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SOCIAL AND BEHAVIORAL SCIENCES. Health Care Sciences

ORIGINAL RESEARCH

Comparative Study of Yogic Practices and Dietary Modifications on Biochemical Variables among Middle-Aged Women on Metabolic Dysfunction – Associated Steatotic Liver Disease

Authors' Contribution:
A – Study design;
B – Data collection;
C – Statistical analysis;
D – Data interpretation;
E – Manuscript preparation;
F – Literature search;
G – Funds collection

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Abstract

Background and Aim of Study: *Non-Alcoholic Fatty Liver Disease (NAFLD), now more broadly termed Metabolic Dysfunction – Associated Steatotic Liver Disease (MAFLD), poses a significant health risk for women, particularly in India where its prevalence ranges from 9.0% to 53.0%, with middle-aged women comprising 29.1% of those affected. Key risk factors include obesity, insulin resistance, metabolic syndrome, and hypertriglyceridemia reported in 95.0% of MAFLD cases.*
The aim of the study: to assess the effects of yoga practices, dietary modifications, and their combination on liver enzyme (ALT/SGPT), triglycerides, and fasting blood glucose levels among middle aged women with mild to moderate MAFLD.

Material and Methods: *Twenty-one women aged between 40 and 50 were randomly divided into three groups: yoga only (n=7), diet only (n=7), and a combination of both yoga and diet (n=7). The study was conducted for 8-week period with 6 days intervention each week. Pre- and post-test values were analysed using ANCOVA with Scheffe's post hoc tests.*

Results: *The study revealed that the combined Yoga and Diet intervention led to a statistically significant improvement in liver function (alanine aminotransferase, $F(2,17)=15.15$, $p<0.05$) and glycemic control (fasting glucose, $F(2,17)=6.64$, $p<0.05$) among MAFLD participants, with the Yoga+Diet group showing the greatest mean reductions (-1.43 U/L and -37.06 mg/dL respectively). While triglyceride levels also declined most in the combined group (-25.10 mg/dL), the difference was not statistically significant ($F=0.41$, $p>0.05$). Quantitative outcomes were supported by qualitative observations, including improved adherence, lifestyle engagement, and subjective well-being among participants in the combined intervention group. These findings highlight the synergistic benefits of integrating Yoga and Diet for metabolic and liver health in individuals with MAFLD.*

Conclusions: *The study found that middle-aged women with mild to moderate MAFLD who underwent a combined yoga and dietary intervention demonstrated significant improvement in fasting blood glucose levels, indicating better glycemic control. Although reductions in alanine aminotransferase and triglyceride levels were observed across all intervention groups, these changes were not statistically significant between groups. These results suggest the combined intervention may be effective in improving metabolic health, with potential for greater impact over longer durations or in larger cohorts.*

Keywords: *MAFLD/NAFLD, yoga, diet, ALT, triglycerides, fasting glucose, liver enzymes.*

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Introduction

The liver is vital and second largest organ for our health, performing essential functions like metabolism, detoxification, digestion, and bolstering the immune system. The liver plays a crucial role in maintaining homeostasis, which refers to the body's ability to keep a stable internal environment despite changes in the external surroundings. Liver's key role includes Regulation of Blood Glucose Levels, Detoxification and Waste Removal, Control of Lipid and Protein Metabolism, Regulation of Blood Volume and Composition, Support for the Immune System.

Liver problems can arise from various sources, including excessive alcohol intake, viral infections such as hepatitis, obesity, diabetes, high cholesterol, exposure to toxins, certain medications, genetic issues like hemochromatosis, and sharing needles for drug use.

Maintaining liver health is essential for overall well-being and preventing serious conditions such as Metabolic Dysfunction-Associated Fatty Liver Disease (MAFLD), cirrhosis, and liver failure.

MAFLD/NAFLD is a comprehensive term that encompasses all stages and grades of the disease, indicating a population where at least 5% of hepatocytes exhibit macrovesicular steatosis without a clear alternative cause (such as medications, starvation, or monogenic disorders) in individuals who consume minimal or no alcohol (defined as less than 20 g/d for women and less than 30 g/d for men (Rinella et al., 2023).

The occurrence of non-alcoholic fatty liver disease is a greatest risk factor for the metabolic diseases such as Hypertriglyceridemia, characterized by elevated fat levels in the blood (found 40.74% of individuals with NAFLD), Hypertension, or high blood pressure (found in 39.34% of NAFLD (Younossi et al., 2016). Metabolic Syndrome is present in 42.54% of NAFLD patients and 41% of individuals with NASH have advanced to fibrosis, and approximately one-third to two-thirds of individuals with type 2 diabetes also have NAFLD (Dusheja, A., et al., 2015). It is estimated that 50.00% of those with dyslipidaemia, which includes abnormal cholesterol and high fat levels, are affected by NAFLD. Liver disease leads to approximately two million fatalities each year, representing 4.00% of total deaths. The primary contributors to cirrhosis globally include viral hepatitis, alcohol consumption, and non-alcoholic fatty liver disease. The most common causes of death in patients with NAFLD overall are cardiovascular disease (CVD) and non-hepatic malignancy, followed by liver disease (Singh et al., 2017).

Non-alcoholic fatty liver disease (NAFLD) has become the primary reason for liver transplants in women (Sampath Kumar et al., 2019). When managing women with NAFLD, it is essential to take into account their specific risk factors, such as hormonal influences and reproductive considerations (Rinella et al., 2023).

Approximately 1 billion people globally are estimated to be living with NAFLD, and this number is expected to grow as obesity, diabetes, and other metabolic syndrome factors continue to rise (Younossi et al., 2016). The figures highlight the significant global impact of NAFLD, underscoring the critical need for improved awareness, diagnosis, and treatment strategies to prevent the disease from advancing to more severe liver conditions such as NASH (Non-Alcoholic Steatohepatitis) and Cirrhosis.

Yoga is highly valued in today's world and offers a hopeful outlook for the future. Esteemed health organizations such as the WHO and NIH acknowledge it as a powerful natural healing method. This ancient discipline is utilized in therapeutic settings, aiding in recovery, alleviating stress, and managing chronic illnesses. A recent investigation conducted has revealed that specific yoga asanas as well as relaxation techniques, significantly enhance liver enzyme levels. Yogic practices may provide a more effective means of improving liver function than conventional medical treatments (Ashok Kumar et al., 2021). In Yoga, food serves a purpose that goes beyond mere nutrition; it is seen as a source of energy (Prana) that influences our body, mind, and spirit.

Adopting a balanced yogic diet can result in improved physical well-being, greater mental clarity, and a more profound spiritual development.

> "Ahara suddhau sattva-suddhih, sattva-suddhau dhruva smrtih, smrti-lambhe sarva-granthinam vipra-moksah" (Chandogya Upanishad, n.d./2019).

Eating pure food promotes mental clarity, which in turn encourages constant reflection. This persistent mindfulness allows individuals to break free from all constraints and attain freedom. A balanced diet and regular exercise are fundamental components of managing NAFLD (Sengupta, 2012).

Yoga, particularly asthanga, is often symbolically represented as a tree and consists of eight components, or "limbs". Patanjali systematized the ancient practice of yoga into asthanga, which is recognized as one of the six branches of Indian philosophy called Yoga Darshan. These limbs include yama (universal ethics), niyama (individual ethics), asana (physical postures), pranayama (breath control), pratyahara (sense withdrawal), dharana (concentration), dhyana (meditation), and samadhi (bliss). Each limb is interconnected, similar to how the limbs of the body are linked; if one leg is pulled, the entire body responds. Likewise, engaging with one of the eight limbs of yoga influences the others, as they are not sequential stages to be completed (Kapatel, 2019).

The collective findings from previous studies provide sturdy support for the therapeutic advantages of yoga in multiple aspects of mental health and well-being.

The favourable results noted in areas such as self-care, mindfulness, emotional fatigue, depersonalization, perceived stress, sleep quality, and overall resilience highlight the adaptability of yoga as a comprehensive intervention.

There may be a connection between NAFLD and mental health issues, such as depression, which could be influenced by dietary habits, lifestyle choices, and environmental factors.

Personality appears to serve as a link between NAFLD and psychiatric disorders, influencing lifestyle choices, weight fluctuations, meticulousness, and immune system performance (Soto-Angona et al., 2020).

Anxiety and depression are considered risk factors for NAFLD (Woodyard, 2011).

Yoga Therapy on Mind and Emotion: Mechanisms of Action

Yoga therapy, a practice combining physical postures (asanas), breathing techniques (pranayama), meditation, and mindfulness, has been widely recognized for its therapeutic benefits on mental and emotional well-being. The underlying mechanisms through which yoga exerts its effects on the mind and emotions involve both physiological and psychological pathways (Tanna & Khatri, 2024). Physiologically, yoga enhances autonomic nervous system regulation, primarily through its impact on the parasympathetic nervous system, leading to a reduction in heart rate, blood pressure, and overall stress levels (Calderone et al., 2024).

This state of relaxation is thought to counterbalance the heightened sympathetic nervous system activity that characterizes stress and emotional distress. On a psychological level, yoga fosters a state of mindfulness, promoting greater awareness and acceptance of thoughts and emotions. This mindfulness practice has been shown to reduce rumination, increase emotional resilience, and improve emotional regulation by engaging brain regions such as the prefrontal cortex and amygdala, which are involved in decision-making, emotional processing, and stress response regulation (Gerritsen & Band, 2018). Moreover, breathing techniques in yoga activate the vagus nerve, which plays a key role in regulating mood and stress (Feingold, 2023). Together, these mechanisms create a holistic approach to emotional and mental health, promoting a balanced emotional state, reducing anxiety and depression, and enhancing overall well-being.

Triglycerides and Cortisol: Mechanistic Link

Cortisol, a glucocorticoid hormone secreted by the adrenal glands during stress, is crucial for metabolic functions, particularly in managing lipid metabolism. Increased cortisol levels are closely associated with elevated triglyceride concentrations in the bloodstream, often observed in conditions of chronic stress, metabolic syndrome, or Cushing's syndrome. Cortisol promotes triglyceride accumulation primarily through its effects on adipose tissue. It stimulates lipogenesis by enhancing the expression of genes involved in fat synthesis, while simultaneously inhibiting lipolysis, the process by which stored fat is broken down for energy. Additionally, cortisol influences liver function by increasing the production of very low-density lipoproteins (VLDL) (Romero-Gómez et al., 2017), a major carrier of triglycerides. Through these mechanisms, elevated cortisol levels contribute to the dysregulation of lipid homeostasis, promoting an increase in circulating triglycerides. This relationship between cortisol and triglycerides is further compounded by the hormone's ability to induce insulin resistance, leading to impaired glucose metabolism and exacerbating lipid dysregulation. Understanding the intricate mechanisms through which cortisol modulates triglyceride levels is crucial for addressing conditions associated with metabolic dysfunction.

Research Hypothesis

Integrative lifestyle interventions involving yoga practices combined with dietary modifications will result in greater improvements in liver enzyme levels (ALT/SGPT), triglycerides, and fasting blood glucose among middle-aged women with mild to moderate MAFLD compared to either intervention alone.

This study explores a significant gap in the management of Metabolic Dysfunction Associated Steatotic Liver Disease (MAFLD) in middle-aged women, a demographic increasingly vulnerable due to hormonal, metabolic, and lifestyle influences.

The research is important for several reasons. Firstly, it assesses the individual and combined impacts of yoga practices and dietary changes both of which are non-pharmacological, cost-effective, and practical interventions on critical biochemical markers related to MAFLD: alanine aminotransferase (ALT), triglycerides, and fasting blood glucose (FBG). The notable improvement in FBG within the combined Yoga and Diet group indicates a synergistic effect that may surpass the efficacy of either intervention alone. Secondly, the study offers new perspectives within the Indian context, where the levels of insulin resistance, hypertriglyceridemia, and NAFLD are particularly high, even among non-obese individuals.

Finally, the results of this research carry significant public health implications, especially for rural and semi-urban areas where obesity is on the rise and healthcare access is limited.

These findings could guide future large-scale intervention programs, health education initiatives, and policy measures aimed at preventing the advancement of MAFLD through community-based, lifestyle-focused strategies.

The aim of the study. To assess the effects of yoga practices, dietary modifications, and their combination on liver enzyme (ALT/SGPT), triglycerides, and fasting blood glucose levels among middle aged women with mild to moderate MAFLD previously known as NAFLD.

Materials and Methods

Participants

A total of 21 middle-aged women diagnosed with mild to moderate Metabolic Dysfunction–Associated Steatotic Liver Disease (MAFLD) were enrolled in the study.

The mean age of participants was 46.5±3.5 years. The cohort predominantly comprised married women (95.2%), with one divorced participant (4.8%). In terms of occupation, the majority were housewives (57.1%), followed by teachers (23.8%), dance professionals (9.5%), and others including a physiotherapist, IT professional, and accountant. The mean height and pre-study weight were 156.8±5.8 cm and 75.26±14.06 kg, respectively (Table 1).

Table 1
Demographic Characteristics of Study Participants

Variable	Frequency	
	Person	Percentage
Age (years) (Mean ± SD)	–	46.5±3.5
Gender		
– Female	20	95.2
– Divorced Female	1	4.8
Marital Status		
– Married	20	95.2
– Divorced	1	4.8
Occupation		
– Housewife	12	57.1
– Teacher	5	23.8
– Dance Teacher / Classical Dancer	1	4.8
– Physiotherapist	1	4.8
– IT Professional	1	4.8
– Accountant	1	4.8
Height (cm) (Mean ± SD)	–	156.8±5.8
Pre-study Weight (kg) (Mean ± SD)	–	75.26±14.1

Participants were randomly assigned to one of three intervention groups: Yoga Only (n=7), Diet Only (n=7), and Combination of Yoga+Diet (n=7). Inclusion criteria included simple to no history of chronic liver disease, having mild to moderate NAFLD/MAFLD, stable medical condition, and volunteer participation to intervention protocols. Men, menopausal women and on sever or chronic medications affecting weight or liver enzymes were excluded.

Design and Procedure

This research was conducted over an 8-week period using a pre-test/post-test experimental design with multiple groups.

The blood tests of before and after intervention were compared: Blood index: triglyceride (TG) and Fasting Blood Glucose (FBG), digestive system index: Glutamic pyruvic transaminase/ alanine aminotransferase (ALT). Informed consent has been obtained from participants and ethical clearance was obtained from the institutional review board.

Intervention Protocols

Yoga Group: Participants received 8 weeks, 6 day a week, 60 minutes each day. The practice is mainly in the form of small and medium intensity yoga exercise, mainly including asanas, pranayama, meditation, and yogic counselling. The patients received 60 minutes yoga training including 10 minutes of warm-up, 20 minutes of yoga training (Surya namaskar - 3 rounds, Ardha Chakrasana, Ardha kati Chakrasana, Trikonasana, Parshvakonasana, Pada Hastasana, Vajrasana, Shansangasana, Janu Shirasasana, Vakrasana, Sarala Bhujangasana, Artha Shalabasana, Pawana Mukthasana, Supta Baddha Konasana, Sarala Matsyasana Setu Bandhasana), 10 minutes of deep relaxation, 10 minutes of pranayama techniques (Kanishta Pranayama, Bhramari Pranayam, Ujjayi, Nadi Shudhhi, Shitkari), 10 minutes of "OM" meditation. All practices are selected based on the scientific studies and conducted under the guidance of professional yoga therapist, and medical personnel supervised the whole process.

Diet Group: Participants received individualized dietary plans based on caloric deficit (500 kcal/day below maintenance) and dietary quality aligned with MAFLD dietary guidelines (low saturated fat, restrained carbohydrate, increased fibre and increased herbal decoction tea). Diet adherence was monitored through daily diet logs and weekly check-ins.

Yoga+Diet Group: Participants followed both the yoga practices and dietary protocols described above.

Test Method

Alanine Aminotransferase (ALT/SGPT) calculated in Method: IFCC (UV without P5P), Triglycerides calculated in Method: Enzymatic (GPO-POD) both using Beckman Coulter DxC 700 AU machine.

Statistical Data Analysis

Analysis of covariance (ANCOVA) was employed to compare post-test BMI scores between the groups while controlling for pre-test scores. Significant differences were further explored using Scheffe's post-hoc test. A significance level of $p<0.05$ was used for all analyses.

Results

Analysis of covariance (ANCOVA) indicated a significant difference in adjusted post-test ALT/SGPT levels among the three groups, $F(2.17)=15.15$, $p<0.05$. However, Scheffé's post hoc test revealed that none of the pairwise comparisons reached statistical significance (CD=0.46). Although the combined Yoga+Diet group showed the largest mean reduction (-1.43 U/L), it was not significantly different from the Yoga or Diet groups (Tables 2, 2A).

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Table 2
ANCOVA on ALT / SGPT Levels (U/L)

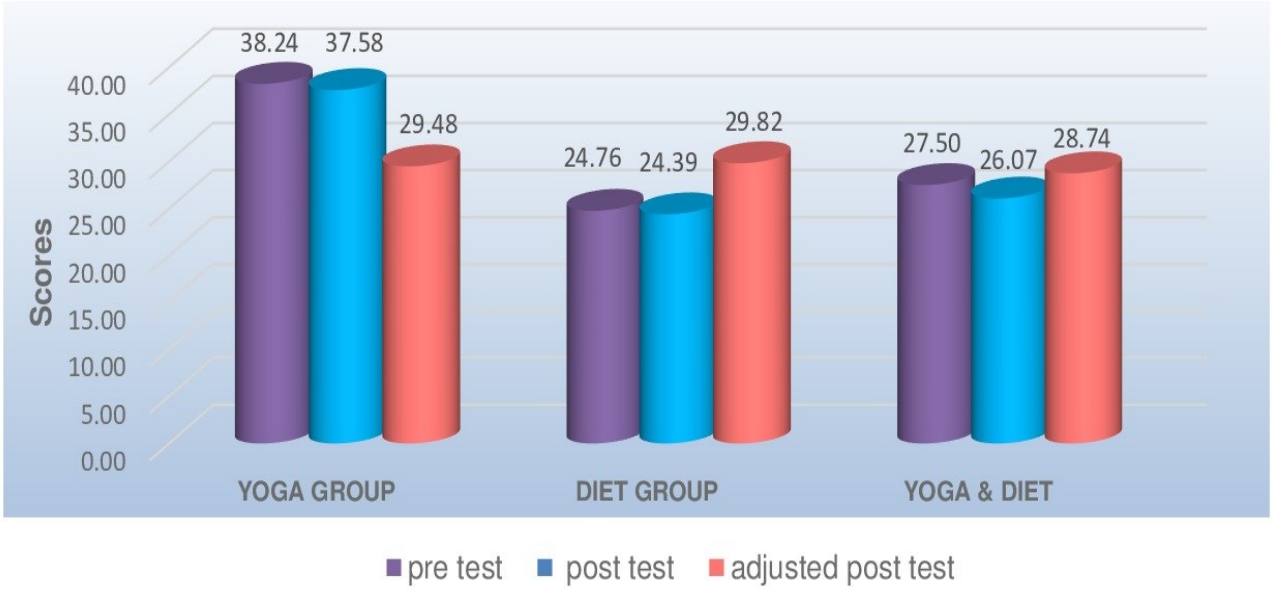
Test	Group			Source of variation	Sum of squares	Degrees of freedom	Mean squares	Factor ratio
	Yoga	Diet	Yoga+Diet					
Pre test	38.24	24.76	27.50	between	710.28	2.00	355.14	1.16
				within	5489.06	18.00	304.95	
Post test	37.58	24.39	26.07	between	720.92	2.00	360.46	1.17
				within	5527.36	18.00	307.08	
Adjusted	29.48	29.82	28.74	between	4.20	2.00	2.10	15.15
				within	2.36	17.00	0.14	
Mean gain	-0.66	-0.37	-1.43	–	–	–	–	–

Table 2A
Scheffe's Posthoc Test on ALT / SGPT Levels

Yoga group	Diet group	Yoga & Diet	Mean Difference	CD at 5% Level
29.48	29.82	–	-0.34	0.46
29.48	–	28.74	-0.73	
–	29.82	28.74	-1.07	

Figure 1 shows the comparative analysis of all three groups (Yoga group, Diet group and Yoga+Diet group) on ALT/SGPT for pre test, post test, and adjusted post test.

Figure 1
Comparative Analysis of All Three Groups on ALT/SGPT



ANCOVA showed no significant group differences in post-test triglyceride levels after controlling for baseline values, F(2.17)=0.41, p>0.05.
All groups showed a reduction in triglyceride levels, with the Yoga+Diet group having the largest decrease (-25.10 mg/dL), but this difference did not reach statistical significance.
Scheffé's post hoc test confirmed that none of the pairwise differences exceeded the critical difference (CD=23.75) (Tables 3, 3A).

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Table 3
ANCOVA on Triglycerides Levels (mg/dL)

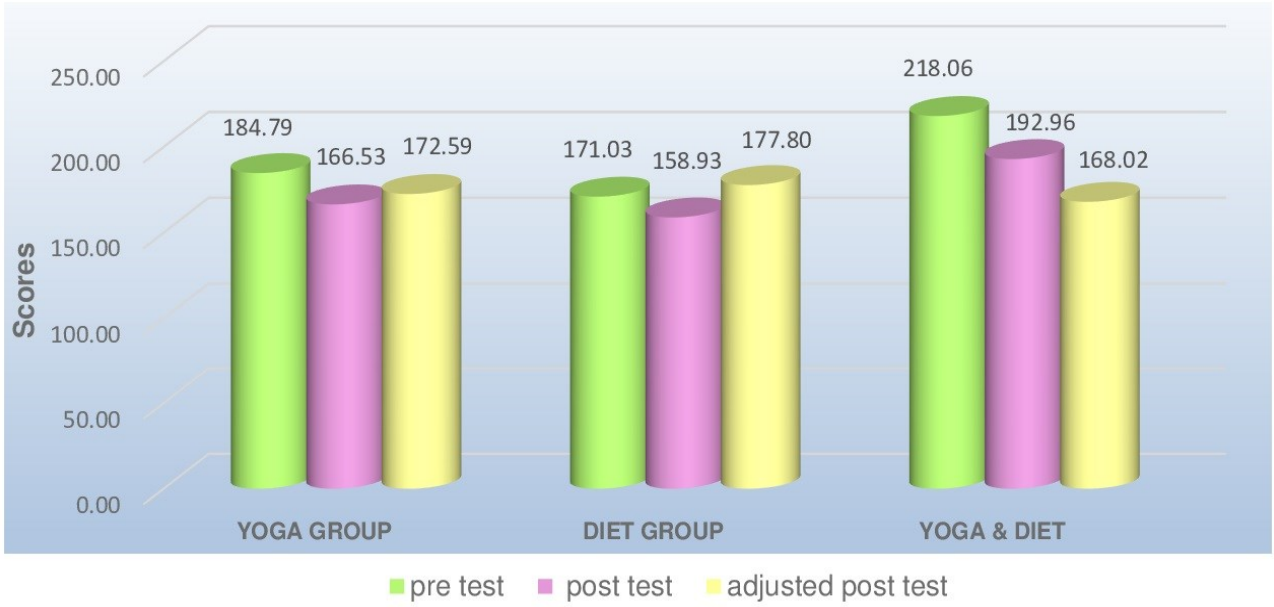
Test	Group			Source of variation	Sum of squares	Degrees of freedom	Mean squares	Factor ratio
	Yoga	Diet	Yoga+Diet					
Pre test	184.79	171.03	218.06	between	8183.56	2.00	4091.78	0.87
				within	84447.03	18.00	4691.50	
Post test	166.53	158.93	192.96	between	4467.21	2.00	2233.60	0.50
				within	79659.69	18.00	4425.54	
Adjusted	172.59	177.80	168.02	between	307.74	2.00	153.87	0.41
				within	6356.09	17.00	373.89	
Mean gain	-18.26	-12.11	-25.10	–	–	–	–	–

Table 3A
Scheffe's Posthoc Test on Triglycerides Levels

Yoga group	Diet group	Yoga+Diet	Mean Difference	CD at 5% Level
172.59	177.80	–	-5.21	
172.59	–	168.02	-4.57	23.75
–	177.80	168.02	-9.78	

Figure 2 shows the comparative analysis of all three groups (Yoga group, Diet group and Yoga+Diet group) on Triglyceride Levels for pre test, post test, and adjusted post test.

Figure 2
Comparative Analysis of All Three Groups on Triglyceride Levels



There was a statistically significant difference in fasting blood glucose levels across the three groups, $F(2.17)=6.64$, $p<0.05$. Post hoc analysis revealed that the difference between the Diet group and the Yoga+Diet group was statistically significant (mean difference=21.70, CD=13.20), indicating that the combined intervention led to a greater reduction in glucose levels than diet alone.

No other pairwise differences were statistically significant (Tables 4, 4A).

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Table 4
ANCOVA on Fasting Blood Glucose Levels (mg/dL)

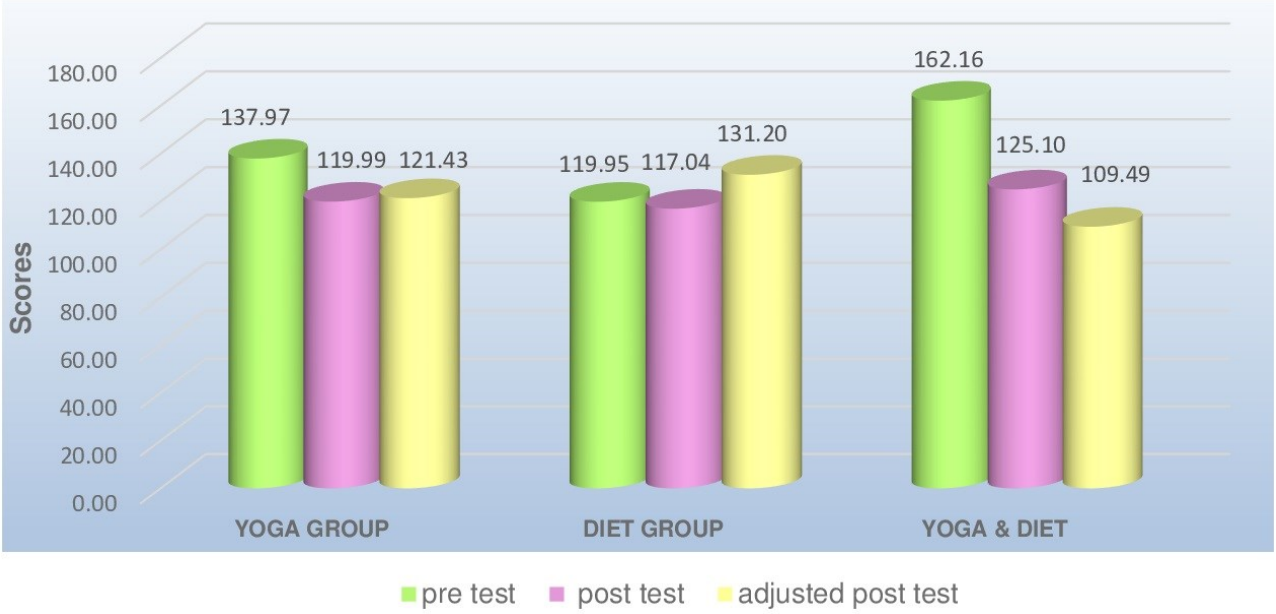
Test	Group			Source of variation	Sum of squares	Degrees of freedom	Mean squares	Factor ratio
	Yoga	Diet	Yoga+Diet					
Pre test	137.97	119.95	162.16	between	6282.27	2.00	3141.14	0.71
				within	79260.47	18.00	4403.36	
Post test	119.99	117.04	125.10	between	233.02	2.00	116.51	0.05
				within	41364.53	18.00	2298.03	
Adjusted	121.43	131.20	109.49	between	1532.69	2.00	766.35	6.64
				within	1962.82	17.00	115.46	
Mean gain	-17.99	-2.91	-37.06	–	–	–	–	–

Table 4A
Scheffe's Posthoc Test on Fasting Blood Glucose Levels

Yoga group	Diet group	Yoga+Diet	Mean Difference	CD at 5% Level
121.43	131.20	–	-9.76	13.20
121.43	–	109.49	-11.94	
–	131.20	109.49	-21.70	

Figure 3 shows the comparative analysis of all three groups (Yoga group, Diet group and Yoga+Diet group) on fasting blood glucose levels for pre test, post test, and adjusted post test.

Figure 3
Comparative Analysis of All Three Groups on Fasting Blood Glucose Levels



A comparative assessment was performed to investigate the impact of three intervention strategies Yoga, Diet, and a combined Yoga with Diet approach on serum ALT/SGPT levels, triglycerides, and fasting glucose (Table 5).

The analysis included adjusted post-test means, mean gains, and inferential statistics (F-values, p-values, and critical differences determined by the Scheffé test).

The group that participated in both Yoga and Diet exhibited the most significant decrease in ALT/SGPT levels (M=28.74, change =-1.43 U/L), in contrast to the Yoga-only group (M=29.48, change =-0.66) and the Diet-only group (M=29.82, change =-0.37). The differences among the groups were statistically significant, F=15.15, $p<0.05$, with a critical difference (CD) of 0.46. Subsequent comparisons revealed that the

combined intervention led to a notably greater reduction than either Yoga or Diet alone.

The Yoga+Diet group exhibited the most significant mean reduction in triglyceride levels (M=168.02, decrease =-25.10 mg/dL), followed by the Yoga group (M=172.59, decrease =-18.26) and the Diet group (M=177.80, decrease =-12.11). Nevertheless, these variations did not reach statistical significance, F=0.41, p>0.05, CD=23.75. The considerable variability indicates that the differences observed may not be confidently attributed to the interventions.

Table 5

ANCOVA Comparative Analysis of All Three Groups

Variable	Group	Adjusted Mean	Mean Gain	F	p	CD (Scheffé)
ALT/SGPT (U/L)	Yoga	29.48	-0.66	15.15	<0.05	0.46
	Diet	29.82	-0.37			
	Yoga + Diet	28.74	-1.43			
Triglycerides (mg/dL)	Yoga	172.59	-18.26	0.41	>0.05	23.75
	Diet	177.80	-12.11			
	Yoga + Diet	168.02	-25.10			
Fasting Glucose (mg/dL)	Yoga	121.43	-17.99	6.64	<0.05	13.20
	Diet	131.20	-2.91			
	Yoga + Diet	109.49	-37.06			

The group that combined Yoga and Diet demonstrated the greatest reduction in glycemic levels (M=109.49, decrease =-37.06 mg/dL), followed by the Yoga group (M=121.43, decrease =-17.99) and the Diet group (M=131.20, decrease =-2.91). The observed differences were statistically significant, F=6.64, p<0.05, CD=13.20, suggesting that the integrated approach was more effective in enhancing glycemic control compared to either intervention on its own.

These findings suggest that a combined Yoga and Diet regimen produces significantly greater improvements in liver function (ALT/SGPT) and fasting glucose compared to isolated interventions. While the trend in triglyceride reduction also favored the combined approach, the results were not statistically significant. Overall, the data support the implementation of integrative lifestyle modifications for improved metabolic health outcomes.

Discussion

This study aimed to evaluate the comparative effectiveness of yoga, dietary modification, and their combination on key metabolic parameters ALT/SGPT, triglycerides, and fasting blood glucose in individuals at risk for or potentially presenting with early-stage Non-Alcoholic Fatty Liver Disease (NAFLD). The findings provide partial support for the role of integrative lifestyle interventions in modulating metabolic risk markers associated with NAFLD.

ALT/SGPT and Hepatic Health

ALT (Alanine Aminotransferase) is a key surrogate biomarker for hepatic inflammation and hepatocellular injury in NAFLD. While ANCOVA revealed a significant overall effect of the interventions on ALT/SGPT levels, post hoc comparisons showed no significant differences between groups. Interestingly, the combined Yoga+Diet group demonstrated the largest mean reduction in ALT, suggesting a trend toward liver function improvement, albeit not statistically significant in this sample. This supports existing literature indicating that even modest reductions in ALT through lifestyle interventions may reflect early histological improvements in liver fat content and inflammation (Romero-Gómez et al., 2017). It is also notable that lifestyle modifications particularly those that are sustainable, such as yoga can lead to reductions in hepatic enzymes over time by improving insulin sensitivity and reducing visceral adiposity. However, the lack of significant pairwise differences could be attributed to the small sample size and relatively short duration of intervention.

Triglycerides and Lipid Metabolism

Hypertriglyceridemia is a hallmark feature of metabolic syndrome and is frequently elevated in patients with NAFLD. Although all groups showed a mean reduction in triglyceride levels, particularly in the Yoga+Diet group, these changes were not statistically significant. These results mirror findings from previous studies suggesting that longer-term or more intensive interventions may be required to elicit meaningful changes in serum triglycerides (Bellentani et al., 2010). Additionally, yoga's role in modulating the hypothalamic-pituitary-adrenal axis and reducing stress hormones like cortisol may indirectly affect lipid metabolism over time. Thus, while short-term reductions in triglycerides were observed, they did not meet the threshold for statistical significance, indicating a need for extended follow-up or more aggressive dietary interventions tailored for NAFLD management such as low-carb diets.

Fasting Blood Glucose and Insulin Sensitivity

The most significant finding in this study was the reduction in fasting blood glucose in the Yoga with Diet group, which was statistically greater than the Diet-only group. This has strong implications for NAFLD, given that insulin resistance is a central mechanism in its pathogenesis. Improved glycemic control through combined interventions likely reflects improved insulin

signaling and reduced hepatic gluconeogenesis critical in halting NAFLD progression.

These results align with previous evidence showing that yoga can improve glycemic control, possibly through mechanisms involving reduced sympathetic activation, enhanced glucose uptake in skeletal muscles, and anti-inflammatory effects (Innes & Selfe, 2016). When combined with dietary adjustments, these effects appear to be additive or even synergistic, making the integrated approach particularly valuable in the management of NAFLD and its metabolic comorbidities.

Clinical Implications

Given that NAFLD is largely a lifestyle-driven condition with no currently approved pharmacological treatments, these findings support the role of non-pharmacologic, integrative interventions. The combined effect of yoga and diet targeting both metabolic and stress-related pathways may offer a low-cost, accessible, and sustainable strategy for early intervention in NAFLD, particularly for patients in resource-limited settings.

Conclusions

The present study demonstrates that integrative lifestyle interventions, particularly the combination of yoga practices and dietary modifications, have a beneficial impact on metabolic health markers in middle-aged women with mild to moderate MAFLD. Among the three intervention groups, the Yoga with Diet group showed a statistically significant improvement in fasting blood glucose levels, indicating enhanced glycaemic control. While reductions in ALT and triglyceride levels were observed across all groups, these changes were not statistically significant between groups, suggesting the need for a longer intervention duration or larger sample size to capture more robust effects.

These findings highlight the potential of combining traditional practices such as yoga with targeted dietary changes as a non-pharmacological approach to managing and possibly preventing the progression of MAFLD. Such interventions are not only cost-effective and sustainable but also culturally appropriate for the Indian population, particularly among women who are often underserved in liver disease research.

Future studies with larger samples and extended intervention periods are warranted to further validate these outcomes and explore long-term benefits. Overall, this research supports the integration of lifestyle-based strategies into public health frameworks aimed at reducing the burden of MAFLD, especially in resource-limited settings.

The small sample size (n=21) and shorter duration (8 weeks) limits the generalizability and statistical power of the findings. Additionally, the study lacked a non-treatment control group, which would have strengthened the internal validity. Future studies should aim for larger, more diverse populations and consider longer intervention durations.

Including biochemical markers such as HbA1c or HOMA-IR levels could also provide more comprehensive insight into metabolic changes.

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Ethical Approval

Obtained Ethical clearance from the Research Review Committee (RRC) and the Institutional Ethics Committee of Vels Institute of Science, Technology & Advanced Studies, Chennai. (Reg. No. UP24G9300003/2024/13-11-2024). Participants consent was obtained from all the participants.

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