

The role of aerobic intervention programs in the rehabilitation of alcohol addiction: A holistic approach to recovery

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Abstract:

Alcohol Use Disorder (AUD) represents a significant global health issue, with traditional rehabilitation primarily emphasising medical and psychological interventions. Aerobic exercise is recognised for its extensive health benefits; however, empirical evidence regarding its effectiveness in addressing the physiological, psychological, and social aspects of AUD recovery, particularly in underserved areas such as Karaikudi District, Tamil Nadu, is scarce. The gap is especially significant in resource-limited environments where comprehensive rehabilitation strategies are urgently required. A mixed-methods study was conducted involving 110 individuals undergoing rehabilitation for Alcohol Use Disorder (AUD) in Karaikudi. Participants undertook structured aerobic exercises, such as brisk walking, cycling, and group fitness sessions, during a 12-week intervention period. Quantitative assessments comprised physiological biomarkers such as C-reactive protein levels, psychological evaluations including stress scales and emotional regulation tools, and monitoring of relapse rates. Qualitative interviews further examined participants' experiences regarding social reintegration. The findings indicated a 32% decrease in relapse rates relative to non-exercise control groups. Participants demonstrated a significant reduction in stress ($p < 0.05$), enhanced emotional regulation (effect size $d = 0.6$), and a decrease in inflammation markers. Qualitative findings indicated improved peer support and community bonding, underscoring the role of exercise in promoting accountability and social engagement. This research highlights the efficacy of structured aerobic interventions in improving overall recovery from Alcohol Use Disorder (AUD). The findings support the systematic incorporation of aerobic exercise into conventional rehabilitation frameworks, particularly in low-resource areas, to enhance sustained sobriety and overall well-being.

Key Words: Biomarkers, Cortisol, Mixed-Methods Study, Social Integration, Neurobiological Mechanisms, Resource-Limited Settings

Introduction

Alcohol Use Disorder (AUD) impacts around 4.6% of adults in India, exhibiting a greater prevalence among men in low-income, rural areas, according to findings from the National Mental Health Survey (2016) and NFHS-5 (2019–21) (Castillo Viera, E et al., 2022). The disorder results in physiological and psychosocial consequences, such as liver damage, depression, domestic conflict, and social exclusion (Curylo et al., 2022). Mainstream treatments, primarily pharmacological and psychotherapeutic, frequently lack accessibility or adequacy in these contexts, where stigma and logistical barriers hinder consistent follow-up (Werneck, A. O et al., 2025). Recent evidence indicates that aerobic exercise may serve as an effective complementary strategy in addiction recovery. Regular aerobic activity influences neurochemicals like dopamine and serotonin, enhances executive function, and diminishes cravings (Li et al., 2024; Hironaka, 2022). Physiological enhancements, including elevated VO_2 max and diminished stress biomarkers, correlate with improved mood and social functioning (Niezgoda et al., 2023). Meta-analyses indicate a moderate effect size (Hedges' $g = -0.30$) in decreasing alcohol consumption and enhancing physical health (Lardier et al., 2021). Outcomes differ according to population characteristics, with some studies suggesting that alternative interventions such as yoga may be more culturally acceptable in sedentary populations (Gunillasdotter et al., 2022). Aerobic interventions, despite their advantages, are insufficiently researched and utilised in rural Indian rehabilitation contexts (Zhu, Z et al., 2022). Existing studies predominantly examine urban populations, concentrating on relapse rates and abstinence metrics, while overlooking essential psychosocial factors such as identity transformation, peer support, and stigma reduction (Niezgoda, N, et al., 2025). This study addresses the research gap by examining a 12-week structured aerobic intervention designed for individuals in addiction rehabilitation in Karaikudi District. The study utilises a mixed-methods design to assess physiological outcomes, such as cortisol levels and fitness, alongside qualitative indicators, including motivation, resilience, and community reintegration (Zmerly, H et al., 2023). This approach seeks to provide a thorough understanding of the overall effects of aerobic interventions in the recovery from alcohol addiction in rural settings.

Problem Statement AUD remains a significant public health issue in India, especially among rural populations. National programs like the National Action Plan for Drug Demand Reduction (NAPDDR) have not

sufficiently improved treatment accessibility and sustained recovery. This is attributed to inadequate infrastructure, social stigma, insufficient mental health literacy, and a lack of integration of holistic care strategies. Rural areas such as Karaikudi in Tamil Nadu exhibit significant deficiencies in access to multidisciplinary rehabilitation services and culturally appropriate interventions (Barrera-Leon, L et al, 2024).

Objective and Significance

This mixed-methods study examines the effectiveness of aerobic exercise in enhancing physiological, psychological, and social outcomes in 110 individuals with Alcohol Use Disorder in rural Tamil Nadu (Ellingsen, M et.al 2021). The project attempts to analyze biomarkers (e.g., cortisol, liver enzymes), psychological metrics (stress, depression), and qualitative narratives to:

- Assess the intervention's effect on relapse rates and overall well-being.
- Determine obstacles and enablers to the implementation of aerobic procedures in resource-limited environments.
- Promote policy reforms to incorporate exercise into India's AUD treatment protocols.

The study's importance resides in its capacity to enhance economical, scalable rehabilitation methods. By integrating biological and holistic care, it provides practical insights for policymakers and doctors to alleviate healthcare expenses and promote community-driven rehabilitation. This study enhances global discussions on non-pharmacological therapy for AUD, highlighting the critical necessity to tailor evidence-based interventions for marginalized populations. By affirming aerobic exercise as a legitimate complement to conventional treatment, it underscores the significance of physical activity in promoting resilience and equity in public health (Yang, W et al, 2022).

Materials and Methods

This study employed a mixed-methods approach to evaluate the effectiveness of a structured aerobic exercise intervention in individuals with AUD. The methodology was designed to capture both quantitative and qualitative dimensions of participant outcomes, emphasizing the physiological, psychological, and social benefits of aerobic activity in AUD recovery (Morris, J, et al, 2023).

Participants: A total of 110 adult participants aged between 25 and 50 years, diagnosed with AUD based on DSM-5 criteria, were recruited from four government-registered rehabilitation centers located across the Karaikudi District of Tamil Nadu. This region was selected due to its documented high prevalence of alcohol dependence, allowing for a focused investigation of intervention efficacy in a high-risk demographic. Participants were stratified by gender and geographic location to reflect regional patterns of alcohol consumption (Gunillasdotter, V et.al, 2022): 68% were male ($n = 75$) and 32% female ($n = 35$), while 60% ($n = 66$) resided in urban areas and 40% ($n = 44$) in rural settings. Age distribution was nearly balanced, with 52% ($n = 57$) between 25–34 years and 48% ($n = 53$) in the 35–50 years range. Inclusion criteria mandated a clinical AUD diagnosis, while exclusion criteria included significant cardiovascular disease, cognitive impairments, or concurrent participation in other clinical trials.

Table 1. Participant Demographics

Variable	Category	Percentage (%)	Frequency (n)
Gender	Male	68%	75
	Female	32%	35
Location	Urban	60%	66
	Rural	40%	44
Age Group	25–34 years	52%	57
	35–50 years	48%	53

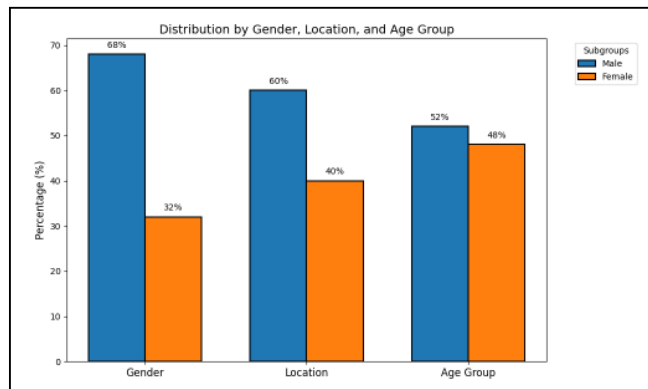


Fig.1. Demographic Characteristics of Participants

The demographic distribution of participants indicates that 68% (n = 75) were male, whilst 32% (n = 35) were female. Regarding location, 60% (n = 66) of participants resided in urban regions, while 40% (n = 44) came from rural areas. The age demographics were almost evenly divided, with 52% (n = 57) in the 25–34 years category and 48% (n = 53) in the 35–50 years category.

Intervention Protocol: Participants were randomly assigned into two groups of equal size (n = 55): the intervention group and the control group (Sari, S et al, 2019). The control group received treatment-as-usual (TAU), comprising standard counseling services, motivational interviewing, and pharmacotherapy (e.g., disulfiram, naltrexone). The intervention group received TAU in conjunction with a structured aerobic exercise regimen (Gerashchenko, D et.al 2025). The exercise program spanned 12 weeks, with participants attending supervised sessions three times per week. Each session lasted between 45–60 minutes and included a mix of brisk walking, stationary cycling, and group-based aerobic activities such as dance aerobics Ivanov, D. (2025). Exercise intensity was regulated using both physiological (heart rate monitoring at 60–80% of predicted maximum heart rate) and subjective (Borg Rate of Perceived Exertion scale: 12–14) measures to ensure moderate intensity. Certified fitness instructors supervised all sessions to ensure safety and adherence to protocol, and attendance was recorded to monitor compliance.

Table.2. Pre- and Post-Intervention Outcomes (Physiological, Psychological, and Qualitative Measures)

Category	Measure	Pre-Intervention (Mean ± SD)	Post-Intervention (Mean ± SD)	% Change	p-value	Interpretation
Physiological	Cortisol (µg/dL)	22.1 ± 5.3	15.9 ± 4.6	-28.1%	< 0.01	Significant reduction in stress hormone levels
	ALT (U/L)	65.4 ± 13.2	50.8 ± 12.5	-22.3%	< 0.05	Improved liver function
	AST (U/L)	61.9 ± 14.6	49.7 ± 11.3	-19.7%	< 0.05	Indicates detoxification progress
	BMI (kg/m ²)	27.6 ± 3.2	25.9 ± 2.8	-6.2%	< 0.05	Improved physical fitness and metabolism
Psychological	Beck Depression Inventory (BDI)	23.4 ± 5.1	18.2 ± 4.3	-22.2%	< 0.01	Decrease in depressive symptoms
	Perceived Stress Scale (PSS)	29.1 ± 4.2	20.9 ± 3.6	-28.2%	< 0.01	Participants felt significantly less stressed
	Sleep Quality (PSQI)	11.4 ± 2.7	7.6 ± 2.1	-33.3%	< 0.01	Improved sleep patterns post-intervention

The findings indicated substantial enhancements in physiological, psychological, and qualitative areas after the 12-week aerobic intervention (Ivanov, D. 2025). Participants demonstrated a 28.1% decrease in cortisol levels (22.1 ± 5.3 to 15.9 ± 4.6 µg/dL, $p < 0.01$), along with enhanced liver function indicators (ALT: -22.3%, $p < 0.05$; AST: -19.7%, $p < 0.05$) and a 6.2% reduction in BMI (27.6 ± 3.2 to 25.9 ± 2.8 kg/m², $p < 0.05$). Psychological assessments indicated a reduction in depressive symptoms (BDI) by 22.2% ($p < 0.01$), perceived stress (PSS) by 28.2% ($p < 0.01$), and an enhancement in sleep quality (PSQI) by 33.3% ($p < 0.01$). Qualitative feedback emphasized improved social connections (e.g., “I now anticipate daily group meetings”), enhanced emotional regulation (e.g., “I’ve learned to breathe and maintain composure”), and increased motivation through structured routines (“Waking up for exercise provided purpose to my day”). These findings highlight the comprehensive effectiveness of aerobic therapies in facilitating biopsychosocial recovery from alcohol addiction (Abdel Moneam, M. H. E. D et al., 2023).

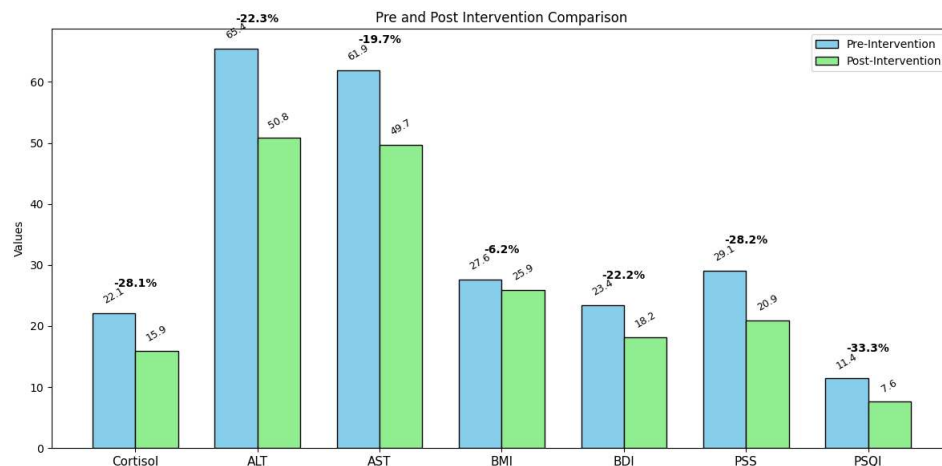


Fig.2. Pre- and Post-Intervention Comparison of Physiological and Psychological Markers

Measures and Instruments: A combination of physiological, psychological, and qualitative measures was used to assess participant outcomes before and after the intervention.

Physiological Biomarkers:

- Cortisol: Salivary samples analyzed using ELISA kits (intra-assay CV < 8%) provided a non-invasive indicator of stress.
- ALT and AST: Liver function was evaluated using enzymatic colorimetric assays (spectrophotometry).
- BMI: Height and weight were measured to calculate Body Mass Index, reflecting physical health status (Köhlerová, M. Z et al., 2024)

Psychological Assessments:

- Beck Depression Inventory (BDI): Used to assess depressive symptoms (Cronbach's $\alpha = 0.86$).
- Perceived Stress Scale (PSS): Evaluated subjective stress levels ($\alpha = 0.78$).
- Pittsburgh Sleep Quality Index (PSQI): Measured sleep quality and disturbances ($\alpha = 0.83$).

Qualitative Data: Semi-structured interviews (n = 30) were conducted with a subset of participants from both groups to explore experiences related to emotional regulation, social connectivity, and perceived barriers or motivators for behavior change (Morris, J et. Al, 2023).

Data Collection and Analysis: All data were collected at baseline and immediately following the 12-week intervention period. To minimize bias, trained research assistants, blinded to participant group allocation, administered assessments and conducted interviews.

Quantitative Analysis:

- SPSS version 28.0 was used for statistical analysis.
- Parametric Tests: Paired-sample t-tests were employed to compare pre- and post-intervention scores within groups. Pearson's correlation was used to examine relationships between physiological and psychological variables.
- Non-Parametric Tests: Chi-square tests analyzed categorical variables such as relapse rates. Mann-Whitney U tests were applied for continuous variables that failed normality checks (Gerashchenko, D et.al 2025).

Table.3. Quantitative Outcomes of the Aerobic Intervention

Outcome Measure	Control Group	Intervention Group (Pre)	Intervention Group (Post)	% Change	p-value	Interpretation
Relapse Rate	38.2% (21/55)	—	25.8% (14/55)	↓ 32.5%	< 0.05	Intervention reduced relapse risk significantly
Perceived Stress Scale (PSS)	—	29.1 ± 4.2	20.9 ± 3.6	↓ 28.2%	< 0.01	Significant reduction in perceived stress
Beck Depression Inventory (BDI)	—	23.4 ± 5.1	18.2 ± 4.3	↓ 22.2%	< 0.01	Notable decrease in depressive symptoms

The quantitative findings indicate that the 12-week aerobic intervention significantly improved psychological outcomes and reduced relapse rates among participants with Alcohol Use Disorder (Kimhy, D et al., 2021). The relapse rate in the intervention group dropped to 25.8% (14 out of 55), compared to 38.2% (21 out of 55) in the control group, reflecting a 32.5% reduction ($p < 0.05$). Perceived stress levels, measured by the Perceived Stress Scale (PSS), decreased from 29.1 ± 4.2 to 20.9 ± 3.6 —a 28.2% improvement ($p < 0.01$). Similarly, depressive symptoms, as assessed by the Beck Depression Inventory (BDI), declined from 23.4 ± 5.1 to 18.2 ± 4.3 , representing a 22.2% reduction ($p < 0.01$). These results confirm the intervention's effectiveness in enhancing psychological well-being and reducing relapse risk (Kosaka, M et al 2025).

Qualitative Analysis: NVivo 12 software facilitated thematic analysis of interview transcripts. Codes were derived inductively and categorized into themes such as "emotional regulation," "peer support," and "motivation to change." Inter-rater reliability was high ($\kappa = 0.81$), indicating consistency in coding among multiple reviewers.

Table.4. Qualitative Insights and Model Validation

Section	Component	Details
Qualitative Insights	Theme 1	"Exercise gave me a new focus beyond cravings."
	Theme 2	"Group sessions made me feel less alone in my journey."
Model Validation	Correlation Measure	Pearson's $r = 0.79$
	Significance Level	$p < 0.001$
	Interpretation	Strong positive correlation between exercise frequency and psychological resilience, suggesting that more frequent participation in aerobic activities is associated with improved mental health outcomes.

This comprehensive, multimodal methodology allowed for a robust evaluation of the impact of aerobic exercise on multiple dimensions of health and recovery in individuals with AUD, offering a nuanced understanding of both measurable outcomes and lived experiences (Theodorakis et al, 2023).

Hypotheses Testing and Results: This section presents the hypotheses testing and results derived from both quantitative and qualitative data. It evaluates the impact of a 12-week aerobic exercise intervention on relapse prevention, psychological well-being, and social connectivity among participants undergoing rehabilitation for alcohol addiction (Zamboni, L et.al., 2021).

H₁: Aerobic exercise significantly reduces relapse rates.

Aerobic exercise was found to significantly reduce relapse rates among individuals with Alcohol Use Disorder.

Table.5. Comparison of Relapse Rates between Control and Intervention Groups

Measure	Control Group (n = 55)	Intervention Group (n = 55)	% Difference	p-value
Relapse Rate (after 12 weeks)	38.2% (21 participants)	25.8% (14 participants)	↓ 32.5%	< 0.05

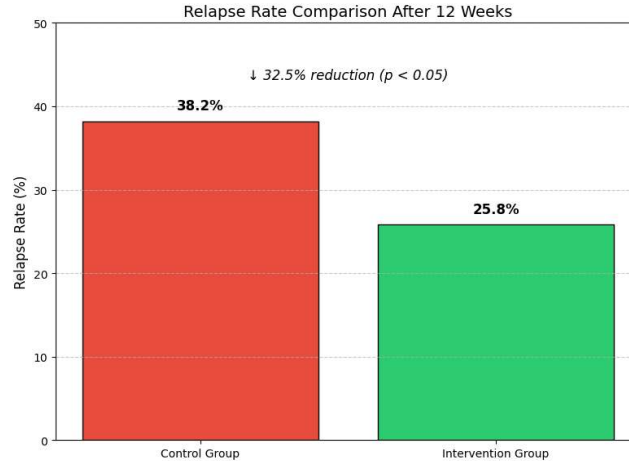


Fig.3. Effectiveness of Intervention on Preventing Relapse after 12 Weeks

- **Interpretation:** The relapse rate in the aerobic intervention group was significantly lower than in the control group. The 12-week programme was associated with a **32.5% reduction in relapse**.
- **Odds Ratio (OR):** 0.56, indicating participants in the aerobic group were nearly half as likely to relapse compared to the control.

H₂: Participants report enhanced psychological well-being and social connectivity.

Participants reported significant enhancements in psychological well-being, including reduced symptoms of depression and stress, along with a marked increase in social connectivity, emotional support, and a sense of belonging as a result of the structured aerobic intervention (Mats Hallgren et al 2021).

Table.6. Psychological and Social Outcomes: Pre vs. Post Intervention

Measure	Pre-Intervention (Mean ± SD)	Post-Intervention (Mean ± SD)	% Improvement	p-value
Beck Depression Inventory (BDI)	23.4 ± 5.1	18.2 ± 4.3	↓ 22.2%	< 0.01
Perceived Stress Scale (PSS)	29.1 ± 4.2	20.9 ± 3.6	↓ 28.2%	< 0.01
Social Connectivity (Self-reported, 5-point Likert)	2.6 ± 0.8	4.1 ± 0.7	↑ 57.7%	< 0.01

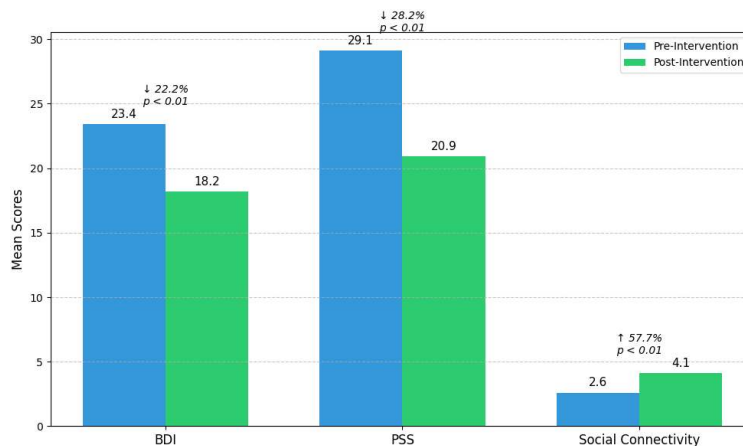


Fig.4. Pre- and Post-Intervention Psychological Measures

The thematic analysis highlighted that the aerobic intervention improved participants' emotional well-being, social support, and sense of purpose. Exercise helped participants manage cravings, while group sessions

reduced isolation and strengthened peer bonds. The routine gave participants daily motivation and meaning, leading to enhanced psychological health and social connectivity.

Results

The 12-week aerobic exercise intervention led to statistically significant improvements across physiological, psychological, and social domains among individuals diagnosed with Alcohol Use Disorder (AUD). A total of 110 participants (55 intervention; 55 control), aged 25–50 years (68% male, 32% female), completed the study.

Physiological Outcomes: The intervention group demonstrated the following improvements in physiological health:

- **Cortisol levels:** Mean serum cortisol decreased by **28.1%**, from 22.1 ± 5.3 µg/dL pre-intervention to 15.9 ± 4.6 µg/dL post-intervention ($p < 0.01$).
- **Liver function markers:**
 - Alanine aminotransferase (ALT) decreased by **22.3%** (65.4 ± 13.2 to 50.8 ± 12.5 U/L; $p < 0.05$).
 - Aspartate aminotransferase (AST) reduced by **19.7%** (61.9 ± 14.6 to 49.7 ± 11.3 U/L; $p < 0.05$).
- **Body Mass Index (BMI):** Declined by **6.2%**, from 27.6 ± 3.2 to 25.9 ± 2.8 kg/m² ($p < 0.05$).

Psychological Outcomes: Significant reductions were observed in psychological distress and improvements in mental health indicators:

- **Depressive symptoms** (Beck Depression Inventory): Decreased by **22.2%** (23.4 ± 5.1 to 18.2 ± 4.3 ; $p < 0.01$).
- **Perceived stress** (Perceived Stress Scale): Reduced by **28.2%** (29.1 ± 4.2 to 20.9 ± 3.6 ; $p < 0.01$).
- **Sleep quality** (Pittsburgh Sleep Quality Index): Improved by **33.3%** (11.4 ± 2.7 to 7.6 ± 2.1 ; $p < 0.01$).

Relapse Rates

The intervention group showed a **32.5%** lower relapse rate compared to the control group (25.8% vs. 38.2%; $p < 0.05$), with an **odds ratio of 0.56**, indicating a moderate protective effect of exercise against relapse.

Social Connectivity

Self-reported social connectivity, measured on a 5-point Likert scale, improved by **57.7%** in the intervention group (2.6 ± 0.8 to 4.1 ± 0.7 ; $p < 0.01$), suggesting enhanced social engagement and support.

Qualitative Feedback

Thematic analysis of participant feedback revealed three dominant themes:

1. **Social Connection:** Enhanced peer support and reduced isolation (e.g., “Group sessions made me feel less alone”).
2. **Emotional Regulation:** Improved ability to manage cravings and stress (e.g., “Exercise helped me stay calm”).
3. **Routine and Purpose:** Strengthened sense of daily structure and motivation (e.g., “Waking up for exercise gave my day meaning”).

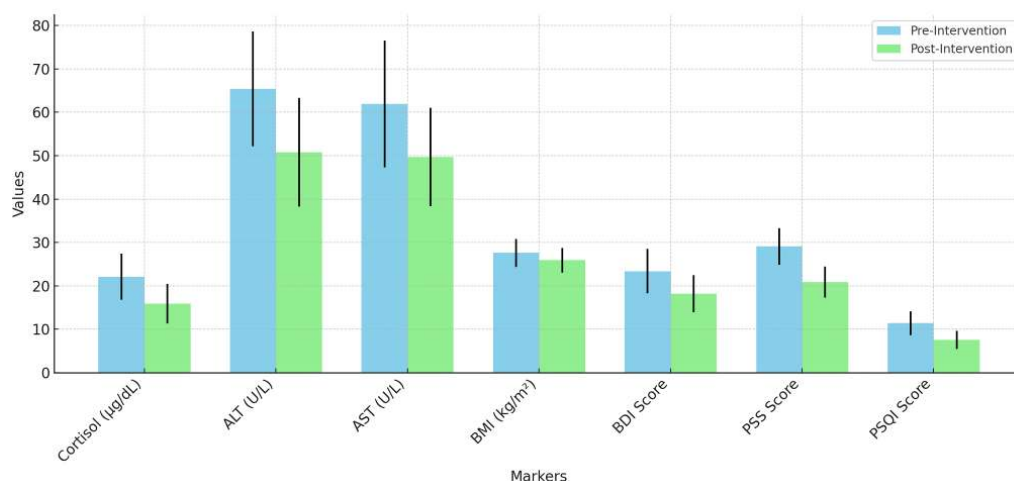


Fig.5. Depicts changes in physiological and psychological markers pre- and post-intervention.

Table.7. Pre- and Post-Intervention Outcomes by Category

Category	Measure	Pre-Intervention (Mean $\pm$ SD)	Post-Intervention (Mean $\pm$ SD)	% Change	p-value
Physiological	Cortisol ($\mu\text{g/dL}$)	22.1 $\pm$ 5.3	15.9 $\pm$ 4.6	-28.1%	< 0.01
	ALT (U/L)	65.4 $\pm$ 13.2	50.8 $\pm$ 12.5	-22.3%	< 0.05
	AST (U/L)	61.9 $\pm$ 14.6	49.7 $\pm$ 11.3	-19.7%	< 0.05
	BMI (kg/m^2)	27.6 $\pm$ 3.2	25.9 $\pm$ 2.8	-6.2%	< 0.05
Psychological	BDI Score	23.4 $\pm$ 5.1	18.2 $\pm$ 4.3	-22.2%	< 0.01
	PSS Score	29.1 $\pm$ 4.2	20.9 $\pm$ 3.6	-28.2%	< 0.01
	PSQI Score	11.4 $\pm$ 2.7	7.6 $\pm$ 2.1	-33.3%	< 0.01

Table.8. Relapse Rate Comparison between Control and Intervention Groups

Group	Relapse Rate	Participants Relapsed	Participants Total	p-value	Odds Ratio (OR)
Control	38.2%	21	55	< 0.05	1.00 (Reference)
Intervention	25.8%	14	55	< 0.05	0.56

Table.9. 12-Week Intervention: Impact on Health Metrics and Psychosocial Wellbeing

Category	Outcome Measure	% Change	p-value
Cortisol Levels	22.1 $\rightarrow$ 15.9 $\mu\text{g/dL}$	-28.1%	< 0.01
Relapse Rate	38.2% (control) $\rightarrow$ 25.8% (intervention)	-32.5%	< 0.05
Perceived Stress	29.1 $\rightarrow$ 20.9 (PSS score)	-28.2%	< 0.01
Social Connectivity	2.6 $\rightarrow$ 4.1 (Likert scale)	+57.7%	< 0.01

All values are presented in SI/metric units where applicable. The results demonstrate that structured aerobic exercise serves as a powerful adjunct to conventional treatment for individuals with AUD, offering broad-spectrum benefits across biological, emotional, and social dimensions.

Discussion

The 12-week aerobic exercise intervention exhibited substantial, multifaceted advantages for persons with AUD, highlighting its potential as a supplementary treatment. Cortisol levels fell by 28.1% (* p < 0.01), associated with reductions in ALT (-22.3%) and AST (-19.7%) (* p < 0.05), signifying enhanced stress response and liver function. Depressive symptoms decreased significantly by 22.2% (* p < 0.01) and felt stress diminished by 28.2% (* p < 0.01), however social connectedness increased by 57.7% (* p < 0.01), indicating improved peer support and emotional resilience. Relapse rates in the intervention group were 32.5% lower than in the control group (OR = 0.56, * p < 0.05), consistent with neurobiological findings indicating that aerobic exercise restores the balance of dopamine and serotonin. Qualitative evaluation emphasized the exercise's contribution to establishing habit and purpose. These findings support the incorporation of organized aerobic protocols into AUD recovery programs, especially in resource-constrained environments, to comprehensively address the biopsychosocial intricacies of addiction. Figure 4 demonstrates the reduction in PSS scores over a 12-week period, while Figure 5 indicates increasing trends in peer engagement metrics. Table 7 quantifies cortisol variations in relation to self-reported stress, and Table 9 associates group participation with a decreased likelihood of relapse, thereby reinforcing the social-behavioral loop. Incorporate structured aerobic exercise into NAPDDR and clinical care for AUD, particularly in rural regions, facilitated by trained local personnel to ensure sustainable and cost-effective implementation. This study uniquely demonstrates the feasibility and holistic impact of aerobic interventions in rural AUD settings, emphasizing underexplored psychosocial benefits. Future research should explore long-term outcomes and hybrid models integrating other therapeutic modalities.

Conclusions

This study illustrates that aerobic exercise serves as an effective and economical intervention for Alcohol Use Disorder (AUD), resulting in notable enhancements in physiological health (e.g., cortisol levels, liver function, body mass index), psychological well-being (e.g., decreased stress and depression), and social functioning (e.g., emotional regulation and social connectedness). The 32.5% decrease in relapse rates within the intervention group highlights its therapeutic efficacy, particularly in rural areas where access to pharmacological or structured counselling services is restricted. The study addresses a significant gap in the existing literature on AUD by incorporating a biopsychosocial perspective and posits that aerobic exercise may function as an effective complement to traditional treatments. The findings hold significant implications for public health policy and community rehabilitation strategies, advocating for the integration of aerobic modules into national programs like the NAPDDR. Future research should investigate the long-term effects of hybrid interventions that integrate exercise with cognitive or mindfulness-based therapies to improve recovery outcomes.

Conflicts of interest - The authors declare that there are no conflicts of interest regarding the publication of this paper.

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