective adjunct therapies for improving inflammatory status and BMI which may positively influence metabolic health among middle-aged women.

Keywords: Yoga, Diet BMI, CRP, inflammation, metabolic health, middle-aged women.

Introduction

In today's fast pace world, many occupational factors, cultural and social norms, technology and urbanisation, individual responsibilities and food habits like eating junk food, irregular meal timings, fast food, excess fat sugar are some of the common causes that alters one's metabolic health[1]. Middle aged women are the most commonly affected[2]. This altered metabolism causes weight gain in women increasing the BMI value which further leads to obesity[3].

Women, due to her lifestyle, aging and hormonal fluctuations experiences changes in her metabolism, inflammatory status and body mass index[4]. All these factors, give rise to metabolic complications which includes insulin resistance, obesity and cardiovascular disorders[5].

C-Reactive Protein (CRP)

Whenever there is a inflammation, infection or any tissue injury in the in the body, the liver produces an acute phase reactant, a plasma protein which is called C-reactive Protein(CRP)[6]. This is produced under the stimulation of cytokines interleukin-6 (IL-6) and (TNF-alpha)[7] -Tumour necrosis factor-alpha. Higher the level of CRP, more the inflammation in the body. These are usually associated with metabolic disorders including obesity, insulin resistance, cardiovascular diseases. CRP is a sensitive biomarker of systemic inflammation. This is used to assess progression in disease of autoimmune, metabolic, cardio- vascular and infectious. High-sensitivity CRP (hs-CRP) levels (> 3 mg/L have been linked to high risk of atherosclerosis, obesity, insulin resistance and metabolic syndrome[9].

Henceforth, high CRP levels reflects inflammation and also metabolic dysfunction.

BMI (Body Mass Index)

BMI, Body Mass Index is a handy screening tool that estimates body fat by comparing our weight

to height[10]. Maintaining an Healthy Body mass index is directly linked to Metabolic Health as it controls how efficiently the body converts food into energy**[11].** Any imbalance in BMI can cause metabolic dysfunction. This may cause insulin resistance, non-alcoholic fatty liver(NAFLD), increased low density lipoprotein (LDL) and also thyroid hormone disturbances**[12].** Maintaining a healthy BMI is very important for women as higher level can lead to fat accumulation and higher range of systemic inflammation. Unhealthy BMI not only contributes to inflammation but can affect overall metabolic and endocrine function.

Furthermore, abnormal BMI has been associated with elevated TSH levels, bad cholesterol (LDL), and insulin resistance in middle-aged women **[13].** Conversely, achieving and maintaining a healthy BMI reduces the risk of fatigue, sleep apnoea, cardiovascular diseases, hypertension, stroke, and type 2 diabetes **[14**]. In middle-aged women, BMI imbalance may also affect estrogenic levels, increase the risk of anxiety and depression, and aggravate thyroid dysfunction as well**.**

Body mass index is calculated using :

$$\textbf{BMI} = \frac{\textbf{Weight (Kg)}}{\textbf{[Height(m)]}^2}$$

BMI RANGE:

Under Weight	<18.5
Normal Weight	18.5-24.9
Over Weight	25.0 – 29.9
Obese	30.0 & above

YOGA

Yoga, the ancient traditional practice signifies the union of the individual self (jivatma) with the universal self (paramatma)[15]. It is not just engaging with physical postures but a path to inner transformation. Yoga emerged thousands of years ago in India, nurtured by sages which was first revealed in Vedas & Upanishads. It was further refined through classical texts like the Bhagavadgeetha, Patanjalis yoga sutra and thirumandiram by saint Thirumoolar.[16, 17]

Yoga according to classical references:

1.Bhagavad Gita:

Lord Krishna defines yoga as:

*" Yogah Karmasu Kaushalam"-(Gita 2.50)(*Yoga is skill in action, i.e. implying mindfulness in every action)

"Samatvam Yoga uchyate"(Gita 2.48)(Yoga is balance and equanimity of mind in success and failure)

"Tapyanthe lokasya hitam"(Gita 5.25)

(Yogis act for the welfare of the world, not personal gain)

2.Patanjali's Yoga Sutras

"Yogas Chitta vritti nirodhah"-(Sutra 1.2)

(yoga is cessation of fluctuations of the mind, he outlines Yama, Niyama, Asana, Pranayama, Pratyahara, Dharana, Dhyana and Samadhi-a stepwise path to liberation)

3. Thirumoolar's Thirumandiram

Thirumoolar beautifully integrated Asana, Pranayama and inner realization. Regulating the air (Prana) within his body devoid of stability-that is Yoga."

Classical frameworks such as Bhagawadgeetha (Karma yoga, bhakti yoga, jnana yoga, Raja yoga), Upanishads (Katha, Svestasvatara, Maitri), Hatha Yoga portrays that yoga is not merely a physical exercise but as a comprehensive spiritual science. Yoga, an ancient Practice found by Patanjali Maharishi in his sutras has systematized Raja yoga into 8 sequential limbs grouped into antaranga and bahiranga internal and external disciplines respectively. Yama, Niyama, Asana, Pranayama, Pratyahara, Dharana, Dhyana & Samadhi. These eight limbs shows a pathway with moral grounding and self-discipline, advancing through postures, breath awareness, withdrawing senses, deepening mind and ultimately union. Traditional texts emphasize that the yoga integrates action, devotion, knowledge, ethics, energy, posture and meditation towards self-realization.

The core pillars of yoga practice can be considered as Abhyasa (practice) and Vairagya (Non-attachment). Further the pillars of kriya yoga (yoga sutras , chapter 2) tapas, svadhyaya, Isvara pranidhana deepens the practitioner's journey through discipline, self inquiry and surrender**[17].**

Anti-inflammatory Diet

Diet, generally refers to food and drink consumed by an individual which supports energy, growth, repair and overall health. When this diet includes, carbohydrates, proteins, fats, vitamins, minerals and water in appropriate portions, we call it a "Balanced Diet".

Inflammation- is the body's natural defence, which means how body fights against injury or infection. It acts like a warning signal. A little inflammation actually helps us to heal, but too much for too long i.e. chronic inflammation can damage healthy cells and lead to various issues like diabetes, thyroid or heart disease. *A way of choosing and eating food that focuses on reducing inflammation in the body is called Anti-inflammatory Diet.* This diet plays an important role in our lives as it reduces chronic inflammation, boosts immunity, supports thyroid health, balances hormones, protects joints, heart and brain. Anti-inflammatory diet includes fruits and vegetables (colourful ones like broccoli, berries and spinach), whole grains (brown rice, quinoa, oats), Healthy fats (avocados, oil seeds), nuts and seeds (walnuts, almonds, chia seeds), fatty fish (salmon), herbs & spices (turmeric, ginger & garlic) [18]. The foods to be avoided includes refined sugar, processed, red meats, white bread and soda [19]. Though the requirement for Anti-inflammatory food is in early adulthood, it is very important during middle-age and menopause as inflammation increases during this time.

Anti-inflammatory diet can help in curing obesity, high blood pressure, type 2 diabetes, arthritis, hypothyroidism**,** heart disease, skin issues like acne and psoriasis, supports mental health and reduces fatigue. It can be incorporated in simple styles on daily basis by consuming fermented foods like curd, kanji, eating seasonal and locally sourced foods, preferring home cooked foods, including herbal teas, eat small frequent meals.

Integrated approach of Yoga and Diet:

The high prevalence of over weight among middle-aged women is a significant public health burden as it slows down the

metabolism. The sluggish metabolism causes metabolic disorders which is risk factors for type 2 diabetes, cardio-vascular diseases, stroke.

This elevated Body mass Index (BMI) contributes to insulin resistance, systemic inflammation and thyroid function which can impair endocrine dysfunction**.[23]** Further Body Mass Index predicts metabolic risk. Yoga promotes Musco skeletal flexibility, enhances circulation and modulates Autonomic nervous system thereby reducing CRP. Yoga mind-body practice with asanas, pranayama and meditation renders great benefits related to physical, mental and metabolic parameters. Yoga functions as a low-impact form of cardiovascular exercise(mild), strength training depending on posture intensity and flow. Anti-inflammatory diets, rich in micronutrients and antioxidants, support thyroid function by reducing systemic inflammation, autoimmunity and oxidative damage**. [24].** The combined approach of yoga and anti-inflammatory diet plays a vital role in managing body weight and inflammation. Yoga improves blood circulation to the nervous system, reduces SNS-sympathetic nervous system activity (stress response) and enhances parasympathetic activity (rest and digest) improving heart rate, BP and insulin sensitivity which collectively support metabolic health and reduce risk of metabolic disorders. An anti-inflammatory diet calms internal inflammation, supports gut and liver health which is very important for hormone conversion and promotes weight loss. Integrating Yoga and Diet can reduce inflammation, help reduction of CRP and bring BMI back to normal.

Objectives of the Study:

- To assess the effect of selected yogic practices on CRP & BMI
- To Evaluate the dietary effect on CRP & BMI
- To determine the combined effect of Yoga and Diet on CRP & BMI
- To compare effective of interventions in managing CRP and reducing BMI.

Hypothesis:

1. There will be a significant reduction in CRP levels & BMI with yogic intervention among Middle-aged women.
2. There will be a significant reduction in CRP levels and BMI following dietary intervention among Middle-aged women.
3. The combined intervention of yoga and diet will result in greater reduction of CRP and BMI compared to yoga or diet alone.
4. There will be a significant difference in the effectiveness of the three interventions (Yoga, Diet, and Yoga + Diet) in managing CRP and reducing BMI.

5. Materials and Methods:

It is an experimental comparative design with 3 groups viz.,

Group A-Yoga Group

Group B-Diet group

Group C- Yoga + Diet group.

Participants:

Sample Size=18

A total of 20 middle-aged women aged about 40-45 were enrolled for the study. 2 Participants withdrew. Total 18 participants were randomly assigned to one of three intervention groups . Yoga only (n=6), Diet only (n=6), combination of yoga+Diet (n=6)

Inclusion

- Women with age 40-50 years.
- BMI between 23.0 and 35.0 $\geq$ 25 kg/$m^{2)}$ Asian cut-off for Indian population
- Able to attend intervention sessions

Exclusion:

- Pregnant Women/Lactating women
- Those who are already practicing yoga
- Acute infection/fever within 2 weeks.
- Use of corticosteroids or immuno-suppressants.
- Women with severe comorbid conditions (cardiac diseases)

Design and Procedure

The research was conducted for a period of 12 weeks using a pre-test/post-test experi- mental design with 3 groups. The blood tests for CRP, before and after intervention were compared. Weight and height of participants were recorded and BMI was calculated. Informed consent was obtained from participants.

Intervention Protocol

Yoga group (GroupA): Yoga group participants received 12 weeks of yoga training, 5days per week for about 60 minutes each day. The practice involved medium intensity yoga and pranayama and meditation. The training schedule included Trikonasana (triangle pose), pawanamuktasana, Ardhamatsyasana, utkatasana and Suryanamaskar along with Pranayama for BMI and asanas like shavasana, viparitakarani, Balasana, suptabaddhakonasa, sethubhandasana were also included which could work for CRP.

Diet group (Group B):

Participants received prescribed anti-inflammatory diet. The anti-inflammatory menu mentioned was mandatory to follow whereas menus for lunch and dinner were optional

Yoga+Diet (Group C):

Participants followed both yoga and diet intervention.

Measurements:

CRP *(C-Reactive Protein):*

- CRP levels were measured through venous blood samples.
- Samples were analysed using CLIA(Chemiluminescent Immunoassay) at a diagnostic laboratory.
- Results were expressed in mg/L/L(milligrams per litre)
- Pre-test and post test were recorded for all groups

(BMI): (Body Mass Index)

Weight was measured using a calibrated digital weighing scale (to the nearest 0.1 kg).

Height was measured using a standard height scale (to the nearest 0.1 cm).

BMI was calculated using the standard formula:

$$\textbf{BMI} = \frac{\textbf{Weight (Kg)}}{\textbf{[Height(m)]}^2}$$

(BMI values were classified according to the World Health Organization (WHO) guidelines.)

Statistical Analysis

1.Mean & SD were calculated for all variables

2.Paired t-test used to assess within group differences between pre-test and post-test values

3.One-way ANOVA was employed to compare between group differences among the three intervention groups.

4. Significance level set at $p<0.05$

Results

A total number of 18 middle-aged women were assigned randomly to 3 groups with the help of dice method: Yoga, Diet and Yoga+Diet i.e n=6 ineach group. Pre-post interventions were conducted for measuring CRP and BMI.

Table 1: Mean Gain Scores

Group	CRP Gain Score (Mean)	BMI Gain Score (Mean)
Yoga	0.125	1.15
Diet	0.175	1.98
Yoga+Diet	0.275	3.22

This table shows that the Yoga+diet group had the highest improvement in reduction of both CRP and BMI.

Table 2: One-way ANOVA summary

Variable	F-value	p-value	Significance
CRP Gain	6.02	0.011	Significant (p < .05)
BMI Gain	27.87	0.000009	Significant (p < .001)

The One-way ANOVA indicated that there were statistically significant differences in both CRP and BMI gain scores among three groups.

Table 3: Post Hoc Test (Tukey HSD)

CRP Gain Scores:

Comparison	Mean Difference	p-value	Significance
Diet vs Yoga	0.050	0.412	Not Significant
Diet vs Yoga+Diet	0.100	0.018	Significant (p < .05)
Yoga vs Yoga+Diet	0.150	0.009	Significant (p < .05)

BMI Gain Scores:

Comparison	Mean Difference	p-value	Significance
Diet vs Yoga	0.833	0.011	Significant (p < .05)
Diet vs Yoga+Diet	-1.233	0.001	Significant (p < .01)
Yoga vs Yoga+Diet	-2.067	0.000	Significant (p < .001)

Table:4

Comparison of Mean Differences with CD (5%)

- **For CRP:**

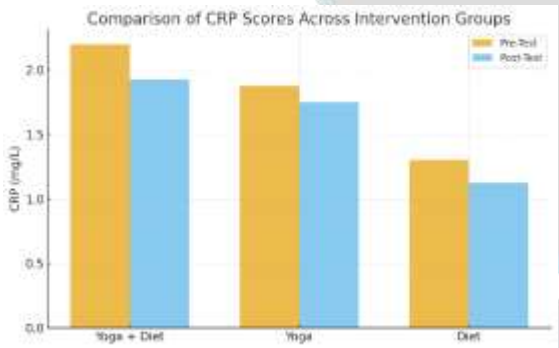
Comparison	Mean Difference	CD (5%)	Significant
Yoga vs Diet	0.05	0.09	Not signficant
Yoga vs Yoga +Diet	0.150	0.09	Yes
Diet vs Yoga +Diet	0.100	0.09	Yes

- **For BMI:**

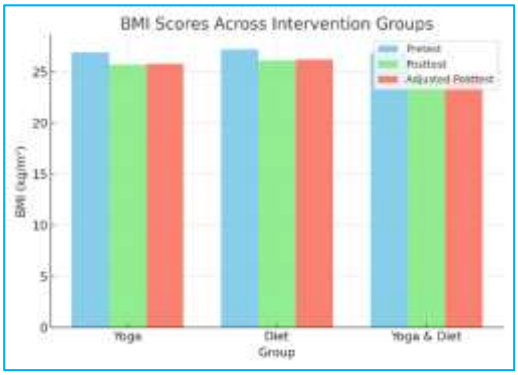
Comparison	Mean Difference	CD (5%)	Significant
Yoga vs Diet	-0.44	0.52	No
Yoga vs Yoga & Diet	-1.23	0.52	Yes
Diet vs Yoga & Diet	-0.79	0.52	Yes

These results indicate that the Yoga+Diet group showed significantly greater improvement in both CRP reduction and BMI compared to the other two groups.

Graph showing CRP scores(Pre-post test)



Graph showing BMI scores(Pre-post test) across 3 interventions Yoga, Diet, Yoga +Die



Discussion

The Present study aimed to evaluate the effect of yoga, anti-inflammatory diet and its combined effect on CRP and body mass index (BMI) among middle-aged women. The statistical analysis revealed significant differences across groups.

CRP Gain

The ANOVA result for CRP gain (F=6.12, p=0.0105) indicated a statistically significant improvement (p< .05) in systemic inflammation across the intervention groups. It suggests that combined effect of yoga and diet had a measurable effect on CRP levels reflecting reduction in low grade chronic inflammation. The CRP reduction could be due to the role of yogic practices in modulating ANS (Autonomic Nervous system), promoting parasympathetic activity and reducing stress. Meanwhile, anti-inflammatory foods may have decreased inflammatory markers reducing the CRP.

BMI Gain

The ANOVA results for BMI gain (F=27.87, p = 0.000009) was highly significant (p < .001), indicating a strong effect of the interventions on weight management. The combination of yoga and diet contributes to the significant reductions in BMI.

Interpretation

The significant improvements in both CRP and BMI suggest that integrative interventions like yoga and diet may serve as effective strategies in managing healthy weight and overall metabolic health in middle-aged women. These findings align with previous research demonstrating the holistic benefits of lifestyle interventions in endocrine and metabolic health**.[25]**

Post Hoc comparisons revealed a significant difference in CRP gain between the Yoga + diet group and yoga group (p=0.009) and Yoga+Diet group and Diet group (p=0.018). However, the difference between the diet and yoga groups was not statistically significant (0.412). These findings suggest that while yoga or diet alone may not have a advantage over each other, the combined intervention has an effect in improving inflammatory marker (CRP)

Limitations:

- Small sample size (n=6 per group)
- Short time intervention
- Limited Biochemical markers.
- Conducted in Vellore alone.

Conclusion

The study concludes that integrating yoga practices with dietary modifications significantly reduces both CRP level and BMI in middle-aged women. Among the three groups, the combined Yoga+Diet group demonstrated the highest mean gain scores and statistically significant improvements. Asanas for reducing inflammatory marker (CRP) promoted deep relaxation, improves lymphatic drainage, calms ANS, reduces oxidative stress, induces parasympathetic dominance, reduces systemic inflammation. Meanwhile, asanas targeted for BMI management enhance metabolism, endocrine balance and muscular engagement. The findings suggest that a holistic approach involving yoga and dietary changes may offer an effective non-pharmacological intervention for improving metabolic health and in reducing inflammation.

Future studies with larger samples and longer follow-up periods are recommended to confirm and expand upon these findings.

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