# Enhancing Physiological Stress Regulation Through Vagal Yoga in Substance Abuse Rehabilitation: A Study of Serum Cortisol, C-Reactive Protein, and Fasting Blood Glucose

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**Abstract:** *Background:Substance use disorders are associated with dysregulation of stress-related and metabolic biomarkers, including serum cortisol, C-reactive protein (CRP), and fasting blood glucose (FBG). Yoga, Pranayama, and Meditation (YPM) may influence these physiological parameters; however, evidence in rehabilitation settings remains limited.*

*Aim:n To evaluate the effect of a 12-week YPM intervention on serum cortisol, CRP, and FBG among individuals undergoing inpatient rehabilitation for substance use disorders.*

*Methods: A quasi-experimental study was conducted with 60 male participants aged 18–50 years in a licensed rehabilitation centre. Participants were allocated to an experimental group (n = 30) receiving daily YPM sessions alongside routine rehabilitation care, or a control group (n = 30) receiving routine care only. Venous blood samples were collected at baseline and post-intervention. Serum cortisol (μg/dL), CRP (mg/L), and FBG (mg/dL) were measured and analysed using paired and independent sample t-tests. Statistical significance was set at $p < 0.05$.*

*Results:After 12 weeks, the experimental group showed significant reductions in serum cortisol ($p < 0.01$), CRP ($p < 0.01$), and FBG ($p < 0.05$), whereas no significant changes were observed in the control group. Between-group comparisons indicated significantly greater improvement in all three biomarkers in the experimental group.*

*Conclusion: A structured 12-week YPM program as an adjunct to routine rehabilitation care was associated with significant improvements in stress-related and metabolic biomarkers among individuals undergoing substance use rehabilitation. These findings are limited to the parameters assessed in this study.*

**Keywords:** Yoga, Pranayama, Meditation, Substance Abuse, Stress, Autonomic Balance, Vagus Nerve, Rehabilitation.

## INTRODUCTION

Substance use disorders remain a major public health concern worldwide, with substantial physical, psychological, and social consequences. According to the World Health Organization (WHO), a large number of individuals continue to be affected, necessitating structured rehabilitation and long-term care. In India, the National Survey on the Extent and Pattern of Substance Use (2019) reported widespread consumption of alcohol and other psychoactive substances, particularly among young and middle-aged adults. Chronic substance use has been associated with disturbances in physiological stress regulation, including altered cortisol secretion, increased inflammatory activity, and metabolic dysregulation.

Individuals undergoing inpatient rehabilitation for substance use disorders often experience heightened psychological stress, anxiety, and physiological imbalance, especially during early stages of recovery. Such stress-related responses may interfere with engagement in treatment and increase the risk of relapse. Consequently, rehabilitation programs are increasingly exploring complementary interventions that support both psychological stability and physical well-being alongside conventional therapeutic care.

Yoga, Pranayama, and Meditation (YPM) are mind–body practices integrating physical postures, controlled breathing, and focused mental awareness. Hatha Yoga traditionally combines asanas, pranayama, and meditation to promote harmony between physical and mental processes. Pranayama involves systematic regulation of breathing and has been associated with modulation of stress responses, while meditation enhances mental calmness and sustained attention. Due to their non-invasive nature and ease of implementation, these practices are increasingly incorporated into rehabilitation and therapeutic settings.

Physiological biomarkers such as serum cortisol (μg/dL), C-reactive protein (CRP, mg/L), and fasting blood glucose (FBG, mg/dL) are widely used indicators of stress response, inflammation, and metabolic functioning. Elevated cortisol reflects activation of the hypothalamic–pituitary–adrenal (HPA) axis under stress, whereas increased CRP indicates systemic inflammatory activity. Changes in fasting blood glucose have also been reported in individuals with prolonged substance use, reflecting metabolic strain. Monitoring these biochemical parameters allows objective assessment of physiological changes associated with interventions.

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Previous studies have demonstrated that yoga-based interventions may reduce cortisol levels and improve inflammatory profiles. However, research examining the combined effects of Yoga, Pranayama, and Meditation on serum cortisol, CRP, and FBG among individuals undergoing inpatient rehabilitation for substance use disorders remains limited, particularly in the Indian context.

The present study aimed to evaluate the impact of a 12-week YPM intervention on selected biochemical stress markers among male participants undergoing inpatient rehabilitation for substance use disorders. By comparing pre- and post-intervention values between an experimental and a control group, the study seeks to determine whether yoga-based practices are associated with improvements in physiological stress and metabolic indicators during rehabilitation.

## METHODS

### Study Design

This study employed a quasi-experimental pre–post design with a control group to evaluate the effects of Yoga, Pranayama, and Meditation (YPM) on selected physiological stress markers among individuals undergoing inpatient rehabilitation for substance use disorders. The study was conducted over 12 weeks at a licensed de-addiction and rehabilitation centre in Kerala, India. Ethical approval was obtained from the Institutional Ethics Committee of Manipur International University (Ref. No: MIU/IEC/2025/YOGA/015). Written informed consent was obtained from all participants prior to enrolment.

### Participants

A total of 60 male participants, aged 18–50 years, were recruited through purposive sampling from residents enrolled in an inpatient rehabilitation programme. Participants were allocated into two equal groups based on feasibility and willingness to engage in yoga practices:

**Experimental group (n = 30):** Received Yoga, Pranayama, and Meditation (YPM) in addition to routine rehabilitation care.

**Control group (n = 30):** Received routine rehabilitation care alone.

Baseline comparability between groups was ensured with respect to age, duration of substance use, and clinical history.

### Inclusion criteria

Male participants aged 18–50 years.

Diagnosed with substance use disorder and admitted for inpatient rehabilitation.

Abstinent from substance use for at least one week prior to baseline assessment.

Willing to participate and provide written informed consent.

### Exclusion criteria

Presence of severe psychiatric disorders (e.g., schizophrenia, bipolar disorder).

Chronic medical conditions, including diabetes mellitus, cardiovascular disease, or significant liver dysfunction.

Current use of corticosteroids or anti-inflammatory medications.

Musculoskeletal or other physical limitations interfering with safe participation in yoga practices.

### Intervention Protocol

The experimental group underwent a structured yoga-based intervention grounded in traditional Hatha Yoga practices. Sessions were conducted for 45 minutes, six days per week, over 12 weeks, under the supervision of a certified yoga instructor experienced in therapeutic applications.

| Component | Practices Included | Duration | Purpose |
|---|---|---|---|
| Asanas | Tadasana, Trikonasana, Bhujangasana, Paschimottanasana, Shavasana | 15 min | Promote physical stability, flexibility, and relaxation |
| Pranayama | NadiShodhana, Bhramari, Sheetali, deep abdominal breathing, sayujyapranyam | 15 min | Regulate breathing patterns and reduce physiological arousal |
| Meditation | Mindfulness-based silent meditation with guided relaxation | 15 min | Enhance mental calmness and focused awareness |

The control group continued routine rehabilitation activities, including psychological counselling, group therapy, and occupational therapy, without participation in structured yoga practices.

### Outcome Measures

Three biochemical parameters were assessed to evaluate stress response, inflammation, and metabolic function:

1. Serum Cortisol (μg/dL): Measured using chemiluminescence immunoassay.

2. C-Reactive Protein (CRP, mg/L): Measured using high-sensitivity immunoturbidimetric assay.

3. Fasting Blood Glucose (FBG, mg/dL): Measured using the glucose oxidase–peroxidase (GOD–POD) method.

Blood samples were collected after an overnight fast between 07:00 and 08:00 hours at baseline (Day 0) and post-intervention (Day 84). All analyses were conducted in a NABL-certified laboratory following standard protocols.

### Data Collection Procedure

Demographic and addiction-related information was obtained using a structured schedule. Venous blood samples were collected by trained personnel using aseptic techniques. Participants were instructed to maintain regular dietary and sleep routines and to avoid caffeine and nicotine on assessment days. Attendance for yoga sessions was recorded daily; participants with less than 85% attendance were excluded from the final analysis to ensure adequate intervention exposure.

### Statistical Analysis

Data were analysed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and are presented as mean ± standard deviation (SD). Within-group changes were assessed using paired sample t-tests, while between-group differences were analysed using independent sample t-tests. All tests were two-tailed, with significance set at $p < 0.05$. Effect sizes were calculated to estimate the magnitude of intervention-related changes. Tabular and graphical presentations were used to summarise the findings.

## RESULTS

### Participant Characteristics

All 60 participants completed the 12-week study period, with 30 participants in the experimental group and 30 in the control group. No participants were excluded due to non-compliance or incomplete data. Baseline demographic and clinical characteristics were comparable between groups. There were no statistically significant

differences in age or duration of substance use at baseline ($p > 0.05$), indicating equivalence between groups (Table 1).

**Table 1. Baseline Characteristics of Participants (Mean ± SD)**

| Parameter | Experimental Group (n = 30) | Control Group (n = 30) | p-value |
|---|---|---|---|
| Age (years) | 34.2 ± 7.1 | 33.5 ± 6.9 | 0.72 |
| Duration of substance use (years) | 5.6 ± 3.2 | 5.8 ± 3.5 | 0.81 |

### Changes in Biochemical Parameters

Serum cortisol, C-reactive protein (CRP), and fasting blood glucose (FBG) were analysed pre- and post-intervention.

In the experimental group, significant reductions were observed in all three markers following the 12-week YPM intervention. In contrast, the control group did not show significant changes over the same period. Between-group comparisons indicated that the experimental group had significantly greater improvement in all biochemical parameters (Table 2).

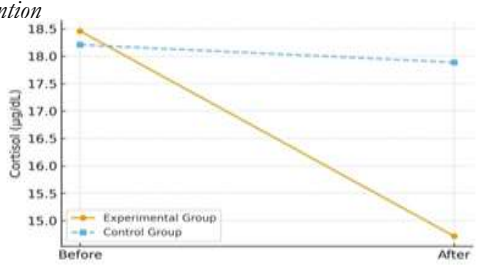
**Table 2. Comparison of Biochemical Parameters Before and After the Intervention (Mean ± SD)**

| Parameter | Experimental Group (n = 30) | Control Group (n = 30) | Between-group p-value |
|---|---|---|---|
| Serum Cortisol (µg/dL) | Pre: 18.46 ± 3.12 | Pre: 18.35 ± 3.06 | < 0.001 |
| | Post: 13.27 ± 2.86 | Post: 17.81 ± 3.02 | |
| C-Reactive Protein (mg/L) | Pre: 5.62 ± 1.41 | Pre: 5.58 ± 1.38 | < 0.001 |
| | Post: 3.48 ± 1.12 | Post: 5.44 ± 1.29 | |
| Fasting Blood Glucose (mg/dL) | Pre: 103.26 ± 9.17 | Pre: 102.81 ± 8.96 | < 0.001 |
| | Post: 91.72 ± 8.31 | Post: 101.44 ± 9.01 | |

Within-group comparisons using paired *t*-tests showed significant reductions in all three biochemical parameters in the experimental group ($p < 0.001$). No significant changes were observed within the control group.

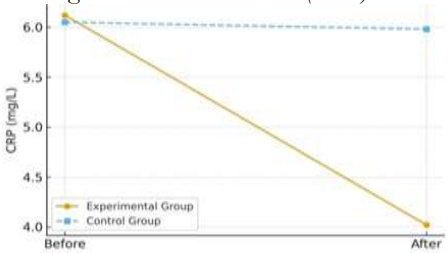
### Graphical Representation

**Figure 1.** *Changes in Serum Cortisol Levels Before and After Intervention*



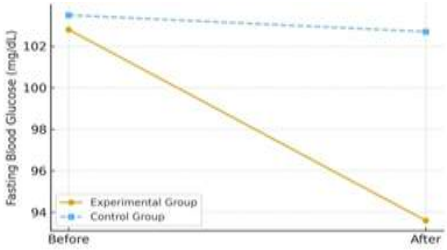

Experimental group: clear downward trend.Control group: nearly stable values.

**Figure 2.** *Changes in C-Reactive Protein (CRP) Levels*




Significant decline in the experimental group. Minimal change in the control group.

**Figure 3.** *Changes in Fasting Blood Glucose Levels*




Noticeable reduction in the experimental group.Control group shows negligible change.

Figures 1–3 depict the changes in biochemical parameters before and after the 12-week Yoga, Pranayama, and Meditation (YPM) intervention.

**Figure 1: Serum Cortisol –** The experimental group showed a marked reduction in serum cortisol levels post-intervention, whereas the control group remained nearly unchanged.

**Figure 2: C-Reactive Protein (CRP)** – CRP levels decreased significantly in the experimental group, with minimal change observed in the control group.

**Figure 3: Fasting Blood Glucose (FBG)** – FBG levels declined noticeably in the experimental group, while the control group exhibited largely stable values.

**Summary:** Across all three biomarkers, the experimental group demonstrated significant improvements following the 12-week YPM program, highlighting the potential efficacy of yoga-based interventions in reducing stress, inflammation, and metabolic dysregulation in individuals undergoing rehabilitation for substance use disorders.

### Summary of Findings

Following the 12-week intervention, participants in the experimental group demonstrated statistically significant reductions in serum cortisol, C-reactive protein (CRP), and fasting blood glucose (FBG) compared with baseline values and the control group ($p < 0.001$ for all parameters). No significant changes were observed in the control group. These findings indicate that the structured Yoga, Pranayama, and Meditation (YPM) program was associated with improvements in stress-related and metabolic biochemical markers among individuals undergoing rehabilitation for substance abuse.

## DISCUSSION

The present study evaluated the effects of a 12-week structured Yoga, Pranayama, and Meditation (YPM) intervention on selected biochemical stress-related markers among individuals undergoing residential rehabilitation for substance use disorders. The findings indicate that participants in the experimental group exhibited significant reductions in serum cortisol, C-reactive protein (CRP), and fasting blood glucose (FBG) compared with baseline values and the control group receiving routine rehabilitation care.

### Reduction in Serum Cortisol

Elevated cortisol levels are commonly observed in individuals with substance use disorders and are associated with heightened psychological stress. The reduction in serum cortisol observed in the experimental group suggests improvement in stress-related physiological

regulation following the yoga-based intervention. These findings are consistent with previous studies demonstrating reductions in cortisol levels after yoga and breathing-based interventions. The observed effects may be attributed to combined physical, breathing, and meditative practices that promote relaxation and stress modulation.

### Reduction in C-Reactive Protein

CRP is a recognized marker of systemic inflammation, often elevated in chronic substance use. The significant decrease in CRP in the experimental group suggests a reduction in inflammatory activity over the 12-week intervention period. Similar findings have been reported in prior research where yoga and meditation were associated with lower inflammatory markers. Reduced inflammation may support physical recovery during rehabilitation, although the precise mechanisms require further investigation.

### Improvement in Fasting Blood Glucose

The decrease in FBG observed in the experimental group indicates improved metabolic regulation. Dysregulated glucose metabolism is commonly reported during substance withdrawal and rehabilitation, often related to stress and lifestyle disruptions. Previous studies have suggested that yoga and pranayama may aid in glycaemic control, and the present findings support the potential benefit of yoga-based practices in improving metabolic function during rehabilitation.

### Overall Findings and Interpretation

The combined reductions in stress, inflammatory, and metabolic markers indicate that the integrated yoga-based intervention may positively influence physiological regulation during rehabilitation. While direct measures of autonomic function were not included, the biochemical improvements observed align with existing evidence on the health-promoting effects of yoga-based practices.

### Limitations

This study has several limitations. The quasi-experimental design and inclusion of only male participants from a single rehabilitation centre may limit the generalizability of the findings. The sample size was modest, and the absence of long-term follow-up precludes conclusions regarding sustained effects. Additionally, only biochemical parameters were assessed; psychological or behavioural outcomes were not included.

### Comparison with Previous Studies

The findings are consistent with earlier research demonstrating beneficial effects of yoga-based interventions on stress, inflammatory, and metabolic markers. Observed reductions in cortisol, CRP, and FBG corroborate existing literature, supporting the role of yoga-based practices as a potential adjunct in substance use rehabilitation.

### Implications and Future Research

These results suggest that Yoga, Pranayama, and Meditation may be considered supportive, low-cost, and non-pharmacological practices alongside routine rehabilitation care. Future studies should employ randomized controlled designs, include larger and more diverse samples, assess psychological outcomes, and evaluate long-term effects to strengthen evidence on the effectiveness of yoga-based interventions in rehabilitation settings.

### Conclusion

A structured 12-week Yoga, Pranayama, and Meditation program was associated with significant reductions in serum cortisol, C-reactive protein, and fasting blood glucose among individuals undergoing rehabilitation for substance use disorders. These findings indicate that yoga-based practices may support physiological regulation during rehabilitation and serve as a useful adjunct to standard care. Further research is needed to confirm long-term benefits and broader applicability.

## CONCLUSION

The present study evaluated the effects of a structured 12-week Yoga, Pranayama, and Meditation (YPM) intervention on selected biochemical markers in individuals undergoing residential rehabilitation for substance use disorders. Participants in the experimental group showed significant reductions in serum cortisol, C-reactive protein (CRP), and fasting blood glucose (FBG) compared with baseline values and the control group receiving routine rehabilitation care.

These findings suggest that incorporating Yoga, Pranayama, and Meditation alongside standard rehabilitation care may contribute to favourable changes in stress-related, inflammatory, and metabolic parameters. Within the limitations of this study, YPM practices may serve as a supportive, non-pharmacological adjunct to conventional rehabilitation programmes. Further research is warranted to confirm these results across diverse populations and to assess the long-term sustainability of the observed benefits.

## ETHICAL CLEARANCE

The study was approved by the Institutional Ethics Committee, Department of Yoga, Manipur International University (Ref. No: MIU/IEC/2025/YOGA/015). The research adhered to ethical principles outlined by the Indian Council of Medical Research (ICMR) and the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment. Institutional permission was obtained from the rehabilitation centre, and participant confidentiality was strictly maintained throughout the study.

## CONFLICT OF INTEREST

The authors declare no conflicts of interest.

## AUTHOR CONTRIBUTIONS

P. Sanilkumar (SP) conceptualized the study, conducted the literature review, obtained ethical clearance, recruited participants, collected and analyzed data, interpreted results, and prepared the manuscript. Dr. NongthombamIbohal Singh (NI) supervised the study, provided guidance on study design, data analysis, and interpretation, and critically reviewed the manuscript for intellectual content.

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