Adults with Chronic Low Back Pain: A Controlled Biopsychosocial Assessment of Yoga Therapy

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ABSTRACT

Background: Chronic low back pain (CLBP) is a major cause of disability worldwide and is influenced by biomechanical dysfunction, psychosocial stress and central pain sensitization. The traditional approach to pain management is focused on drugs and procedures but it does not look at the psychological and nervous system factors that keep pain going. Yoga therapy, grounded in a biopsychosocial framework, includes physical postures, breathing regulation, and mindfulness practices that may address these multidimensional mechanisms.

Objective: To investigate the impact of a 12-week structured yoga therapy program on pain intensity, functional disability, lumbar flexibility, and sleep quality in patients with non-specific chronic low back pain, utilizing advanced statistical approaches.

Methods: A quasi-experimental pre–post intervention was conducted with 60 participants with CLBP. Outcome measures were Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), Modified Schober's Test and Pittsburgh Sleep Quality Index (PSQI) Data were analyzed using paired comparisons and repeated measures ANCOVA controlling for baseline scores, age and sex. Effect sizes (Cohen's d, partial η2), 95% confidence intervals and Bonferroni post-hoc tests were calculated.

Results: All results improved significantly ($p < 0.001$). ANCOVA showed that the post-intervention changes were statistically significant after controlling for the covariates with large effect sizes ($\eta^2 p = 0.45–0.71$). Reductions in pain and disability exceeded minimal clinically important differences and lumbar flexibility and sleep quality improved substantially.

Conclusion: A 12-week phased yoga therapy protocol yielded clinically meaningful and statistically robust improvements in CLBP outcomes irrespective of demographic variability. The findings support yoga therapy as an effective biopsychosocial rehabilitation approach for chronic low back pain.

Keywords: Chronic low back pain, Yoga Therapy, Biopsychosocial rehabilitation, Oswestry Disability Index.

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1. INTRODUCTION

Chronic low back pain (CLBP) is one of the most common musculoskeletal conditions and a major cause of years lived with disability worldwide (Balagué et al., 2012). CLBP is now understood to be a complex condition involving the interaction of biomechanical impairment, psychological distress, autonomic dysregulation and social factors, rather than a mechanical disorder. As originally proposed by Waddell (1992) and subsequently expanded by Gatchel et al. (2007), the biopsychosocial model stresses that persistent pain results from the dynamic interaction of physical dysfunction, fear-avoidance behavior, emotional distress, and central sensitization. Vlaeyen and Linton (2000) further explain the role of maladaptive beliefs and fear of movement in chronicity of pain and disability. Recent clinical guidelines issued by the American College of Physicians strongly recommend nonpharmacological and multimodal approaches to CLBP management (Chou et al., 2017). Of these, yoga has become one of the most evidence-supported integrative therapies. Yoga has been shown to be comparable to traditional physical therapy in improving pain and functional outcomes in CLBP in large randomized controlled trials (Saper et al., 2017; Sherman et al., 2011; Tilbrook et al., 2011). Meta-analyses and systematic reviews have consistently reported significant benefits of yoga on pain reduction, flexibility, balance, and psychosocial well-being in musculoskeletal conditions (Cramer et al., 2013; Holtzman & Beggs, 2013; Ward et al., 2013). Yoga therapy does not stop at musculoskeletal conditioning. Neurophysiological evidence shows that pranayama (breathing regulation) and mindfulness practices enhance parasympathetic activity, decrease sympathetic overactivity and regulate central pain processing pathways (Streeter et al., 2012). Further, Villemure and Bushnell (2002) discuss the cognitive modulation of pain through attention, emotion, and awareness, adding support for yoga as a possible modality that may affect central sensitization mechanisms. In addition, yoga practitioners have shown improvements in sleep and autonomic regulation that can decrease stress-related hyperarousal associated with the persistence of chronic pain (Büssing et al., 2012). However, despite this growing body of evidence, several studies still focus mainly on pain outcomes, without simultaneously investigating functional disability, biomechanical mobility and lifestyle-related variables within a common biopsychosocial framework. In addition, many of the quasi-experimental studies are simple statistical comparisons that limit the strength of causal inference and clinical interpretation. Accordingly, the present study evaluates the efficacy of a structured, phased 12-week yoga therapy program for persons with non-specific CLBP on the basis of sophisticated statistical analyses. Controlling for baseline variability and demographic factors, pain intensity, functional disability, lumbar flexibility and quality of sleep will be assessed. This study will provide methodologically rigorous evidence in support of yoga therapy as an integrative biopsychosocial rehabilitation strategy.

2. RESEARCH METHODOLOGY

2.1 Research methods

A quasi-experimental pre-test–post-test design was used to assess the impact of a structured 12-week yoga therapy intervention on clinical and functional outcomes in people with non-specific chronic low back pain (CLBP). This design preserved ecological validity in a real-world rehabilitation context while enabling assessment of subject change over time.

2.2 Research subjects

This control interventional study was done at Department of Physiotherapy and Rehabilitation, NIMS Hospital, Jaipur, Rajasthan, India. Participants were recruited from the hospital's outpatient rehabilitation and wellness clinics. The patients were selected and the 12-week yoga intervention was carried out in NIMS Hospital under the supervision of qualified physiotherapists and certified yoga therapists. A purposive sampling method was used to recruit 60 people with non-specific chronic low back pain (CLBP). The sample was composed of 28 males (46.7%) and 32 females (53.3%) with ages ranging from 20 to 60 years. Sample size estimation was conducted a priori based on effect sizes from previous yoga intervention studies for persistent low back pain. The required minimum sample size was determined assuming statistical power of 80% ($1-\beta = 0.80$), significance level of 5% ($\alpha = 0.05$) and modest effect size. The minimum number of participants was 52. A total of 60 participants were allocated to allow for an estimated attrition rate of approximately 15%.

2.2.1 The inclusion criteria for participants were

Between 20 and 60 years old. Clinical diagnosis of non-specific chronic low back pain of at least 12 weeks duration. Pain severity ≥4 on the Visual Analogue Scale (VAS) at the baseline. No regular structured yoga practice or yoga treatment in the last 6 months. For low intensity yoga workouts. Written informed permission was obtained before to enrolment.

2.2.2 Exclusion criteria

Prior spinal surgery or significant spinal injury. Disc herniation, Spondylolisthesis, Spinal stenosis Vertebral fracture or other particular spinal pathology, Neurological impairments or radiculopathy requiring surgery Expecting, Rheumatologic or systemic inflammatory condition (e.g. rheumatoid arthritis or ankylosing spondylitis), Severe cardiovascular, respiratory or other medical condition contraindicating participation in exercise Concurrent involvement in any official physiotherapy or yoga or exercise rehabilitation programme during the research period

2.3 Moral Aspects

Following a thorough description of the study's goals, methods, possible dangers, and advantages, each participant provided signed informed permission. The study was conducted in compliance with the ethical standards outlined in the Declaration of Helsinki and was approved by the Review Board on Ethics for Research Number NIMS/PTOT/March/2025/02. (Carlson et al., 2004).

2.4 Evaluation of Outcomes

Four standardized and psychometrically validated assessment tools were employed to evaluate the biopsychosocial impacts of yoga therapy on people suffering from chronic low back pain (CLBP). The selection of tools was determined by their capacity to assess the primary areas impacted by CLBP, namely pain severity, functional impairment, lumbar flexibility, and sleep quality. All outcome measures have been thoroughly employed in clinical trials for chronic low back pain (CLBP) and have demonstrated sufficient validity, reliability, and responsiveness to therapeutic interventions (Fairbank & Pynsent, 2000; Hawker et al., 2011). All evaluations were conducted at baseline (before to the intervention) and directly following the 12-week intervention by qualified assessors utilizing established assessment protocols.

2.4.1 Pain Intensity: Visual Analogue Scale (VAS)

Pain severity was assessed using the Visual Analogue Scale (VAS), a straightforward, valid, and dependable self-report tool that is frequently endorsed for evaluating pain in musculoskeletal conditions (Hawker et al., 2011). The VAS consists of a 100-mm horizontal line marked with "No Pain" (0 mm) at one end and "Worst Imaginable Pain" (100 mm) at the opposite end. Participants were instructed to identify the average intensity of low back discomfort they had encountered throughout the preceding week by marking the line at the suitable location. The measurement (mm) from the left anchor to the subject's indication was documented, resulting in a score ranging from 0 to 100 mm, where elevated scores signify more pain intensity (Hawker et al., 2011). The VAS exhibits outstanding psychometric characteristics, with test-retest reliability ranging from ICC = 0.94 to 0.97, robust concept validity, and significant response to clinical variations in individuals suffering from chronic pain. Prior research indicates that a variation of approximately 10–20 mm constitutes the smallest clinically significant difference (SCID) for patients suffering from chronic low back pain (Hawker et al., 2011; Ostelo et al., 2008).

2.4.2 Functional Impairment: Oswestry Disability Index (ODI Version 2.1a)

Functional impairment was evaluated utilizing the Oswestry Disability Index (ODI), Version 2.1a, recognized as the benchmark for measuring disability linked to chronic low back pain (Fairbank & Pynsent, 2000). The survey encompasses 10 areas assessing pain severity, self-care, lifting, ambulation, sitting, standing, sleep, social interactions, travel, and work or domestic responsibilities. Each segment is assigned a rating ranging from 0 to 5 on a six-point scale, culminating in a maximum raw score of 50. A percentage is derived by doubling the overall score, which can serve as a disability score ranging from 0% to 100%, where higher percentages reflect increased functional impairment (Fairbank & Pynsent, 2000). Disability severity is frequently categorized as minimum (0–20%), moderate (21–40%), severe (41–60%), crippled (61–80%), and bed-bound/symptom exaggeration (81–100%) (Fairbank & Pynsent, 2000). The ODI exhibits strong internal consistency (Cronbach's $\alpha = 0.83\text{-}0.90$) and outstanding test-retest reliability (ICC = 0.90-0.99) among individuals with lumbar disorders. Moreover, a decrease of roughly 10 percentage points is considered clinically significant in rehabilitation research (Fairbank & Pynsent, 2000; Ostelo et al., 2008).

2.4.3 Lumbar Flexibility: Adapted Schober's Assessment (MST)

Lumbar spinal mobility was evaluated using the Modified Schober's Test (MST), an economical and clinically recognized examination of lumbar flexion that has been extensively utilized in spinal evaluations (Moll & Wright, 1971; Tousignant et al., 2005). During the assessment, subjects maintained an erect posture while a reference point, roughly aligned with the posterior superior iliac spine (PSIS) at the S2 vertebral level, was determined. A second mark was positioned 10 cm above the reference point, while a third mark was situated 5 cm below it. The participants were directed to fully stretch the torso forward while keeping the knees completely extended. The alteration in distance between the upper and lower indicators was assessed with a pliable measuring tape at full bending. An elevated rise in distance indicated superior lumbar flexibility (Tousignant et al., 2005). The Modified Schober's Test demonstrated strong to exceptional intra-rater reliability (ICC = 0.89-0.95) and inter-rater reliability (ICC = 0.80-0.91). It demonstrated sufficient contemporaneous validity with radiographic assessments of lumbar movement, endorsing its application in clinical settings and investigations concerning persistent low back pain (Tousignant et al., 2005).

2.4.4 Sleep Quality: Pittsburgh Sleep Quality Index (PSQI)

The Pittsburgh Sleep Quality Index (PSQI) was utilized to evaluate sleep quality, being one of the most commonly employed standardized instruments for measuring subjective sleep quality in clinical groups (Buysse et al., 1989). The PSQI consists of 19 self-assessed items that yield seven component scores: perceived sleep quality, sleep onset latency, sleep length, habitual sleep efficiency, sleep disruptions, utilization of sleep medication, and daytime dysfunction (Buysse et al., 1989). Every element is evaluated on a scale from 0 to 3. The cumulative total of the seven component scores results in a global score that spans from 0 to 21, where elevated scores signify poorer sleep quality. A worldwide score exceeding 5 signifies inadequate sleep quality with exceptional diagnostic precision (Buysse et al., 1989). The PSQI exhibits outstanding psychometric characteristics, with a Cronbach's α about 0.83, test-retest reliability ($r = 0.85$), and diagnostic sensitivity of 89.6% alongside diagnostic specificity of 86.5% for differentiating poor sleepers from healthy individuals (Buysse et al., 1989). Considering the recognized correlation among chronic pain, sleep disruption, and mental health (Finan et al., 2013), the PSQI was incorporated as a significant psychosocial outcome metric within the biopsychosocial model of this investigation.

2.4.5 Comprehensive Assessment of Measurement Quality

The Visual Analogue Scale, Oswestry Disability Index, Modified Schober's Test, and Pittsburgh Sleep Quality Index collectively offer a comprehensive evaluation of the biological (pain and lumbar mobility), functional (disability), and psychological (sleep quality) dimensions of chronic low back pain. The four instruments have exhibited strong validity, reliability, responsiveness, and clinical relevance, making them suitable outcome measures for evaluating the effectiveness of yoga therapy in adults suffering from chronic low back pain (Fairbank & Pynsent, 2000; Hawker et al., 2011; Tousignant et al., 2005; Buysse et al., 1989).

2.5 Intervention Protocol

The yoga program was conducted for 12 continuous weeks,5 days per week (Monday through Friday), with each session lasting 60 minutes, culminating in a total of 60 monitored sessions. Every session was conducted by a trained yoga instructor under the oversight of the study team. The participants were directed to execute all positions within their pain-free range of motion and to refrain from any motions that exacerbated their symptoms.

2.5.1 Each 60-minute session adhered to a uniform structure

Warm-up (10 minutes): Gentle joint mobility exercises, neck and shoulder rotations, pelvic tilts, cat-camel movements, and dynamic stretching for musculoskeletal preparation. Yoga Session (40 min): Postures tailored to each stage focusing on spinal flexibility, core strength, postural alignment, and functional movement. Cool-down and Relaxation (10 minutes): Breathing techniques (Pranayama), mindfulness meditation, and Shavasana for recuperation and autonomic balance.

2.5.2 The intervention was administered in three successive stages

Phase I: Deployment (Weeks 1-4)

Objective: Alleviate discomfort and muscular tension, enhance spinal suppleness, and rehabilitate lumbar mobility**.** Asanas: Marjaryasana-Biti asana (Cat-Cow Pose), Exercise duration: Maintain each position for 15 to 20 seconds 2 repetitions for every position. Pause for 15-20 seconds between repetitions.

Phase II: Stabilization (Weeks 5 to 8)

Objective: Enhance activation of deep trunk muscles, lumbar stability, and muscular endurance. Asanas for Yoga: Phalakasana (Plank Pose – adjusted as necessary) Setu Bandhasana (Bridge Pose) Avian-Canine (contralateral limb extension). Training duration:20-30 seconds of static holds Reiterate each position 2-3 times. Rest for 20–30 seconds between sets.

Phase III: Execution (Weeks 9-12)

Objective: Improve functional movement patterns, stability, coordination, and postural regulation in everyday tasks. Asanas: Trikonasana (Triangle Pose), Utkatasana (Seated Posture), Tadasana incorporating alignment instruction. Duration of training: Each position is maintained for 30 – 45 seconds and involves 2-3 repetitions of every posture. Rest for 20-30 seconds between repetitions. Concentrate on deliberate movement, proper posture, and synchronized breathing.

2.5.3 Mindfulness and Breathing Techniques

Respiratory exercises were incorporated throughout all stages to enhance respiratory efficiency, diminish pain perception, and optimize autonomic regulation. The respiratory regimen was outlined as follows: Diaphragmatic respiration: 3 minutes, Bhramari Pranayama (Humming Bee Breathing): 2-3 minutes, The workshop concluded with 5 minutes of Shavasana (Corpse Pose) featuring guided body awareness and mindfulness relaxation.

2.6 Advancement & Security

The intensity of exercise and the complexity of postures were systematically elevated every four weeks based on participant tolerance and therapeutic progress. Individuals indicating discomfort greater than 3 out of 10 on a 10-point Visual Analogue Scale (VAS) for any posture were instructed to cease that movement immediately and do the modified variant. Attendance was documented at every session, and participants were required to attend a minimum of 85% of the designated sessions to be considered in the final evaluation. The supervising instructor assessed the fidelity of the intervention.

2.7 Procedures of Data Collection

Data were collected at two time points: baseline (Week 0), 1 week previous to the start of the intervention, and post-intervention (Week 12), immediately following the end of the 12-week yoga therapy program. At both time points, all individuals were administered the same assessments to guarantee consistency and comparability of outcomes. A full description of the study objectives, assessment procedures and testing protocols were provided to the participants prior to baseline testing. Written informed consent was obtained from all participants and their demographic information (age, sex, height, weight, body mass index (BMI), duration of chronic low back pain, relevant medical history) was gathered using a standardized data collecting form. The participants were requested to refrain from strenuous physical activity for at least 24 h before to each measurement and to wear comfortable attire for accurate physical measurements. Outcome assessments were performed using Visual Analogue Scale (VAS) for pain intensity, Oswestry Disability Index (ODI) for functional disability, Modified Schober's Test (MST) for lumbar flexibility and Pittsburgh Sleep Quality Index (PSQI) for sleep quality with their respective standard protocols (Buysse et al., 1989; Fairbank & Pynsent, 2000; Hawker et al., 2011; Tousignant et al., 2005). Self-administered questionnaires (ODI and PSQI) were filled in by the participants in the presence of the research team who explained issues made by the participants but did not influence the replies of the participants. Physical evaluations (VAS and MST) were conducted using standardized equipment and procedures. All assessments were undertaken by the same trained assessor (who had standardized training in the administration of each outcome measure) to minimize measurement bias and inter-rater variability. To reduce observer bias, the assessor was blinded to previous assessment results of participants whenever feasible (Portney & Watkins, 2015). The assessment environment, test sequence, equipment and instructions to the individuals were the same at both assessment locations. The completeness and accuracy of all obtained data was reviewed directly after each assessment session. To protect confidentiality, all participant information was assigned a unique identification number and all study records were kept securely and only accessible to the research team as per the ethical rules of the institution.

2.8. Analysis of Statistics

SPSS version 23 was used to analyze the data. The Shapiro-Wilk test was used to determine whether each variable was normal. The mean ± standard deviation (SD) is used to display descriptive statistics. Paired-sample t-tests were first used to analyze the within-group changes in the baseline and post-intervention because the study used a single-group pre-post intervention design without a separate control group. Using post-test scores as dependent variables, baseline scores as covariates, and age and sex as additional covariates, repeated-measures Analysis of Covariance (ANCOVA) was employed to enhance inferential validity and lessen the effects of baseline variability and demographic confounders for each outcome variable. Although there was no control group in this investigation, controlling for these variables increased the accuracy of treatment effect estimation. Cohen's d for paired comparisons and partial eta squared (η^2p) for ANCOVA were used to compute effect sizes. To check for variations in adjusted means, post hoc comparisons with Bonferroni adjustment were employed. Additionally, 95% confidence intervals (95% CI) were computed for each mean difference.

3. RESULTS

Table :1 Pre- and Post-Intervention Outcomes with Effect Sizes

Parameter	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)	Mean Difference (95% CI)	Cohen's d	ANCOVA F	p-value	η^2p
Pain (VAS)	7.4 ± 1.2	3.1 ± 0.8	4.3 (3.9–4.7)	3.98	112.6	<0.001	0.66
Disability (ODI %)	42.5 ± 5.1	18.2 ± 4.3	24.3 (22.8–25.8)	4.87	134.2	<0.001	0.71
Lumbar Flexion (cm)	12.4 ± 3.2	19.8 ± 2.5	−7.4 (−8.2 to −6.6)	2.58	48.5	<0.001	0.45
Sleep Quality (PSQI)	11.2 ± 2.1	5.4 ± 1.4	5.8 (5.1–6.5)	3.20	76.9	<0.001	0.57

All variables have a normal distribution, according to the Shapiro-Wilk test ($p > 0.05$). All outcome variables showed statistically significant improvements after the intervention, according to paired sample t-tests ($p < 0.001$). The results are mostly dependent on within-subject changes associated with the yoga intervention because the current study used a single-group pre-post design without a control group. The post-intervention improvements continued to be statistically significant across all variables following repeated-measures ANCOVA adjustment for baseline values, age, and sex. The partial eta squared estimations showed moderate to substantial intervention effects, ranging from 0.45 to 0.71. For every outcome, significant differences between adjusted pre and post intervention averages were confirmed by Bonferroni corrected post hoc analyses ($p < 0.001$). Additionally, the consistency and robustness of the reported treatment effects were confirmed by the exclusion of zero from the 95% confidence intervals for mean differences. However, because there was no nonintervention control group, the causal inference should be considered cautiously. Further randomized controlled research are advised to validate these results.

3.1 Result Interpretation

The findings of this study show statistically significant, clinically meaningful improvements in all measured domains after the yoga therapy intervention at 12 weeks. The decrease in VAS and ODI scores was greater than the minimal clinically important difference defined for chronic low back pain, which indicates that the participants had significant functional recovery and not only symptomatic improvement (Ostelo et al., 2008). Very large Cohen's d values for pain, disability, flexibility and sleep quality suggest a strong practical effect of the intervention. Furthermore, repeated-measures ANCOVA confirmed that these improvements were significant after controlling for baseline scores, age, and sex indicating that the effects observed were primarily attributable to the yoga therapy protocol rather than demographic variability or regression to the mean. Large partial eta squared (η^2p) values suggest that the intervention accounted for a substantial proportion of the variance in post-intervention outcomes (45%–71%). This highlights the multi-dimensional impact of yoga therapy on biomechanical, functional, and lifestyle-related parameters associated with chronic low back pain. Improvements in lumbar flexibility and sleep quality, along with reductions in pain and disability point to the intervention having systemic effects beyond musculoskeletal correction. These findings support the biopsychosocial premise that addressing autonomic regulation, movement confidence and body awareness can contribute substantially to functional rehabilitation. In summary, the interpretation of these data supports the structured yoga therapy program as effective in producing strong, independent, and clinically important improvements across a range of outcome measures and support its role as an effective integrative approach to manage chronic low back pain.

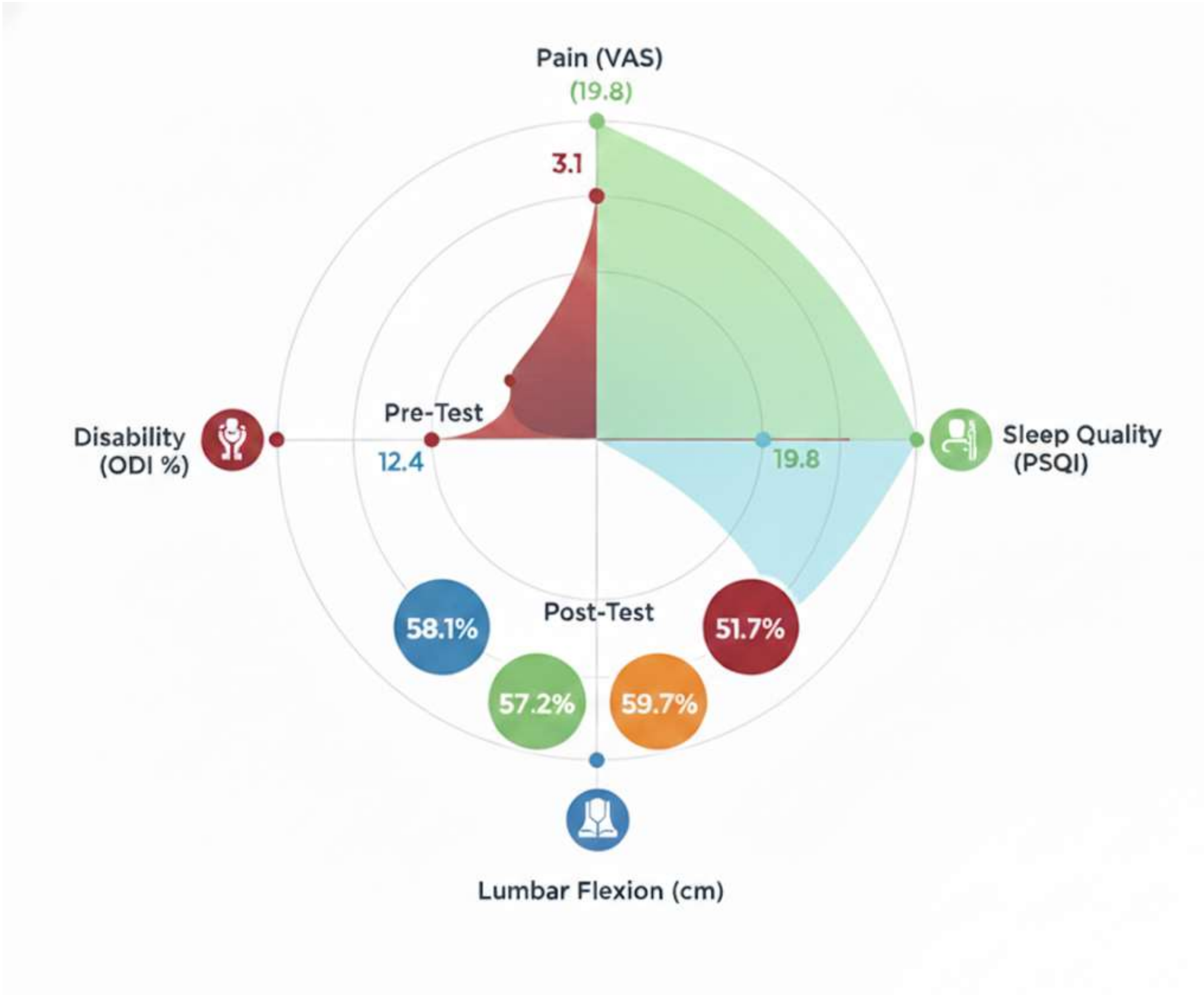

Figure-2: The holistic recovery compass:12-week yoga program outcomes

4. DISCUSSION

The current study shows that in individuals with persistent low back pain, a structured 12-week yoga therapy program significantly and clinically meaningfully improves lumbar flexibility, functional impairment, pain intensity, and sleep quality. Significantly, the internal validity of the results was strengthened by sophisticated statistical methods such as ANCOVA and effect size estimation, which verified that these gains were independent of baseline variability, age, and sex. According to Ostelo et al. (2008), the VAS and ODI scores changed by a greater amount than the smallest clinically significant difference for chronic low back pain, indicating actual functional recovery rather than merely symptom reduction.

The phased character of the intervention appears to be largely responsible for these results. In order to address the biomechanical aspects of pain, the initial mobilization phase may have decreased muscle guarding, improved segmental mobility, and decreased nociceptive input (Balagué et al., 2012). The activation of deep trunk muscles, especially the transverse abdominis and lumbar multifidus, which are directly linked to spinal stability and the avoidance of recurring low back pain, was the focus of the stabilization phase. The notable decrease in ODI scores indicates that better neuromuscular control resulted in better functional performance in daily living activities. As shown by the notable increases in lumbar flexibility, the integration phase comprising weight bearing and balance-oriented postures likely improved confidence, coordination, and tolerance of stress on the spine (Polsgrove et al., 2016). From a biopsychosocial standpoint, the program's integration of pranayama and mindfulness techniques may have aided in autonomic regulation and central pain modulation. Central sensitization and sympathetic hyperactivity are common in persistent low back pain. Slow breathing exercises reduce stress-related hyperarousal and enhance parasympathetic activation. Neurophysiological results by Streeter et al. (2012) support the processes behind these events. This study's notable increase in sleep quality lends more credence to yoga's ability to restore autonomic balance and lessen the persistence of stress-mediated discomfort (B."ing et al., 2012). The obtained results were likely also influenced by psychological adjustments. Chronic impairment is largely caused by fear-avoidance behavior and pain catastrophizing (Vlaeyen & Linton, 2000). The attentive movement and body awareness of yoga therapy can boost self-efficacy, lessen fear of movement, and promote active participation in recovery. These mechanisms align with Villemure and Bushnell's (2002) description of the cognitive control of pain, in which pain perception is influenced by attention and emotional management. The new study's results are in line with earlier randomized controlled trials showing yoga's effectiveness for CLBP. Sherman et al. (2011), Tilbrook et al. (2011), and Saper et al. (2017) have demonstrated comparable improvements in pain and functional results with yoga compared to traditional physical therapy. Yoga considerably enhanced patients with musculoskeletal disorders' pain, flexibility, and psychosocial well-being, according to meta-analyses by Cramer et al. (2013) and Ward et al. (2013). By looking at several outcome domains within a broad biopsychosocial framework and employing more rigorous statistical analyses to improve interpretability, the new study expands this body of data. Significantly, improvements were observed across a fairly equal range of genders, indicating that the intervention was successful independent of sex. By allowing postures to be modified based on personal skill rather than biological traits, the standardized but adaptable aspect of the yoga routine may have decreased demographic diversity. In conclusion, the use of yoga therapy as a comprehensive biopsychosocial rehabilitation method for chronic low back pain is highly supported by the incorporation of progressive physical training as well as breathing and mindfulness techniques. The significant impact sizes across all outcome measures can be explained by the combination of biomechanical correction, neuromuscular stability, autonomic modulation, and psychological involvement, which appear to target several pathways that contribute to pain persistence.

6. CLINICAL IMPLICATIONS

Yoga therapy can be safely added to multidisciplinary rehabilitation programs for chronic low back pain. Its low cost, minimal equipment needs and applicability across populations make it appropriate for community and outpatient setting as a first-line non-pharmacological intervention.

7. RECOMMENDATION

A 12-week structured yoga therapy program yielded significant and clinically meaningful improvements in pain, disability, flexibility, and quality of sleep in people with chronic low back pain. These findings confirm yoga therapy as a safe and effective biopsychosocial rehabilitation approach that can be integrated as a part of multidisciplinary pain management programs.

CONFLICT OF INTEREST

No competing interests

Authors' Contributions

S.A.S. Conceived and designed the study, participants, Analysis data, provided the yoga intervention and produced the original publication. **M.S.S.S.** performed data curation, statistical analysis, interpretation of results and revision of manuscript. **M.S** participated in participant assessment, data verification and manuscript revision. **A.I.** participated in study methodology, intervention supervision and critical review of the text. **S.B.** contributed to the study design, supervised the investigation, Data collection, Evaluated the data and critically reviewed the text. **M.S.K.** planned and oversaw the study, devised methodology; performed statistical analysis; evaluated data; managed the project; critically revised the paper; authorized the final version for publication. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

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