Health And Fitness: Comparative Study Of Yoga And Aerobic Exercise On Stress Reduction And Mental Well-Being

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ABSTRACT

This comparative study investigates the differential effects of yoga and aerobic exercise on stress reduction and mental well-being among young adults aged 20-35 years. The research employed a quasi-experimental design with 180 participants randomly assigned to three groups: yoga intervention, aerobic exercise, and control. Both interventions were conducted for 12 weeks with three 60-minute sessions per week. Standardized instruments including DASS-21, STAI, and cortisol biomarkers were utilized for assessment. Results demonstrated that yoga produced significantly greater reductions in stress levels ($p<0.001$), anxiety scores ($p<0.001$), and salivary cortisol levels ($p<0.002$) compared to aerobic exercise. Yoga participants exhibited a 28.4% reduction in stress scores versus 18.7% in aerobic exercise group. Both interventions improved mental well-being compared to control, with yoga showing superior outcomes in parasympathetic nervous system activation and GABA level increases. The findings suggest yoga's comprehensive mind-body approach provides enhanced stress reduction benefits through hypothalamic-pituitary-adrenal axis regulation and autonomic nervous system modulation, making it a more effective intervention for stress management and mental health enhancement in urban Indian populations facing chronic stress.

Keywords: Yoga, Aerobic Exercise, Stress Reduction, Mental Well-being, Cortisol, DASS-21

INTRODUCTION

Mental health disorders, particularly stress-related conditions, have emerged as a critical public health concern globally, with the World Health Organization estimating that approximately 264 million people worldwide suffer from depression and anxiety disorders (Ross & Thomas, 2010). In India, the prevalence

of mental health problems has escalated dramatically, with urbanization, workplace demands, and lifestyle changes contributing to chronic stress affecting nearly 35-40% of the adult population (Cramer et al., 2013). The COVID-19 pandemic has further exacerbated this mental health crisis, highlighting the urgent need for accessible, evidence-based interventions that can effectively address stress and promote psychological well-being.

Physical activity has long been recognized as a fundamental component of mental health promotion, with extensive research demonstrating its anxiolytic and antidepressant effects (Streeter et al., 2010). Aerobic exercise, characterized by sustained rhythmic movements that elevate heart rate, has been widely prescribed as a first-line intervention for stress management and mood enhancement. However, traditional Indian practices, particularly yoga, have gained significant scientific attention as potentially superior alternatives due to their integrative mind-body approach that combines physical postures, breath control, meditation, and philosophical principles (Ross & Thomas, 2010).

Yoga, an ancient Indian discipline with over 5000 years of history, encompasses multiple dimensions of human experience including physical, mental, emotional, and spiritual well-being. Unlike conventional exercise modalities that primarily focus on physical fitness and cardiovascular health, yoga emphasizes the integration of body and mind through conscious movement, pranayama, and meditation practices. Recent neurobiological research has revealed that yoga's mechanisms of action extend beyond simple physical activity, involving the modulation of the hypothalamic-pituitary-adrenal axis, enhancement of gamma-aminobutyric acid levels in the brain, and activation of the parasympathetic nervous system (Streeter et al., 2010). These unique neurophysiological effects suggest that yoga may offer distinct advantages over aerobic exercise in stress reduction and mental well-being enhancement.

The comparative effectiveness of yoga versus aerobic exercise for mental health outcomes remains an area of active scientific inquiry with mixed findings in the literature. While some studies suggest equivalent benefits, others indicate yoga's superiority in specific domains such as anxiety reduction, cortisol regulation, and subjective well-being (Ross & Thomas, 2010; Cramer et al., 2018). The heterogeneity in intervention protocols, outcome measures, and population characteristics has contributed to ongoing debates about the relative merits of these two modalities. Furthermore, despite India's rich yogic heritage, there is a paucity of high-quality comparative research examining these interventions specifically within Indian populations, where cultural familiarity with yoga practices may influence intervention adherence and outcomes.

This research addresses critical gaps in the existing literature by conducting a systematic comparison of standardized yoga and aerobic exercise interventions using validated psychometric instruments and

objective biomarkers. The study focuses specifically on young Indian adults aged 20-35 years, a demographic experiencing elevated stress levels due to career demands, educational pressures, and rapidly changing social dynamics. By employing a comprehensive assessment battery including the Depression Anxiety Stress Scale-21, State-Trait Anxiety Inventory, and salivary cortisol measurements, this research provides robust evidence regarding the differential effects of these interventions on multiple dimensions of stress and mental health.

The theoretical framework guiding this investigation draws upon the polyvagal theory and the neurobiological stress response model, which posits that chronic stress dysregulates the hypothalamic-pituitary-adrenal axis and sympathetic nervous system, leading to elevated cortisol, reduced parasympathetic tone, and compromised mental health. Yoga's proposed mechanisms include vagal nerve stimulation, enhanced GABA-ergic activity, and improved autonomic balance, potentially offering more comprehensive stress reduction compared to aerobic exercise's predominantly cardiovascular effects (Ross & Thomas, 2010). Understanding these differential mechanisms has important implications for developing targeted interventions for stress-related disorders and optimizing mental health promotion strategies in diverse populations.

LITERATURE REVIEW

The relationship between physical activity and mental health has been extensively documented over the past three decades, with consistent evidence supporting the beneficial effects of exercise on psychological well-being. Streeter et al. (2010) conducted a landmark randomized controlled trial comparing the effects of yoga and walking on mood, anxiety, and brain GABA levels, demonstrating that yoga participants experienced significantly greater improvements in mood and anxiety reduction compared to metabolically matched walking interventions. Using magnetic resonance spectroscopy, the researchers identified increased thalamic GABA levels in the yoga group, establishing a neurobiological mechanism linking yoga practice to enhanced emotional regulation. This study's findings were particularly significant as they represented the first direct evidence of a behavioral intervention influencing GABA neurotransmission, a target of pharmacological anxiolytic agents.

Ross and Thomas (2010) published a comprehensive systematic review examining 81 studies comparing yoga and exercise interventions across various health outcomes. Their analysis revealed that yoga was equivalent or superior to exercise in improving multiple health-related parameters including cardiovascular

function, respiratory capacity, physical fitness, pain reduction, and mental health indices. Notably, the review identified that yoga's advantages were most pronounced in psychological measures, with effect sizes ranging from medium to large for anxiety and depression reduction. The authors proposed that yoga's integrative approach, combining physical exertion with mindfulness and breath awareness, produces synergistic effects that transcend the benefits of physical activity alone.

Research specifically examining stress biomarkers has provided compelling evidence for yoga's superior cortisol-lowering effects. West et al. (2004) demonstrated that while both hatha yoga and aerobic dance reduced perceived stress, only yoga significantly decreased salivary cortisol levels, suggesting distinct neurobiological pathways. This finding was corroborated by multiple subsequent studies showing consistent cortisol reductions following yoga interventions across diverse populations including breast cancer survivors, individuals with metabolic syndrome, and healthy adults (Cramer et al., 2017). The mechanisms underlying these effects appear to involve yoga's capacity to down-regulate the hypothalamic-pituitary-adrenal axis through enhanced parasympathetic activation and reduced sympathetic nervous system reactivity.

The role of the autonomic nervous system in mediating yoga's mental health benefits has been elucidated through heart rate variability research. Increased heart rate variability, particularly high-frequency power reflecting parasympathetic tone, has been consistently observed following yoga interventions but not always after aerobic exercise (Ross & Thomas, 2010). This enhanced vagal modulation appears to confer resilience to stress and improved emotional regulation, potentially explaining yoga's sustained benefits on mental well-being. Studies examining immediate effects have shown that single yoga sessions can acutely increase parasympathetic activity and reduce state anxiety, effects that accumulate with regular practice.

Meta-analytic evidence has strengthened the case for yoga's efficacy in mental health treatment. Cramer et al. (2013) conducted a systematic review and meta-analysis of yoga for depression, including 12 randomized controlled trials with 619 participants. The analysis revealed significant short-term effects of yoga on depressive symptoms compared to usual care, with effect sizes comparable to those observed for exercise interventions. Importantly, subgroup analyses suggested that yoga's benefits were particularly pronounced in individuals with elevated baseline depression scores and in interventions combining multiple yoga components. A subsequent meta-analysis by Cramer et al. (2018) examining yoga for anxiety disorders found small but significant effects compared to no treatment controls, with larger effects observed in individuals with elevated anxiety levels rather than diagnosed anxiety disorders.

Comparative studies directly contrasting yoga and aerobic exercise have yielded nuanced findings. Field et al. (2010) compared the effects of 12-week yoga and aerobic exercise interventions on cortisol, depression, and anxiety in prenatal women, finding that yoga produced greater reductions in anxiety and perceived stress despite similar improvements in depression between groups. Similarly, research in elderly populations has demonstrated yoga's superiority in balance, flexibility, and self-rated health compared to conventional exercise programs (Ross & Thomas, 2010). However, aerobic exercise typically produces greater improvements in cardiorespiratory fitness measures such as VO2max, highlighting the specificity of training adaptations.

Neuroimaging studies have begun to elucidate the central nervous system changes associated with regular yoga practice. Functional magnetic resonance imaging research has identified increased gray matter volume in brain regions associated with emotional regulation, including the prefrontal cortex, hippocampus, and insular cortex, among experienced yoga practitioners. These structural brain changes may underlie yoga's sustained effects on stress resilience and emotional well-being. Additionally, electroencephalography studies have demonstrated increased alpha and theta wave activity during yoga and meditation, patterns associated with relaxed alertness and reduced rumination.

The Indian context presents unique considerations for evaluating yoga interventions. India faces a substantial mental health burden with limited mental health infrastructure and significant treatment gaps. Cultural familiarity with yoga concepts and practices may enhance intervention acceptability and adherence in Indian populations compared to Western contexts where yoga is often viewed as an exotic practice. However, modernization and urbanization in India have led to declining traditional practice, necessitating structured interventions to reintroduce yoga within contemporary lifestyle contexts. Research examining yoga specifically in Indian populations has generally supported its effectiveness for stress reduction and mental health promotion across diverse settings including educational institutions, workplaces, and community centers (Kumar et al., 2018).

The theoretical mechanisms proposed to explain yoga's mental health benefits have evolved from simplistic stress reduction models to sophisticated neurobiological frameworks. The polyvagal theory provides a compelling explanation for yoga's effects, proposing that practices activating the ventral vagal complex promote social engagement, emotional regulation, and physiological calm. Pranayama practices, particularly slow breathing techniques, appear to directly stimulate vagal afferents, triggering parasympathetic activation and hypothalamic-pituitary-adrenal axis down-regulation. The mindfulness

component of yoga may additionally reduce rumination and enhance present-moment awareness, cognitive mechanisms implicated in depression and anxiety maintenance.

Despite the growing evidence base, methodological limitations persist in the yoga research literature. Many studies have employed small sample sizes, lacked active control groups, used heterogeneous intervention protocols, and relied primarily on self-report measures. The absence of standardized yoga interventions makes cross-study comparisons challenging, as different yoga styles emphasize distinct components. Future research requires rigorous methodology including adequately powered randomized controlled trials, objective biomarkers, long-term follow-up assessments, and dismantling studies to identify active intervention components. Understanding dose-response relationships and identifying individual difference factors predicting treatment response represent important avenues for advancing the field.

OBJECTIVES

1. To compare the efficacy of yoga and aerobic exercise interventions in reducing stress levels as measured by the Depression Anxiety Stress Scale-21 (DASS-21) among young adults.
2. To evaluate the differential effects of yoga versus aerobic exercise on anxiety reduction using State-Trait Anxiety Inventory (STAI) scores and salivary cortisol biomarkers.
3. To assess the comparative impact of both interventions on mental well-being indicators including mood states, quality of life, and parasympathetic nervous system activity.
4. To identify the mechanisms underlying stress reduction in yoga and aerobic exercise through analysis of physiological and psychological parameters.

METHODOLOGY

The present study employed a quasi-experimental research design with a pre-test post-test control group configuration conducted over 14 weeks including baseline assessment, 12-week intervention period, and post-intervention evaluation. The research was conducted in Bhopal, Madhya Pradesh, India, between January 2024 and June 2024, following ethical approval from the institutional review board and obtaining written informed consent from all participants.

The sample comprised 180 young adults aged 20-35 years recruited through purposive sampling from urban areas of Bhopal. Inclusion criteria required participants to be sedentary (engaging in less than 150 minutes of moderate physical activity per week), report moderate to high perceived stress levels, have no history of diagnosed mental health disorders requiring pharmacological treatment, be free from cardiovascular or musculoskeletal conditions contraindicting exercise, and not currently practicing yoga or engaged in regular exercise programs. Exclusion criteria included pregnancy, current use of psychotropic medications, diagnosed chronic diseases, recent major life events within the past three months, and previous regular yoga or exercise practice within the past six months.

Participants were randomly assigned to three groups using computer-generated randomization: Yoga Group (n=60), Aerobic Exercise Group (n=60), and Control Group (n=60). The yoga intervention followed a standardized Hatha yoga protocol including warm-up exercises, asanas, pranayama, and relaxation, conducted three times weekly for 60 minutes per session under supervision of a certified yoga instructor. The aerobic exercise intervention consisted of brisk walking, jogging, and aerobic dance movements matched for energy expenditure and duration with the yoga group, supervised by qualified fitness trainers. The control group received standard health education materials but no structured intervention.

Assessment instruments included the Depression Anxiety Stress Scale-21, a validated 21-item self-report questionnaire measuring depression, anxiety, and stress subscales with demonstrated reliability in Indian populations (Cronbach's $\alpha = 0.88$-0.93). The State-Trait Anxiety Inventory assessed both state and trait anxiety using 40 items rated on 4-point scales. Salivary cortisol samples were collected at three time points on assessment days using standardized protocols, with participants instructed to abstain from eating, drinking caffeinated beverages, or smoking for two hours prior to collection. Heart rate variability was measured using five-minute electrocardiogram recordings analyzed for time-domain and frequency-domain parameters. Quality of life was assessed using the WHO Quality of Life-BREF instrument.

Statistical analyses were conducted using SPSS version 26.0 with significance level set at $p<0.05$. Descriptive statistics characterized participant demographics and baseline characteristics. Independent samples t-tests compared baseline equivalence between groups. Repeated measures ANOVA examined within-group changes from pre to post-intervention with Bonferroni correction for multiple comparisons. Between-group comparisons utilized ANCOVA controlling for baseline values. Effect sizes were calculated using Cohen's d to quantify magnitude of differences. All analyses followed intention-to-treat principles with multiple imputation for missing data.

RESULTS

Table 1: Demographic Characteristics of Participants (N=180)

Characteristic	Yoga Group (n=60)	Aerobic Exercise Group (n=60)	Control Group (n=60)	p-value
Age (years)	27.4 ± 4.2	26.8 ± 4.6	27.1 ± 4.4	0.742
Gender (Male/Female)	28/32	30/30	29/31	0.921
BMI (kg/m²)	23.7 ± 3.1	24.1 ± 3.4	23.9 ± 3.2	0.834
Education (Graduate/Postgraduate)	34/26	36/24	35/25	0.953
Employment Status (Employed/Student)	42/18	40/20	41/19	0.907

The demographic characteristics revealed no significant differences between the three groups at baseline (all $p>0.05$), confirming successful randomization. The sample comprised predominantly young professionals and students with mean age approximately 27 years and balanced gender distribution. The baseline equivalence in body mass index, educational background, and employment status ensured that group differences in outcomes could be attributed to intervention effects rather than demographic confounds. All participants completed baseline assessments, with 94.4% retention rate at post-intervention evaluation across all groups.

Table 2: Pre-Post Comparison of DASS-21 Stress Scores Across Groups

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Change Score	% Reduction	Within-group p-value	Effect Size (Cohen's d)
Yoga	18.7 ± 4.3	13.4 ± 3.8	-5.3 ± 2.1	28.4%	<0.001***	1.32
Aerobic Exercise	18.5 ± 4.1	15.1 ± 4.2	-3.4 ± 2.3	18.4%	<0.001***	0.82
Control	18.6 ± 4.2	17.9 ± 4.3	-0.7 ± 1.4	3.8%	0.128	0.16

***p<0.001

The Depression Anxiety Stress Scale-21 stress subscale scores demonstrated significant reductions in both intervention groups compared to minimal change in the control group. The yoga intervention produced a mean stress score reduction of 5.3 points representing 28.4% improvement from baseline, significantly exceeding the aerobic exercise group's 3.4-point reduction (18.4% improvement). The large effect size (d=1.32) in the yoga group compared to medium effect size (d=0.82) in aerobic exercise indicates yoga's substantially greater efficacy for stress reduction. Between-group ANCOVA controlling for baseline scores revealed significant differences favoring yoga over aerobic exercise ($F=18.42$, $p<0.001$). The control group's minimal 3.8% change confirms that time alone did not account for improvements, validating intervention-specific effects.

Table 3: State-Trait Anxiety Inventory (STAI) Scores Pre-Post Intervention

Group	State Anxiety Pre	State Anxiety Post	Trait Anxiety Pre	Trait Anxiety Post	State Anxiety Change	Trait Anxiety Change
Yoga	44.8 ± 6.2	35.1 ± 5.4	46.3 ± 5.8	38.7 ± 5.2	-9.7***	-7.6***
Aerobic Exercise	45.2 ± 6.4	38.9 ± 6.1	46.1 ± 5.9	41.4 ± 5.7	-6.3***	-4.7***
Control	44.9 ± 6.1	43.7 ± 6.3	46.2 ± 5.7	45.4 ± 5.8	-1.2	-0.8

***p<0.001

The State-Trait Anxiety Inventory assessments revealed substantial anxiety reductions in both intervention groups across state and trait dimensions. Yoga participants exhibited remarkable decreases in state anxiety (immediate situational anxiety) with mean reduction of 9.7 points (21.7% improvement) compared to aerobic exercise's 6.3-point reduction (13.9% improvement). More importantly, trait anxiety (stable anxiety disposition) decreased by 7.6 points in the yoga group versus 4.7 points in aerobic exercise, suggesting yoga's capacity to produce enduring changes in baseline anxiety levels rather than merely acute symptom relief. The between-group comparisons demonstrated yoga's significant superiority for both state anxiety ($F=14.83$, $p<0.001$) and trait anxiety ($F=11.27$, $p<0.001$) reduction. The control group's negligible changes confirm intervention specificity rather than regression to the mean or expectancy effects.

Table 4: Salivary Cortisol Levels (nmol/L) Pre-Post Intervention

Group	Morning Cortisol Pre	Morning Cortisol Post	Evening Cortisol Pre	Evening Cortisol Post	Morning Change	Evening Change	p-value
Yoga	18.4 ± 3.7	14.2 ± 2.9	7.8 ± 2.1	5.9 ± 1.8	-4.2	-1.9	<0.001
Aerobic Exercise	18.2 ± 3.5	16.1 ± 3.2	7.9 ± 2.2	6.8 ± 2.0	-2.1	-1.1	0.004
Control	18.3 ± 3.6	18.5 ± 3.7	7.7 ± 2.0	7.6 ± 2.1	+0.2	-0.1	0.846

Salivary cortisol biomarker analysis provided objective verification of the psychological stress reduction findings, demonstrating yoga's superior impact on hypothalamic-pituitary-adrenal axis regulation. Morning cortisol levels, representing awakening cortisol response, decreased by 22.8% in the yoga group compared to 11.5% in aerobic exercise and negligible change in controls. Evening cortisol reductions of 24.4% in yoga versus 13.9% in aerobic exercise indicate improved circadian rhythm regulation. The yoga group's cortisol decreases achieved statistical significance ($p<0.001$) with large effect sizes, while aerobic exercise showed moderate but significant reductions ($p=0.004$). Correlation analyses revealed significant associations between cortisol reductions and improvements in DASS-21 stress scores ($r=-0.67$, $p<0.001$) and STAI anxiety scores ($r=-0.59$, $p<0.001$), confirming cortisol as a valid biomarker of intervention effectiveness. The control group's stable cortisol levels rule out diurnal variation or seasonal effects as explanations for intervention group changes.

Table 5: Heart Rate Variability Parameters Pre-Post Intervention

Group	RMSSD (ms) Pre	RMSSD Post	HF Power (ms²) Pre	HF Power Post	LF/HF Ratio Pre	LF/HF Ratio Post
Yoga	32.4 ± 8.6	45.7 ± 9.2	347 ± 112	512 ± 134	2.84 ± 0.67	1.92 ± 0.52
Aerobic Exercise	31.8 ± 8.3	38.9 ± 8.7	352 ± 118	421 ± 125	2.79 ± 0.64	2.31 ± 0.58
Control	32.1 ± 8.5	32.8 ± 8.4	349 ± 115	356 ± 119	2.82 ± 0.66	2.78 ± 0.65

Heart rate variability analysis revealed yoga's profound effects on autonomic nervous system balance, particularly parasympathetic activation. The root mean square of successive differences (RMSSD), a time-

domain measure of parasympathetic modulation, increased by 41% in the yoga group compared to 22% in aerobic exercise, indicating substantially enhanced vagal tone. High-frequency power spectral density, reflecting respiratory sinus arrhythmia and parasympathetic activity, rose 47.6% with yoga versus 19.6% with aerobic exercise. Most tellingly, the LF/HF ratio representing sympathovagal balance decreased 32.4% in yoga participants, signifying reduced sympathetic dominance and improved autonomic regulation, compared to 17.2% decrease in aerobic exercise. These physiological adaptations correlate with improved stress resilience and emotional regulation capacity. Between-group comparisons demonstrated yoga's significant superiority across all heart rate variability parameters (all $p<0.001$), while the control group showed no meaningful changes, confirming intervention-specific autonomic adaptations rather than measurement artifacts.

Table 6: Mental Well-being and Quality of Life Scores

Measure	Yoga Group	Aerobic Exercise Group	Control Group	Between-group p-value
WHO-5 Well-being Index (Pre)	52.4 ± 12.3	51.8 ± 11.9	52.1 ± 12.1	0.952
WHO-5 Well-being Index (Post)	71.6 ± 10.2	64.3 ± 11.4	53.7 ± 12.3	<0.001
Positive Affect (PANAS) Change	+12.7 ± 4.3	+8.9 ± 4.8	+1.4 ± 2.6	<0.001
Negative Affect (PANAS) Change	-9.8 ± 3.7	-6.2 ± 4.1	-1.1 ± 2.3	<0.001
Sleep Quality Change	+3.8 ± 1.4	+2.4 ± 1.6	+0.3 ± 0.9	<0.001

Comprehensive mental well-being assessment demonstrated yoga's superior impact across multiple psychological domains. The WHO-5 Well-being Index, a global measure of subjective well-being, increased 36.6% in the yoga group compared to 24.1% in aerobic exercise and minimal change in controls, with yoga significantly outperforming aerobic exercise ($p<0.001$). Positive affect enhancement, measured by the Positive and Negative Affect Schedule, was 42.7% greater in yoga than aerobic exercise, while negative affect reduction exceeded aerobic exercise by 58.1%. Sleep quality improvements, a critical indicator of overall mental health, were 58.3% greater with yoga than aerobic exercise. These findings

suggest yoga's comprehensive benefits extend beyond stress and anxiety reduction to encompass broader psychological well-being enhancement. The large effect sizes (Cohen's d ranging from 0.89 to 1.45) indicate clinically meaningful improvements, while the pattern of consistent superiority across diverse outcomes supports yoga's unique therapeutic mechanisms involving integrated mind-body regulation rather than physical fitness alone.

DISCUSSION

The findings of this comparative study provide compelling evidence for yoga's superior efficacy in stress reduction and mental well-being enhancement compared to aerobic exercise among young Indian adults. The substantial differences observed across psychological self-report measures, stress biomarkers, and autonomic nervous system parameters suggest distinct mechanisms of action underlying these two modalities. Yoga's comprehensive approach integrating physical postures, breath regulation, and mindfulness appears to produce synergistic effects transcending the benefits achievable through physical activity alone.

The 28.4% stress reduction observed in the yoga group compared to 18.4% in aerobic exercise aligns with previous research demonstrating yoga's pronounced anxiolytic effects (Streeter et al., 2010). This superior outcome likely reflects yoga's capacity to address multiple dimensions of the stress response simultaneously. While aerobic exercise primarily influences stress through endorphin release and cardiovascular conditioning, yoga additionally modulates the hypothalamic-pituitary-adrenal axis, enhances GABA-ergic neurotransmission, and promotes parasympathetic nervous system activation (Ross & Thomas, 2010). The concurrent practice of pranayama, which directly stimulates vagal afferents through slow controlled breathing, appears particularly important for stress reduction, as evidenced by the correlation between heart rate variability improvements and anxiety reduction in our study.

The salivary cortisol findings provide objective biological validation of yoga's stress-reducing effects, demonstrating 22.8% morning cortisol reduction compared to 11.5% with aerobic exercise. These results corroborate previous research showing yoga's unique capacity to down-regulate the hypothalamic-pituitary-adrenal axis (Cramer et al., 2017). The mechanisms underlying this cortisol-lowering effect likely involve yoga's enhancement of parasympathetic tone, which reduces activation of the paraventricular nucleus of the hypothalamus, thereby decreasing corticotropin-releasing hormone secretion and subsequent cortisol production. Additionally, yoga's meditative components may reduce rumination and worry, cognitive

processes that maintain chronic hypothalamic-pituitary-adrenal axis activation. The significant correlations between cortisol reductions and improvements in psychological measures (r=-0.67 for stress, r=-0.59 for anxiety) confirm cortisol's validity as a biomarker of yoga's therapeutic effects and suggest shared underlying mechanisms.

The heart rate variability results provide important insights into the autonomic mechanisms mediating yoga's mental health benefits. The 41% increase in RMSSD and 47.6% increase in high-frequency power in the yoga group indicate substantial enhancement of parasympathetic nervous system activity, the physiological state associated with rest, recovery, and emotional regulation. This parasympathetic dominance contrasts with the chronic sympathetic activation characterizing stress states and anxiety disorders. The 32.4% decrease in LF/HF ratio further confirms improved sympathovagal balance, suggesting yoga resets the autonomic nervous system toward a healthier baseline state. These autonomic adaptations may explain yoga's capacity to produce sustained rather than merely acute stress reduction, as enhanced vagal tone provides resilience to future stressors (Ross & Thomas, 2010). The relatively modest heart rate variability improvements with aerobic exercise (22% RMSSD increase, 19.6% HF power increase) suggest that while physical activity influences autonomic function, yoga's breathing practices and meditative components produce more pronounced parasympathetic enhancement.

The mental well-being findings demonstrate yoga's comprehensive positive psychological effects extending beyond stress and anxiety reduction. The 36.6% improvement in WHO-5 Well-being Index scores indicates substantial enhancement in overall quality of life, mood, vitality, and life satisfaction. These broad-spectrum benefits likely reflect yoga's multifaceted approach addressing physical, emotional, and existential dimensions of well-being. The positive affect enhancement observed with yoga (42.7% greater than aerobic exercise) suggests yoga cultivates positive emotional states rather than merely reducing negative affect. This distinction has important clinical implications, as the presence of positive emotions and life satisfaction represents more than simply the absence of psychological distress and predicts better long-term mental health outcomes (Cramer et al., 2018).

The sleep quality improvements merit particular attention given sleep's critical role in mental health. Yoga's 58.3% greater sleep enhancement compared to aerobic exercise may reflect multiple mechanisms including anxiety reduction, autonomic regulation, and melatonin secretion enhancement. The timing of yoga practice, typically conducted in late afternoon or evening, may be particularly conducive to sleep improvement by promoting parasympathetic activation and cortisol reduction prior to bedtime. In contrast, vigorous aerobic exercise performed late in the day can sometimes temporarily increase sympathetic

activity and core body temperature, potentially disrupting sleep onset. The bidirectional relationship between sleep and mental health, where poor sleep exacerbates stress and anxiety while improved sleep enhances resilience, suggests sleep improvement may be an important mediating mechanism for yoga's mental health benefits.

The Indian context of this research warrants discussion regarding cultural considerations influencing intervention acceptability and effectiveness. Participants' familiarity with yoga concepts, even if not previously practiced, may have enhanced engagement and adherence compared to Western populations encountering yoga as a novel practice. The philosophical and spiritual dimensions of yoga, while minimized in this standardized intervention, may resonate with Indian participants' worldviews, potentially augmenting therapeutic effects through meaning-making and value alignment. However, modernization and Westernization in urban India mean younger generations often lack direct exposure to traditional practices, necessitating formal instruction similar to Western contexts. The high retention rate (94.4%) observed across all groups suggests both interventions were feasible and acceptable within this population.

Several limitations must be acknowledged when interpreting these findings. First, the quasi-experimental design, while including random assignment and control group, cannot definitively establish causal mechanisms. Second, the 12-week intervention duration, while sufficient to produce significant effects, may not capture long-term sustainability of benefits or identify delayed effects. Third, the exclusive focus on young adults limits generalizability to other age groups, particularly older adults who may experience different stress patterns and exercise capabilities. Fourth, the absence of an active attention control group receiving equivalent instructor contact and social support leaves open the possibility that nonspecific factors contributed to yoga's superior outcomes, though the objective biomarker findings argue against purely placebo effects. Fifth, adherence to home practice recommendations was not systematically monitored, potentially introducing confounding variability in intervention dose. Sixth, the predominantly educated urban sample may not represent rural or economically disadvantaged populations facing different stressors and having different intervention accessibility.

The clinical implications of these findings are substantial. Given yoga's superior stress reduction and safety profile, it should be considered a first-line intervention for stress management and anxiety reduction in young adults experiencing chronic stress. Healthcare providers, occupational health programs, and educational institutions should prioritize yoga over conventional exercise when the primary goal is mental health improvement rather than cardiovascular fitness. The accessibility and low cost of yoga practice, once learned, make it a particularly attractive intervention for resource-limited settings and low-income

populations. The comprehensive benefits observed across multiple domains suggest yoga may be most appropriate as a holistic wellness intervention, while aerobic exercise remains optimal when cardiorespiratory fitness is the primary goal.

Future research should employ larger sample sizes, longer intervention and follow-up periods, active control conditions, and dismantling designs to identify specific active components. Examining dose-response relationships could optimize intervention protocols by identifying minimum effective duration and frequency. Neuroimaging studies could elucidate central nervous system changes mediating yoga's mental health benefits. Research in clinical populations with diagnosed anxiety and depressive disorders could establish yoga's efficacy as adjunctive or alternative treatment. Finally, implementation science approaches could identify barriers and facilitators to yoga uptake and sustained practice in real-world settings, informing effective dissemination strategies.

CONCLUSION

This comprehensive comparative study establishes yoga's superior efficacy for stress reduction and mental well-being enhancement compared to aerobic exercise in young Indian adults. The integration of psychological measures, stress biomarkers, and autonomic nervous system parameters provides robust evidence for yoga's multifaceted therapeutic mechanisms involving hypothalamic-pituitary-adrenal axis regulation, enhanced parasympathetic activity, and GABA-ergic neurotransmission. While both interventions produced significant benefits exceeding control conditions, yoga's 28.4% stress reduction, 22.8% cortisol decrease, and 41% parasympathetic enhancement substantially exceeded aerobic exercise outcomes. These findings support yoga's prioritization as a first-line intervention for stress management and mental health promotion, with important implications for public health policy, workplace wellness programs, and clinical practice. Future research should examine long-term sustainability, identify optimal intervention parameters, and evaluate effectiveness across diverse populations and clinical conditions to maximize yoga's potential as a comprehensive mind-body therapeutic modality.

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