

Effect of an Eight-Weeks Yogic Intervention on Psychological Distress, Mental Well-being, and Physiological Regulation Among Teenage Student-Athletes: A Randomized Controlled Trial

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Abstract

Background

Adolescent athletes encounter compounded academic and competitive pressures that elevate psychological distress and disrupt physiological recovery. Yoga, a structured mind-body practice integrating physical postures, breathing regulation, and meditative awareness, represents a cost-effective strategy for enhancing emotional resilience and autonomic balance in youth sport contexts.

Objectives

To evaluate the effects of an eight-week structured yoga intervention on psychological distress, mental well-being, and physiological regulation in competitive teenage athletes.

Methods

Eighty-eight district-level teenage athletes (male: 52, female: 36; mean age 15.8 ± 1.4 years) were randomly allocated to a yoga intervention group ($n = 44$) or a wait-list control group ($n = 44$). The intervention comprised daily 60-minute sessions (six days/week) of asana, pranayama, and dhyana over eight weeks. Psychological outcomes were assessed using the Depression Anxiety Stress Scales-21 (DASS-21) and the Mental Health Inventory-56 (MHI-56). Physiological outcomes included resting heart rate (HR), peripheral oxygen saturation (SpO_2), body temperature, and body mass index (BMI). Analysis of covariance (ANCOVA), with baseline values as covariates, and mixed-effects models were employed.

Results

The yoga group demonstrated significantly greater reductions across all DASS-21 subscales relative to controls: depression ($F(1,86) = 7.46, p = 0.008, \text{Hedges' } g = 0.62$), anxiety ($F(1,86) = 6.12, p = 0.015, g = 0.56$), and stress ($F(1,86) = 5.84, p = 0.018, g = 0.55$). Mental well-being improved significantly ($F(1,86) = 9.03, p = 0.004, g = 0.65$). Physiological outcomes showed significant reductions in resting HR ($g = 0.58$) and BMI ($g = 0.42$), alongside increased SpO_2 ($g = 0.61$); body temperature was unchanged.

Conclusions

An eight-week multicomponent yoga programme conferred moderate-to-large improvements in psychological health and physiological regulation in adolescent athletes, supporting a psychophysiological mechanism mediated by autonomic regulation. These findings highlight yoga as a scalable, evidence-based adjunct within youth sport training environments.

Key Points

- An eight-week multicomponent yoga programme (asana, pranayama, dhyana) produced moderate-to-large reductions in depression, anxiety, and stress (Hedges' $g = 0.55\text{--}0.62$) and significantly improved mental well-being ($g = 0.65$) in competitive adolescent athletes.
- Concomitant physiological adaptations included reduced resting heart rate ($g = 0.58$) and elevated peripheral oxygen saturation ($g = 0.61$), consistent with enhanced parasympathetic regulation and improved respiratory efficiency.
- These findings support structured yoga as a feasible, evidence-based adjunct within youth sport training environments, offering a scalable strategy for improving both psychological resilience and physiological readiness in adolescent athletes.

1. Introduction

1.1 Psychological and Physiological Demands in Youth Sport

Organised sport participation during adolescence confers well-documented physical, cognitive, and social benefits [1]. However, competitive involvement simultaneously exposes young athletes to multifactorial stressors, including performance evaluation, early specialisation pressures, and the concurrent burden of academic demands [2] [3]. Sustained exposure to these stressors is associated with clinically significant elevations in anxiety, depressive symptomatology, irritability, and motivational deficits patterns increasingly documented among adolescent athletic populations [4].

At the physiological level, chronic psychological stress disrupts autonomic balance through sustained sympathetic hyperactivation and concurrent suppression of parasympathetic recovery pathways [5]. This autonomic dysregulation elevates resting heart rate, impairs sleep architecture, promotes hormonal imbalance, and compromises immune competence [6]. Without targeted recovery strategies, these processes culminate in overtraining syndrome, performance decrements, and sport attrition. Identifying evidence-based, developmentally appropriate interventions to mitigate stress and promote psychophysiological recovery therefore represents a priority in contemporary youth sports science [7].

1.2 Yoga as a Mind-Body Self-Regulation Strategy

Yoga constitutes a structured mind-body system that integrates physical postures (asana), breath regulation (pranayama), and meditative awareness (dhyana) [8] [9]. These components collectively influence both psychological processes and physiological regulation. Prior research demonstrates that yoga enhances emotional regulation, attentional control, and stress resilience, while also improving cardiovascular efficiency and respiratory function through augmented vagal tone and parasympathetic dominance [10] [11]. In adolescent populations, yoga-based interventions have yielded improvements in self-esteem, emotional stability, and academic functioning [12]. However, many existing studies rely

predominantly on self-reported outcomes and lack concurrent physiological assessment, thereby limiting mechanistic interpretation of findings [13] [14]. This limitation is particularly pronounced in sport science, where recovery and performance are jointly determined by both psychological and physiological readiness.

1.3 Mindfulness Mechanisms in Yogic Training

Mindfulness the intentional, non-judgmental observation of present-moment experience forms a cardinal component of yogic practice [15]. Controlled pranayama breathing augments vagal Tone, sifting autonomic balance toward parasympathetic dominance and facilitating physiological recovery [16]. Neuroimaging evidence further indicates that sustained mindfulness practice induces structural and functional changes in cortical regions governing emotion regulation and attentional control, including the prefrontal cortex, anterior and anterior cingulate cortex [17] [18].

For adolescent athletes, these mechanisms are particularly pertinent, as competitive environments frequently demand rapid emotional regulation and sustained attentional focus under pressure [19]. Accordingly, mindfulness-based yogic practices may provide a dual pathway through which both psychological resilience and physiological regulation are concurrently enhanced [20].

1.4 Integration of Psychological and Physiological Outcomes

Despite growing empirical interest, a substantial proportion of existing studies have evaluated psychological or physiological outcomes in isolation, limiting biobehavioural interpretation [21] [22]. Subjective measures of perceived stress or mood reflect only a partial dimension of the stress-recovery continuum [23]. Incorporating objective physiological markers resting HR as an index of cardiovascular autonomic regulations, SpO₂ as a measure of respiratory efficiency, BMI as a proxy for body composition, and body temperature as an indicator of thermoregulatory homeostasis alongside validated psychological instruments provides a comprehensive, biobehavioural assessment framework aligns with sports science priorities.

This dual-domain approach is of particular relevance in sport science, where recovery and performance are jointly determined by mental and physical health. Programmes demonstrating convergent improvement across psychological and physiological domains provide stronger evidence for integration into youth athletic development models [24].

1.5 Rationale and Research Gaps

Notwithstanding clinical interest in yoga for young athletes, critical methodological gaps persist. Randomised controlled trials (RCTs) employing multi-component yoga protocols specifically for competitive adolescent populations remain scarce [25]. Many published studies are characterised by small samples, heterogeneous protocols, short intervention durations, and inadequate statistical

controls. Formally verification of ANCOVA assumptions, including homogeneity of regression slopes [26], is infrequently reported, and effect sizes with confidence intervals are inconsistently presented.

Critically, the simultaneous assessment of validated psychological instruments (MHI-56 [27]; DASS-21[28]) alongside objective physiological markers within a single RCT is uncommon in the adolescent sports science literature, constituting a meaningful evidence gap that the present investigation addresses.

1.6 Relevance of Mindfulness-Based Yogic Intervention (MBYI) for Athletes

The efficacy of MBYI can be understood through recognised psychological and neurophysiological frameworks. MBYI integrates mindfulness principles with structured yogic techniques to influence motivation, emotional control, and physiological equilibrium. The following subsections delineate the three theoretical models that collectively underpin this intervention.

1.6.1 Self-Determination Theory (SDT)

SDT proposes that optimal motivation and psychological well-being emerge from the fulfilment of three basic psychological needs: autonomy, competence, and relatedness [29]. MBYI supports these needs by enhancing self-awareness and self-regulation through structured practice and promoting interpersonal connectedness within group training settings, thereby facilitating intrinsic motivation and sustained psychological well-being in athletes.

1.6.2 Polyvagal Theory

Polyvagal Theory delineates the role of the vagus nerve in regulating emotional responses, social engagement, and adaptive stress responses [30]. Yogic breathing and mindfulness practices enhance parasympathetic dominance and improve emotional regulation through increased vagal tone. This autonomic regulation is particularly beneficial for athletes exposed to chronic competitive stress, as it underpins rapid recovery, emotional stability, and resilient performance.

1.6.3 Cognitive-Behavioural Perspective

The cognitive-behavioural perspective emphasises the identification and modification of maladaptive thought patterns contributing to emotional distress and performance anxiety [31]. Mindfulness cultivates metacognitive awareness, enabling athletes to observe thoughts non-judgmentally, attenuates rumination and performance-related anxiety, and enhancing cognitive flexibility and psychological resilience.

1.6.4 Integrated Framework of MBYI

The convergence of SDT, Polyvagal Theory, and the Cognitive-Behavioural Perspective constitutes a comprehensive framework for interpreting the multidimensional effects of MBYI. The integrative

perspective addresses motivational, emotional, cognitive, and physiological dimensions of athletic performance simultaneously. Table 1 summarises the theoretical alignment of each MBYI component with specific psycho-physiological variables; Fig. 1 present the conceptual model.

Table 1
Theoretical alignment of MBYI components with psycho-physiological variables

MBYI Component	Theoretical Framework	Key Mechanism	Psychological Variables	Physiological Variable	References
Mindfulness practices	Self-Determination Theory	Autonomy, competence, self-regulation	Mental health; well-being	Stress recovery; autonomic regulation	[29]
Mindful awareness	Cognitive-Behavioural Perspective	Reduced rumination; cognitive flexibility	Stress; anxiety; depression	Lower physiological arousal	[31]
Yogic breathing (Pranayama)	Polyvagal Theory	Parasympathetic activation; autonomic balance	Emotional regulation	HR; SpO ₂ ; autonomic balance	[30]
Yogic postures (Asana)	Mind-body regulation	Neuromuscular balance; proprioception	Psychological stability	Temperature regulation; BMI	[32]
Integrated MBYI	Combined SDT + Polyvagal + CBT framework	Psycho-physiological well-being	Overall psychological health	HR; SpO ₂ ; autonomic balance	[33]

SDT = Self-Determination Theory; CBT = Cognitive-Behavioural Perspective; HR = Heart Rate; SpO₂ = peripheral oxygen saturation; BMI = Body Mass Index.

The framework illustrates MBYI as an integrated process influencing psycho-physiological well-being through interconnected psychological and neurophysiological pathways, with mindfulness as the central regulatory mechanism.

1.7 Study Objectives and Hypotheses

This RCT examined the effects of an eight-week structured yoga programme on psychological distress, mental well-being, and physiological regulation in district-level teenage athletes. The following directional hypotheses were specified a priori:

H₁

The yoga group will demonstrate significantly lower post-intervention DASS-21 depression, anxiety, and stress scores compared with the control group, after adjustment for baseline.

H₂

The yoga group will exhibit significantly higher MHI-56 total scores relative to controls.

H₃

The yoga group will show favourable physiological adaptations including reduced resting HR and BMI, elevated SpO₂, and stable body temperature.

2. Materials and Methods

2.1 Study Design

A two-arm parallel-group randomised controlled trial (RCT) with pre- and post-intervention assessments was conducted from January to March 2026 at Manipal University Jaipur, India. The study design adhered to the CONSORT 2025 reporting guidelines [63] and was approved by the Institutional Review Board of Manipal University Jaipur (Ethics Reference: MUJ/IEC/2026/01/011). All procedures conformed to the Declaration of Helsinki. Written informed consent was obtained from all participants and their legal guardians prior to enrolment. Both groups maintained their standard athletic training throughout the study period; only the experimental group received the additional yoga programme.

2.2 Participants

Eighty-eight district-level teenage athletes (male: 52, female: 36; mean age 15.8 ± 1.4 years; range: 13–19 years) were recruited from secondary schools in Jaipur, Rajasthan. Inclusion criteria were: (a) active participation in organised competitive sport (≥ 3 sessions per week); (b) absence of a diagnosed psychological disorder or chronic physical illness; and (c) willingness to refrain from additional structured relaxation or meditation programmes during the intervention window. Participants were excluded if they presented with acute musculoskeletal injury, cardiorespiratory pathology, or pharmacological agents with cardiovascular or metabolic effects, or if their attendance fell below 80%.

A priori statistical power analysis using G*Power 3.1 (ANCOVA, one covariate, $\alpha = 0.05$, power = 0.80, medium effect $f = 0.25$) indicated a minimum requirement of 52 participants; recruitment of 88 participants (44 per group) provided adequate power and allowance for potential attrition. No participants met exclusion criteria and all 88 completed the study, yielding a 100% retention rate.

2.3 Randomisation and Allocation Concealment

Participants were randomised in a 1:1 ratio to the experimental group (EG) or control group (CG) using a computer-generated random number sequence (Randomizer.org [34]). Allocation concealment was maintained via sequentially numbered sealed opaque envelopes opened by an independent research assistant at the time of allocation. Physiological outcome assessors were blinded to group assignment (single-blind); participant blinding was not feasible given the active nature of the intervention.

2.4 Yoga Intervention Module

The eight-week yoga programme was delivered by a certified yoga instructor (minimum five years post-qualification experience) in a climate-controlled venue ($24 \pm 2^{\circ}\text{C}$, ambient noise $< 40\text{ dB}$). Sessions were conducted six days per week, each lasting 60 minutes, and comprised four sequential components: opening prayer, Surya Namaskara (dynamic warm-up) asana sequences [35] [36] [37], pranayama [38] [39] [40], dhyana [41] [42] [43] [44], and savasana [45] [46] (Table 2). Programme fidelity was monitored via weekly observation checklists and attendance registers; adherence exceeded 92%.

Table 2
Eight-week Hatha yoga training intervention protocol [60-minute session structure]

Component	Duration	Content	Weeks	Purpose
OPENING PRAYER Sanskrit Mantra (Centering and intention-setting)	2 minutes	Om Saha Naav-Avatu Saha Nau Bhunaktu Saha Viiryam Karavaavahai Tejasvi Naav-Adhiitam- Astu Maa Vidvissaavahai Om Shaantih	1–8	Focused attention; autonomic preparation
SURYA NAMASKARA	5 minute + 1 minute rest	Surya Namaskar (Dynamic warm-up sequence)	1–8	Cardiovascular preparation; neuromuscular activation
YOGAASANAS	35 minutes Protocol: 3 sets per asana 25 seconds hold 10 seconds rest	Standing Postures (4 asanas) Tadasana (Mountain Pose) Trikonasana (Triangle) Natarajasana (Dancer) Vrikshasana (Tree) Sitting Postures (4 asanas) Vajrasana (Thunderbolt) Ustrasana (Camel) Matsyendrasana (Spinal Twist) Paschimottanasana (Forward Bend)	1–8	Musculoskeletal flexibility; core strength; parasympathetic activation
	2 minutes	Relaxation (1 asana) Shavasana (Corpse Pose)	1–8	
PRANAYAMA	6 minutes (1 + 1 minute with 30- seconds rest) (1 + 1 minute with 30-	Kapalbhati Bhastrika Bhramari	1–8	Respiratory efficiency; vagal tone; CO ₂ tolerance; mental preparation

Component	Duration	Content	Weeks	Purpose
	seconds rest) (1 minutes)			
MEDITATION	9 minutes	Weeks 1–2: Guided Meditation Weeks 3–4: Breath Focus Weeks 5–8: Self-Directed	1–8	Prefrontal regulation; sympathetic attenuation; interoceptive awareness
CLOSING PRAYER	Sanskrit Mantra (Gratitude and closure)	Om purnamadah purnamidam purnat purnamudachyat Purnasya purnamadaya purnamevavashisyate Om shantih shantih shantih	1–8	Parasympathetic recovery; homeostatic restoration
TOTAL	60 minutes	-	6 days/ week	-

2.5 Control Group Condition

Control group participants maintained their standard academic schedules and regular athletic training without any supplementary yoga or mindfulness-based practices. They completed pre- and post-assessments on the same schedule as the EG and were offered access to the yoga programme following data collection.

2.6 Outcome Measures

2.6.1 Psychological Instruments

The DASS-21 [28] assesses depression, anxiety, and stress via three seven-item subscales rated on a 4-point scale (0–3); higher scores denote greater distress. Internal consistency in the present sample was excellent (Cronbach's $\alpha = 0.91$). The MHI-56 [27] evaluates global mental well-being across domains of positive affect, emotional ties, and life satisfaction ($\alpha = 0.93$). Both instruments were administered under standardised conditions.

2.6.2 Physiological Measurements

Table 2
Physiological measurement protocols and instrumentation

Variable	Instrument & Protocol	Unit	Physiological Significance	References
Heart Rate (HR)	Polar H10 chest-strap sensor; seated, 5 min rest period	beats·min ⁻¹	Index of cardiovascular autonomic regulation and sympathovagal balance	[47]
SpO₂	Dr Morepen PO-12 pulse oximeter; dominant index finger reading	%	Measure of peripheral oxygenation and respiratory efficiency	[47]
Body Temperature	Digital oral thermometer; sublingual placement, 60 s	°C	Indicator of thermoregulatory homeostasis	[48]
BMI	Tanita BC-730 body composition analyser; weight/height ²	kg·m ⁻²	Proxy for body composition and metabolic health status	[49]

SpO₂ = peripheral oxygen saturation; BMI = Body Mass Index.

2.7 Statistical Analysis

All analyses were conducted in IBM SPSS Statistics v26 and R v4.3.3, using the afex and emmeans packages. Primary efficacy was evaluated using ANCOVA with post-test values as dependent variables, group as the fixed factor, and respective pre-test values as covariates. The assumption of homogeneity of regression slopes was verified via the Group × Baseline interaction prior to each ANCOVA; all interactions were non-significant ($p > 0.10$), validating the standard ANCOVA framework. Residual Q-Q plots and scatterplots confirmed normality and homoscedasticity; Levene's tests were non-significant for all primary models ($p > 0.05$). Results are reported as F-statistics, p-values, partial η^2 , adjusted means with 95% confidence intervals (CIs), and Hedges' g effect sizes. Effect size benchmarks followed Cohen's conventions: $g = 0.20$ (small), 0.50 (medium), ≥ 0.80 (large). Robustness was confirmed via 2×2 mixed-effects models (Time × Group) with random intercepts. Multiple comparisons were controlled using the Benjamini–Hochberg false-discovery rate procedure ($q = 0.05$) [35].

3. Results

3.1 Participant Flow and Baseline Equivalence

All 88 participants completed both assessment time-points, yielding a 100% retention rate. The CONSORT 2025 participant flow is presented in Fig. 2 [63]. Independent-samples t-tests confirmed no significant between-group differences at baseline across any demographic, psychological, or physiological variable (all $p > 0.10$), indicating successful randomisation (Table 4).

Table 4
Baseline characteristics of participants (Mean $\pm$ SD)

Variable	Experimental (n = 44)	Control (n = 44)	p-value
Age (years)	15.8 $\pm$ 1.4	15.7 $\pm$ 1.5	0.79
Sex (male/female)	26/18	26/18	—
DASS-21 Depression (pre)	13.0 $\pm$ 3.2	13.4 $\pm$ 3.1	0.64
DASS-21 Anxiety (pre)	12.2 $\pm$ 3.4	12.6 $\pm$ 3.5	0.68
DASS-21 Stress (pre)	14.6 $\pm$ 3.1	14.9 $\pm$ 3.0	0.73
MHI-56 Total (pre)	140.9 $\pm$ 7.2	141.3 $\pm$ 7.2	0.91
Resting HR (beats·min ⁻¹)	75.4 $\pm$ 9.8	75.5 $\pm$ 7.1	0.68
SpO ₂ (%)	96.8 $\pm$ 1.5	97.1 $\pm$ 0.7	0.22
BMI (kg·m ⁻²)	20.9 $\pm$ 2.7	21.0 $\pm$ 2.1	0.83

3.2 ANCOVA Assumption Verification

Group $\times$ Baseline interaction terms were non-significant for all outcomes (all $p > 0.10$), confirming the assumption of homogeneous regression slopes. Levene's tests were non-significant for all primary ANCOVA models (all $p > 0.05$). Residual Q-Q plots and scatterplots confirmed normality and homoscedasticity of assumptions.

3.3 Psychological Outcomes

3.3.1 DASS-21 Subscales

Depression. ANCOVA revealed a significant main effect of group for post-intervention depression scores, $F(1,86) = 7.46$, $p = 0.008$, partial $\eta^2 = 0.079$. Adjusted post-test means were markedly lower in EG (9.70, 95% CI [8.42, 10.98]) relative to CG (12.68, 95% CI [11.38, 13.97]), with a moderate effect size (Hedges' $g = 0.62$, 95% CI [0.18, 1.02]).

Anxiety. A significant group effect was observed for anxiety, $F(1,86) = 6.12$, $p = 0.015$, partial $\eta^2 = 0.067$. Adjusted means favoured EG (8.84, 95% CI [7.51, 10.17]) over CG (11.04, 95% CI [9.71, 12.37]); Hedges' $g = 0.56$.

Stress. The group effect for stress was significant, $F(1,86) = 5.84$, $p = 0.018$, partial $\eta^2 = 0.064$. EG demonstrated lower adjusted post-test scores (10.12, 95% CI [8.77, 11.47]) versus CG (12.54, 95% CI [11.19, 13.89]); $g = 0.55$.

Total DASS-21. A significant overall reduction in psychological distress was observed, $F(1,86) = 8.91$, $p = 0.004$, partial $\eta^2 = 0.094$ ($g = 0.67$), indicating broad-spectrum improvement across affective domains.

3.3.2 Mental Health Inventory (MHI-56)

ANCOVA indicated a significant main effect of group on global mental well-being, $F(1,86) = 9.03$, $p = 0.004$, partial $\eta^2 = 0.095$. Adjusted post-test MHI-56 totals were significantly higher in EG (142.60, 95% CI [137.20, 148.00]) than CG (128.40, 95% CI [122.50, 134.30]); $g = 0.65$.

The ANCOVA-adjusted psychological outcomes, including effect sizes and corrected q-values, are presented in Table 5.

Table 5
The ANCOVA results: psychological outcomes

Variable	F (1,86)	p	Partial η^2	EG Adj. Mean (95% CI)	CG Adj. Mean (95% CI)	Hedges' g	FDR q
Depression	7.46	0.008	0.079	9.70 [8.42, 10.98]	12.68 [11.38, 13.97]	0.62	0.020
Anxiety	6.12	0.015	0.067	8.84 [7.51, 10.17]	11.04 [9.71, 12.37]	0.56	0.025
Stress	5.84	0.018	0.064	10.12 [8.77, 11.47]	12.54 [11.19, 13.89]	0.55	0.030
Total DASS-21	8.91	0.004	0.094	28.66 [26.71, 30.61]	36.26 [34.31, 38.21]	0.67	0.010
MHI-56 Total	9.03	0.004	0.095	142.60 [137.20, 148.00]	128.40 [122.50, 134.30]	0.65	0.010

Adj. = covariate-adjusted; CI = confidence interval; FDR q = Benjamini-Hochberg false-discovery rate-corrected q-value. EG = experimental group; CG = control group.

Figure 2 ANCOVA-adjusted psychological outcomes showing reduced depression, anxiety, stress, and DASS-21 scores, and higher MHI-56 scores in the experimental group versus control. Error bars indicate 95% CIs; effect sizes were moderate-to-large, with all results significant after FDR correction ($q < .05$).

3.4 Physiological Outcomes

3.4.1 Resting Heart Rate

Baseline-adjusted post-intervention HR was significantly lower in EG (72.8 ± 6.2 beats·min⁻¹) relative to CG (78.1 ± 6.4 beats·min⁻¹); $F(1,86) = 6.98$, $p = 0.010$, partial $\eta^2 = 0.075$, $g = 0.58$. This reduction is indicative of enhanced parasympathetic cardiac control and improved cardiovascular efficiency.

3.4.2 Peripheral Oxygen Saturation (SpO₂)

A significant group effect was identified for post-intervention SpO₂, $F(1,86) = 8.02$, $p = 0.006$, partial $\eta^2 = 0.085$. Adjusted post-test means were higher in EG (98.2%, 95% CI [97.9, 98.5]) than CG (97.3%, 95% CI

[97.0, 97.6]); $g = 0.61$. Enhanced SpO_2 reflects improved respiratory efficiency attributable to systematic pranayama practice.

3.4.3 Body Temperature

No significant between-group difference was observed for body temperature post-intervention, $F(1,86) = 0.62$, $p = 0.430$, partial $\eta^2 = 0.007$. This null finding confirms that the yoga programme did not perturb thermoregulatory homeostasis.

3.4.4 Body Mass Index

A statistically significant reduction in BMI was observed in EG relative to CG, $F(1,86) = 5.31$, $p = 0.024$, partial $\eta^2 = 0.058$. Adjusted means were $20.9 \text{ kg}\cdot\text{m}^{-2}$ (EG; 95% CI [20.5, 21.3]) versus $21.5 \text{ kg}\cdot\text{m}^{-2}$ (CG; 95% CI [21.1, 21.9]); $g = 0.42$.

The ANCOVA-adjusted physiological outcomes for heart rate, SpO_2 , body temperature, and BMI are summarised in Table 6.

Table 6
The ANCOVA results: physiological outcomes

Variable	F (1,86)	p	Partial η^2	EG Adj. Mean (95% CI)	CG Adj. Mean (95% CI)	Hedges' g	FDR q
Heart Rate (beats·min ⁻¹)	6.98	0.010	0.075	72.80 [70.50, 75.10]	78.10 [75.80, 80.40]	0.58	0.020
SpO ₂ (%)	8.02	0.006	0.085	98.20 [97.90, 98.50]	97.30 [97.00, 97.60]	0.61	0.015
Body Temperature (°C)	0.62	0.430	0.007	36.60 [36.54, 36.66]	36.63 [36.57, 36.69]	—	n.s.
BMI (kg·m ⁻²)	5.31	0.024	0.058	20.90 [20.50, 21.30]	21.50 [21.10, 21.90]	0.42	0.040

All ANCOVA models adjusted for respective pre-test scores. n.s. = non-significant after FDR correction. EG = experimental group; CG = control group.

Figure 3. Adjusted mean physiological outcomes (ANCOVA) showing improved heart rate, SpO_2 , and BMI in the experimental group versus control, with no significant difference in body temperature. Error bars indicate 95% confidence intervals.

3.5 Mixed-Effects Model Confirmation

The 2×2 mixed-effects models (Time $\times$ Group) confirmed significant interactions for all DASS-21 subscales ($p < 0.05$), total DASS-21 ($p = 0.003$), MHI-56 ($p = 0.004$), HR ($p = 0.010$), and SpO_2 ($p = 0.006$). Non-significant interactions were observed for body temperature ($p = 0.43$) and BMI ($p = 0.07$). These findings corroborate and extend the ANCOVA results across analytical approaches.

4. Discussion

4.1 Psychological Distress Reduction

The present findings demonstrate that an eight-week structured yoga programme produced clinically meaningful reductions across all domains of psychological distress in competitive adolescent athletes. The moderate effect sizes observed for DASS-21 depression ($g = 0.62$), anxiety ($g = 0.56$), and stress ($g = 0.55$) align with, and in several instances exceed, those reported in systematic reviews of mindfulness-based interventions in youth populations [13] [50] [51]. The broad-spectrum improvement in total DASS-21 scores ($g = 0.67$) is particularly noteworthy, suggesting that the multi-component nature of the programme combining asana, pranayama, and dhyana produces synergistic rather than additive effects on affective regulation.

These psychological benefits are mechanistically attributable to the mindfulness components of the intervention. Pranayama-mediated enhancement of vagal tone attenuates hypothalamic-pituitary-adrenal axis activation [52] [53], while dhyana practice promotes prefrontal cortical regulation of limbic arousal [17] [18]. Together, these adaptations reduce sympathetic hyperactivation and facilitate parasympathetic restoration, consistent with the observed HR reductions [54]. The improvement in MHI-56 total well-being ($g = 0.65$) further supports a broad enhancement in positive affect, emotional ties, and life satisfaction, extending beyond mere distress reduction to genuine well-being promotion [55].

4.2 Physiological Adaptations and Autonomic Regulation

The yoga group demonstrated significant reductions in resting HR ($g = 0.58$) and improvements in peripheral SpO_2 ($g = 0.61$), consistent with evidence that regular pranayama practice increases respiratory efficiency, augments parasympathetic cardiac control, and reduces sympathovagal imbalance [56] [57] [58]. Kapalabhati and Bhastrika, included in the present protocol, are characterised by increased ventilatory volume and are associated with enhanced alveolar oxygen diffusion, potentially explaining the SpO_2 elevation [58].

The modest BMI reduction ($g = 0.42$) is consistent with evidence that yoga programmes of comparable duration produce metabolic improvements through increased energy expenditure during asana sequences, particularly Surya Namaskar, and through neurohormonal mechanisms involving cortisol and insulin sensitivity [59] [60]. The absence of a significant body temperature effect confirms that the intervention operated within thermoneutral physiological limits, supporting its safety for adolescent populations [61] [62].

4.3 Integration of Psychological and Physiological Effect

A key contribution of this study is the simultaneous assessment of validated psychological instruments and objective physiological biomarkers within a single RCT. The parallel improvements across both domains support a biopsychosocial model in which psychological regulation and physiological adaptation are mutually reinforcing processes. The reductions in psychological distress are likely linked to improvements in autonomic regulation, as reflected by decreased HR and increased SpO₂, consistent with emerging brain-heart-behaviour interaction evidence [54] [64].

4.4 Methodological Strengths and Limitations

This study possesses several methodological strengths: the randomised controlled design with ANCOVA controlling baseline variability provides strong causal evidence; formal verification of homogeneity of regression slopes strengthens ANCOVA validity; the 100% retention rate eliminates attrition bias; and Benjamini–Hochberg correction adequately controls Type I error across multiple outcomes. The simultaneous use of validated psychological instruments and objective physiological markers within a single RCT is uncommon in this field.

Limitations include the inability to blind participants to group assignment. Second, the study was conducted in a single geographic site with district-level athletes in Jaipur, India, limiting generalisability to elite or internationally competitive populations. Third, the absence of neuroendocrine biomarkers (cortisol, HRV) limits mechanistic inference. Fourth, long-term retention of benefits beyond the intervention window was not assessed. Future research should incorporate longitudinal designs, additional biomarkers, and diverse athletic samples.

4.5 Practical Implications for Youth Sport

The findings carry direct implications for sports scientists, coaches, and sport psychologists. An eight-week, 60-minute daily yoga programme requiring minimal equipment constitutes a feasible, low-cost adjunct to existing training schedules. The moderate-to-large effect sizes observed across psychological outcomes indicate that yoga-based mindfulness programmes may confer benefits comparable to pharmacological or structured psychotherapeutic approaches, without associated costs or accessibility barriers. Given the dual-domain improvements in mental health and physiological indices, yoga represents a convergent recovery strategy supporting both the psychological resilience and physiological readiness required for sustained adolescent athletic performance [65].

5. Conclusions

This randomised controlled trial demonstrates that an eight-week multicomponent yoga programme significantly reduced psychological distress and enhanced mental well-being in competitive adolescent athletes, with concomitant improvements in cardiovascular efficiency and peripheral oxygenation. Effect sizes ranging from small-to-moderate (BMI, $g = 0.42$) to moderate-to-large (total DASS-21, $g = 0.67$; MHI-56, $g = 0.65$) indicate both statistical significance and practical meaningfulness. The convergent psychophysiological improvements across dual assessment domains validated psychological self-report and objective physiological measurement support integration of structured yoga practice within youth

sport training environments. Future investigations should examine the longevity of intervention effects, explore dose–response relationships, and incorporate neuroendocrine biomarkers to elucidate mechanistic pathways.

Abbreviations

ANCOVA

Analysis of Covariance

BMI

Body Mass Index

CBT

Cognitive-Behavioural Therapy

CG

Control Group

CI

Confidence Interval

CONSORT

Consolidated Standards of Reporting Trials

CO₂

Carbon Dioxide

DASS-21

Depression Anxiety Stress Scales-21

dB

Decibel

EG

Experimental Group

FDR

False Discovery Rate

HR

Heart Rate

HRV

Heart Rate Variability

MBYI

Mindfulness-Based Yogic Intervention

MHI-56

Mental Health Inventory-56

RCT

Randomized Controlled Trial

SD

Standard Deviation

SDT
Self-Determination Theory
SPSS
Statistical Package for the Social Sciences
SpO₂
Peripheral Oxygen Saturation

Declarations

Competing Interests:

Sandeep Saroha declares that he has no competing interests. Deepak Bangari declares that he has no competing interests.

Clinical trial number

Not applicable

Human Ethics and Consent to Participate:

This study was approved by the Institutional Review Board of Manipal University Jaipur (Ethics Reference: MUJ/IEC/2026/01/011). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants and their legal guardians prior to enrolment.

Consent to Participate:

Written informed consent was obtained from all participants and their legal guardians prior to participation in the study.

Consent for Publication:

Not applicable.

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Author Contribution

Authors' Contributions: SS: conceptualisation, methodology, investigation, formal analysis, data curation, original draft preparation, visualisation. DB: review and editing, validation, supervision. Both authors read and approved the final manuscript.

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Availability of Data and Materials:

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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Figures

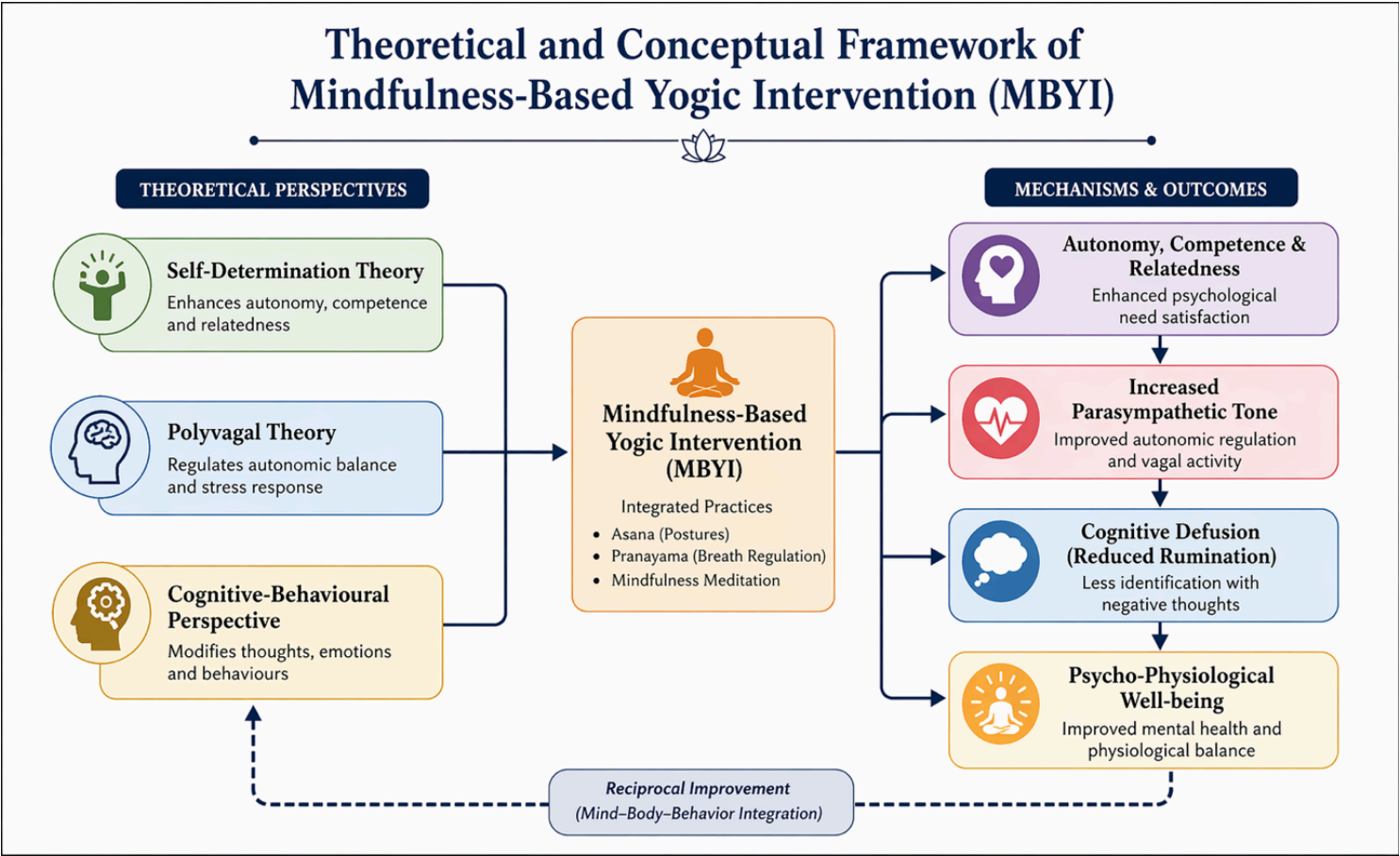


Figure 1

Theoretical and Conceptual Framework of MBYI

The framework illustrates MBYI as an integrated process influencing psycho-physiological well-being through interconnected psychological and neurophysiological pathways, with mindfulness as the central regulatory mechanism.

Figure 2 CONSORT 2025 Flow Diagram showing participant recruitment, allocation, follow-up, and analysis (n = 88).

Analyzed for primary outcome of control group (n= 44) Included in ANCOVA

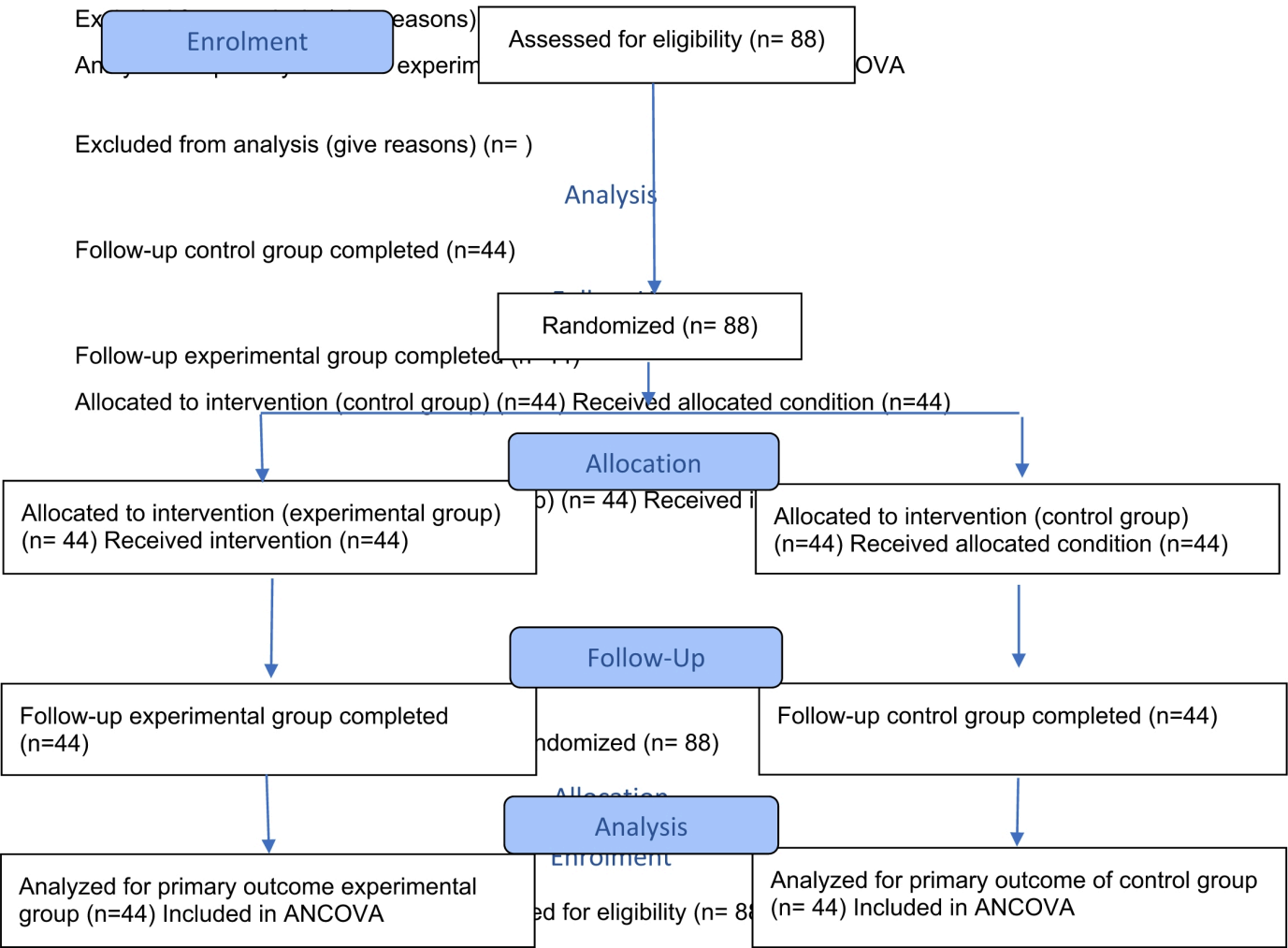


Figure 2

CONSORT 2025 Flow Diagram showing participant recruitment, allocation, follow-up, and analysis (n = 88).

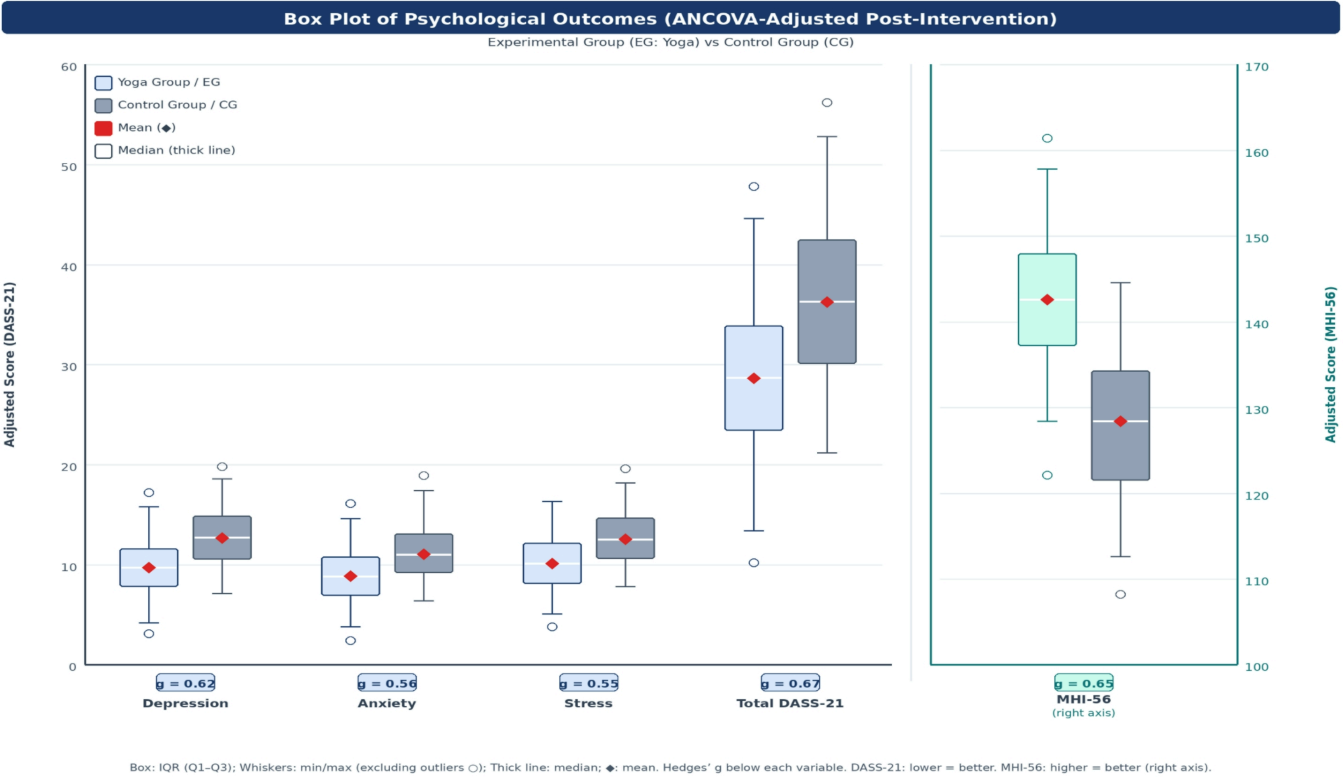


Figure 3

ANCOVA-adjusted psychological outcomes: experimental (yoga) versus control group

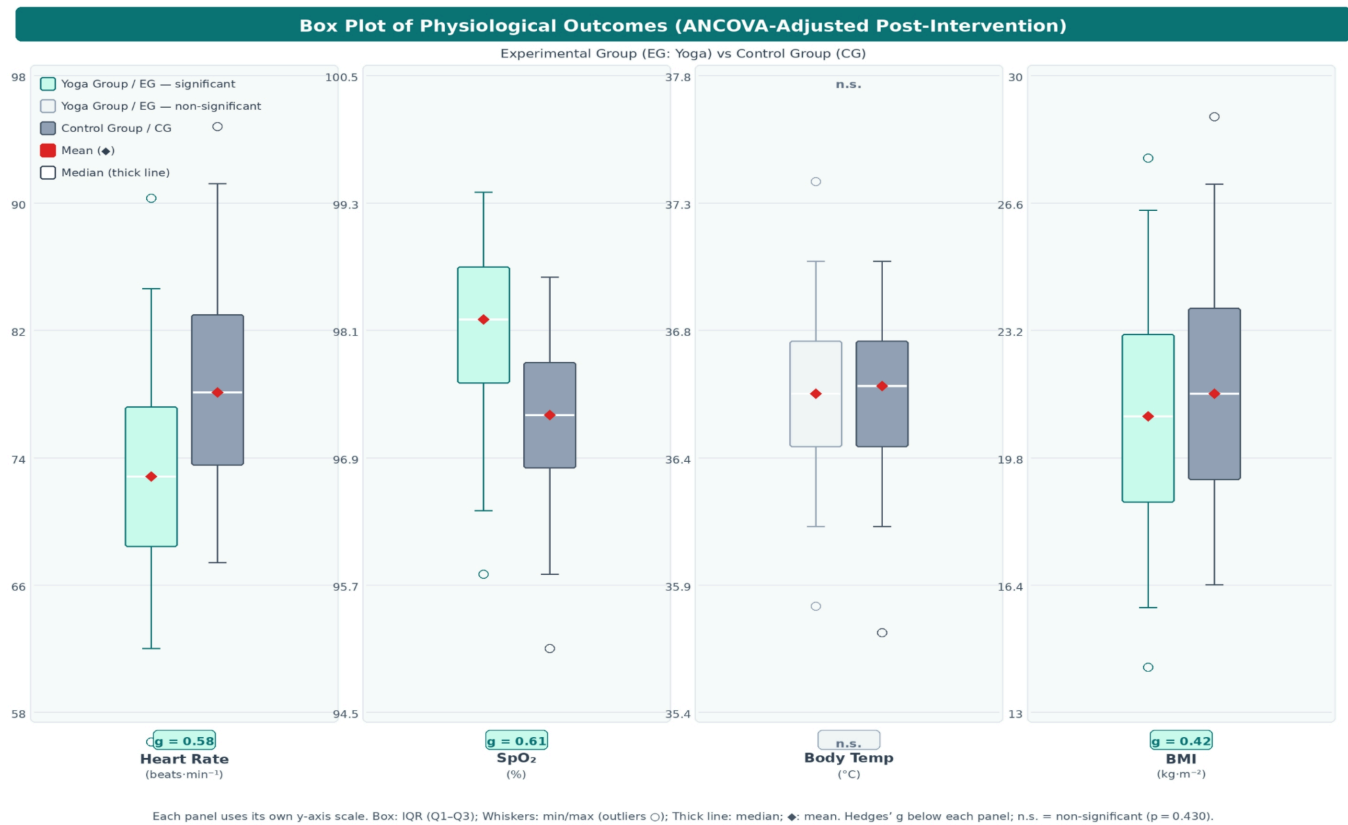


Figure 4

ANCOVA-adjusted physiological outcomes: experimental (yoga) versus control group