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COMPARATIVE EFFECTIVENESS OF PNF - BASED AND YOGA - BASED ELASTIC RESISTANCE TRAINING ON POSTURAL CONTROL IN PATIENTS WITH DIABETIC PERIPHERAL NEUROPATHY: A TWO - GROUP COMPARATIVE STUDY.

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Abstract

Background: Low back pain is a major source of disability, and non-pharmacological rehabilitation is central to contemporary management. Yoga combines graded movement, postural control, breathing and attentional regulation, but short-term comparative trajectories of pain and functional disability remain clinically relevant.

Objective: To compare 21-day changes in Visual Analog Scale (VAS) pain scores and raw Oswestry Disability Index (ODI) totals between a Yoga group and a Control group.

Methods: This comparative longitudinal analysis included 33 participants: Yoga, n=15 (IDs 1-15), and Control, n=18 (IDs 16-33). VAS and ODI were recorded on Days 1, 7, 14 and 21. Participant-level spreadsheet data were independently cleaned and analysed; names were removed. Gaussian generalized estimating equations (GEE) with exchangeable working correlation and robust standard errors tested group, time and group-by-time effects. Friedman, Wilcoxon, Mann-Whitney U and Spearman procedures provided non-parametric sensitivity and exploratory analyses.

Results: No statistically significant baseline difference was detected for age (27.6±9.2 vs 31.5±9.6 years; $p=0.243$), VAS (median 8 vs 8; $p=0.359$) or ODI (median 25 vs 23; $p=0.363$). Significant group-by-time interactions occurred for VAS (Wald $\chi^2=52.59$, $df=3$, $p<0.001$) and ODI ($\chi^2=35.34$, $df=3$, $p<0.001$). By Day 21, median VAS was 0 (IQR 1) in Yoga and 2.5 (IQR 1) in Control; median ODI was 1 (IQR 1.5) and 5 (IQR 3.75), respectively. Baseline-to-Day-21 improvement favoured Yoga for VAS (median 8 vs 5; rank-biserial $r=0.663$, Holm-adjusted $p=0.001$) and ODI (23 vs 16.5; $r=0.456$, adjusted $p=0.027$). Age, yoga-introduction day and sex were not statistically associated with Yoga-group improvement, although subgroup precision was limited.

Conclusion: The Yoga group showed a faster and greater short-term reduction in pain and disability than the Control group. Because allocation, co-interventions and protocol details were unavailable, causal interpretation requires caution and confirmation in larger controlled studies.

1. Introduction

Low back pain is both a common reason for seeking healthcare and a leading source of disability. In the Global Burden of Disease 2021 analysis, the estimated burden due to low back pain in 2020 was in the hundreds of millions, and the burden is expected to increase substantially by 2050 due to population growth and population aging [1]. The World Health Organization (WHO) identifies low back pain as the leading condition for the greatest years lost due to disability [2]. Its clinical burden is far greater than the intensity of the pain. These include restricted movement, impaired sleep, decreased the ability to work, anxiety regarding pain, decreased participation in social activities, and increased use of health services. A primary focus of therapy for low back pain is the recovery of function.

Multidimensional rehabilitation is the focus of contemporary rehabilitation for low back pain, given the role that pain, physical loading, muscular capacity, sensory processing, psychological distress, behavioral avoidance, and the social context play. Musculoskeletal disorders comprise a large majority of conditions that would benefit from rehabilitation services worldwide, considering current rehabilitation estimates [3]. The 2023 WHO guideline for chronic low back pain, which is of a primary non-chronic nature, focuses on coordinated, non-surgical, holistic, and person-centered care, and offers a framework for inclusion of both education and an exercise component [4]. In line with the 2021 physical therapy clinical practice guideline, a focus on safe, acceptable, and sustainable activity programs is encouraged, which take into consideration the unique patient circumstances and practice setting [5].

Compared to no treatment, standard treatment or placebo, exercise therapy has moderate-certainty evidence for alleviating chronic low back pain, however, the average impact on functional limitations is variable and may be lesser [6]. According to network meta-analysis, varying exercise families may have varying short-term impacts, however, comparative evidence is affected by program design and adherence, the choice of comparators, and study quality [7]. The quality of home-based therapy may impact pain and functional outcomes, but the best therapy depends on a number of other factors, including supervision and adherence [8]. Recent studies continue to endorse exercise, and, while supporting the intervention, indicate the significant variability and the need for the interpretation to take into account not only the statistical improvements, but also the clinical relevance [9].

Yoga is a system of mind-body exercises that could address multiple components of low back pain. Protocols may incorporate coordinated spinal and hip movement, isometric and dynamic exercises, balance and breathing activities, relaxation and concentration exercises, and more. Along with pain-related threat, these may lower sympathetic arousal and increase trunk endurance, flexibility, and movement confidence and awareness. Although the mechanisms outline possibilities, they are not replacements for proof of a causal relationship in an observational or non-randomised study. One Cochrane review concluded that in comparison to no exercise, small-to-moderate improvements were seen in pain and exercise-related functions. However, adverse-event reporting and certainty were inconsistent across studies. One overview of reviews stated potentially positive outcomes overall, and noted, however, that the majority of studies reviewed were of low-quality and showed poor methodology. One rapid review of systematic reviews stated the potential for positive outcomes across multiple pain conditions, however, suggested that the results were highly inconsistent, and that there was a great deal of uncertainty.

Recent studies demonstrate the potential and situational necessity of yoga implementation. In a 2024 randomized control trial, synchronous virtual yoga sessions were integrated into standard care, and an improvement in chronic low back pain was observed. This study showed the benefit of a yoga delivery model that is not solely in-person [13]. In another trial of veterans, the benefit of yoga was observed in comparison to education, and a yoga delivery model was described. This study showed the impact of the population, adherence, and the comparison being made [14]. An integrated yoga-therapy program was studied in comparison to routine care and showed important improvements. The intensity of program protocols and the health

care delivery context are important factors that limit the transferability to other short-duration programs. This research shows that yoga is a helpful rehabilitation modality, but unlike a therapeutic panacea.

The selection of outcomes is critical when assessing the impact of an intervention for chronic low back pain. The visual analog scale (VAS) is a pain intensity scale. The Oswestry Disability Index (ODI) assesses the impact of low back pain on a person's ability to engage in activities of daily living. Would pain and function be assessed in the same way? Pain scales are responsive, but bounded, and are susceptible to floor effects when the score is low [21,23]. The ODI is responsive to clinically significant change; however, the magnitude of a change that is considered important also varies by the baseline severity, the intervention, and the analysis used to evaluate the change [22,24]. Assessing both the VAS and ODI would provide greater insight into the symptoms and function of chronic low back pain.

Data from a 21-day, two-group study with VAS and ODI scores recorded on the first, seventh, fourteenth, and twenty-first days, was the basis of the study. The major goal was to evaluate differences in the development of pain and disability in the Yoga therapy and standard care groups. The main focus was on the group-by-time interaction effect for VAS and ODI scores. The additional focus was to measure changes, effect sizes, and percentage improvements along with the delays from the baseline to the first, third, and final phases. The additional focus included the delays from the baseline to the follow-up phases and the influence of the age and gender of the participants and the delay from the baseline to the first, third, and final phases. Because the source files provided no information on randomization, concealment of allocation, adherence to the protocol, or other treatments given at the same time, the analysis attempted to provide the strongest possible evidence for comparison, without being overly confident in the results.

2. Materials and Methods

2.1 Study design and data sources

This study consisted of a comparative, longitudinal analysis of two groups, defined over a 21-day period. The main source of the study was the "backpain.xslx" participant-level spreadsheet. The statistical PDF served its function as a limited visual and numerical crosscheck. In the event of a discrepancy, the value recorded in the spreadsheet was retained. Description of the recruitment setting, diagnostic pathway, and data collection dates was required prior to submission: [insert study setting and data collection dates]. The dataset provided no evidence of randomization, allocation concealment, or blinding and as such, the study was not termed a randomized controlled trial.

Analytic samples consisted of 33 participants. IDs 1 to 15 were the Yoga group (n = 15), and IDs 16 to 33 were the Control group (n = 18). The Yoga group was recorded having an Introduction to Yoga Day between Day 2 and Day 5. For all Control participants, yoga was not introduced, and a value of zero was recorded. The source materials did not contain the eligibility criteria and the diagnostic definitions: [Insert inclusion and exclusion criteria and the operational definition of low back pain]. There were presumed to be no exclusions, withdrawals, or losses to follow-up, because the spreadsheet showed complete VAS and ODI data for all 33 participants for all four evaluations.

2.3 Interventions

Interventions. The available documents named a Yoga/Test group and a Control/standard-care group, but did not describe what the interventions were. Therefore, the manuscript prior to submission needs to have the following items filled: [Insert yoga postures/asanas, breathing or relaxation components, session length, session frequency, supervision, therapist expertise, home practice, and adherence assessment]. The comparator also needs to be specified: [Insert control-group treatment, education, medication, physiotherapy, and co-interventions]. These omissions directly impact reproducibility and the ability to make conclusions about causality, and were not addressed by any conjectures.

2.4 Outcome measures

2.4.1 Outcome measures

Pain intensity was assessed with the Visual Analog Scale (VAS) on Days 1, 7, 14, and 21. We have no record of the exact wording of the anchors or the length of the line: [Insert VAS administration method and anchors]. The VAS scores in the spreadsheet were between 0 and 9, which is consistent with a bounded measure of pain intensity. Functional disability was assessed as an Oswestry value on the same days. Due to a lack of visible level-of-item-response, the number of items completed, and the denominator needed for a percentage, the observed data were analyzed as raw total scores of the Oswestry Disability Index (ODI) rather than a percentage. This was to avoid creating a fictitious denominator. Prior to submission, the version of the ODI and the scoring method of the ODI and the maximum score that could be attained should be described: [Insert ODI version, item scoring and the max obtainable score].

2.5 Data cleaning and quality control

Study ID's were anonymized in place of participant numbers; the name column was deleted. There were two columns for age: in one column age was entered as a number, and in the other column, the participants' names were recorded. Only the column with the numeric value was retained for analysis. The entries for sex were standardized to Female and Male. For two Yoga-group participants, sex was documented as missing. No other data were assumed, and no other data were imputed. There were no duplicated IDs, age entries were complete, and entries for all outcomes were complete with the exception of VAS values which were all within the range of 0 to 9. For members of the control group, all starting values for yoga were zero. Outcome data were not changed, winsorized, or substituted. Data were transformed from a wide to long format for the purpose of longitudinal modeling.

2.6 Descriptive and assumption assessment

Age was summarized in terms of mean, SD, median, IQR, min and max. Sex was summarized in terms of frequency, valid percentage, and count of missing data. At each time point, VAS and ODI were summarized principally using median and IQR, with means and SDs, and range and 95% CIs of the mean provided as supplementary. For the assessment of distribution, the Shapiro Wilk test was supplemented with histograms, Q-Q plots, boxplots, skewness, and kurtosis. Due to small sample sizes, bounded scores, and clear Day 21 floor effects, formal normality tests were not carried out and the absence of normal distribution was not the only consideration for choosing the method.

2.7 Baseline comparisons

Age was compared using the Welch t test, as it is continuous and does not assume equal variance. The distribution of sex in the complete cases was compared using Fisher's exact test. The VAS and ODI scores at baseline were compared using the Mann-Whitney U test. A non-significant baseline test was interpreted as the absence of a difference and not evidence for equivalence. For age, Hedges' g was calculated and for Mann-Whitney comparisons, rank biserial correlation was calculated.

2.8 Primary longitudinal analysis

Primary longitudinal analysis. For both the VAS and ODI, separate Gaussian generalized estimating equations (GEE) models were built where participant was set as the clustering variable and included identity link, exchangeable working correlation and robust standard errors. Group was set with Control as the reference, and time was set with Day 1 as the reference. Each model had group, time, and group-by-time terms. GEE was built to incorporate robust variance that offered protection against working correlation misspecification. The main inferential test was the three-degree-of-freedom Wald test for the group-by-time interaction. Due to small sample size and bounded outcomes, GEE was complemented by non-parametric tests.

2.9 Supplementary and exploratory analyses

Supplementary analyses & Exploratory analyses. Each group was analyzed using the Friedman test to assess for any changes using data collected at four time intervals. Kendall's W was calculated to measure effect size. In the event of a significant result, baseline measurements were compared to post-intervention measurements (Days 7, 14, and 21) using Wilcoxon signed-rank tests

(Holm adjusted). Mann-Whitney U tests (Holm adjusted) were used for post-intervention comparisons measured at each time point and for each group. Improvement (a positive value denoting a benefit) was defined as baseline measurement minus post-intervention measurement. For those that did not measure improvement, a percentage improvement to Day 21 was measured as (Day-1 Score – Day-21 Score)/Day-1 Score × 100. Improvement scores and final scores of the Yoga group were assessed using the Spearman correlation to measure the relationship between the Yoga group final score and both Age and the day the individual was introduced to Yoga. These analyses were conducted for each member that completed the study and were exploratory in nature for each sex. Effect sizes were measured using a bootstrap method to create a 95% confidence interval. These estimates were measured using interval width and clinical value to determine the effect size, and the standard magnitude descriptors were used sparingly. All comparisons were made using two-tailed tests with an alpha value set at 0.05. Analyses were performed using Python, with the included libraries pandas, SciPy, and statsmodels.

2.10 Ethics

Ethics. The source files did not contain any documentation of ethics or consent. Before the submission, the following must be included: [Insert institutional ethics-committee name and approval number], [Insert informed-consent procedure], and [Insert trial-registration details, where applicable]. There were no participants whose names are included in this manuscript.

3. Results

3.1 Participant characteristics and data completeness

Participant characteristics and data completeness. All 33 participant IDs had age and complete VAS and ODI data on Days 1, 7, 14, and 21. Therefore, each endpoint had 132 repeated observations. The Yoga group had 15 participants and the Control group, 18. The participant's sex was recorded for 31 participants. The Yoga group had 13 participants with recorded sex, 9 of whom (69.2%) were female and 4 (30.8%) were male. In the Control group, 9 participants were female and 9 participants were male, and there were no missing values. There were no duplicate participant IDs or outcome values that were out of range.

3.2 Baseline demographic and clinical characteristics

Baseline demographic and clinical characteristics. The mean age of the participants in the Yoga group was 27.6 years (SD 9.2, median 27, IQR 8.5, range 16-46), and the mean age of the Control group was 31.5 years (SD 9.6, median 28.5, IQR 11.75, range 22-51). There was no statistically significant difference in the age between the two groups (Welch's t=-1.19, df=30.30, p=0.243, Hedges' g=-0.405). There was no statistically significant difference between the two groups for the participant's sex (Fisher's exact test, odds ratio=2.25, p=0.462), although the two missing values in the Yoga group decreased precision.

3.3 Baseline VAS and ODI Comparability

Day 1 Yoga and Control groups reported a median VAS of 8 (IQR 1), and 8 (IQR 2), respectively. The Mann-Whitney comparison was not statistically significant (U=159.5, p=0.359; rank-biserial r=0.181, 95% CI approximately -0.22 to 0.54). Yoga group's median baseline ODI was 25 (IQR 7.5) and 23 (IQR 5.75) for the Control. No difference was detected (U=160.5, p=0.363; r=0.189). These findings suggest baseline comparability for the measured variables. However, they do not suggest equivalence or the absence of unmeasured confounding.

3.4 Longitudinal VAS Changes

VAS declined for both groups, with earlier separation observed in the Yoga group. Day 1, 7, 14 and 21 Yoga group medians were 8, 3, 2 and 0, with Control medians of 8, 5, 4 and 2.5, respectively. Day 7, Yoga VAS was significantly lower than Control (U=18.0, Holm-adjusted p<0.001; r=-0.867, 95% CI -0.99 to -0.69). The observed difference was statistically significant for Day 14 (U=14.0, adjusted p<0.001; r=-0.896, 95% CI -0.99 to -0.74) and Day 21 (U=45.0, adjusted p=0.001; r=-0.

3.5 VAS group-by-time interaction

In the primary GEE model, the overall time effect was significant (Wald χ^2=337.43, df=3, p<0.001), and the group-by-time interaction was significant (χ^2=52.59, df=3, p<0.001). Relative to the change from baseline in the Control group, the Yoga group was estimated to have a reduction in VAS of 2.82 points at Day 7 (95% CI 1.96-3.68), 2.90 points at Day 14 (95% CI 2.00-3.80), and 2.01 points at Day 21 (95% CI 0.98-3.04). All interaction coefficients were statistically significant (p<0.001). The baseline group coefficient was non-significant (p=0.299). Thus, the longitudinal analysis supports different pain trajectories, not a static group difference.

3.6 Longitudinal ODI changes

Scores for functional disability in both groups showed improvement. For the Yoga group, the Day 1, Day 14, Day 21, and Day 28 median scores were 25, 10, 3, and 1, respectively. The median scores for the Control group were 23, 17.5, 11, and 5. Group differences at Day 7 (U=37.0, Holm-adjusted p<0.001; r=-0.726, 95% CI -0.95 to -0.44), Day 14 (U=16.5, adjusted p<0.001; r

3.7 ODI group-by-time interaction

In the ODI GEE model, time and group-by-time interaction both had significant results (time: Wald χ^2=171.87, df=3, p<0.001; group by time interaction: χ^2=35.34, df=3, p<0.001). Yoga group reductions compared to Control were estimated to be 6.42 ODI points at Day 7 (95% CI 3.31-9.54; p<0.001), 8.53 points at Day 14 (95% CI 4.83-12.24; p<0.001), and 4.88 points at Day 21 (95% CI 0.83-8.92; p=0.018). The smaller Day-21 interaction coefficient compared to Day 14 represents convergence, as the Control group showed improvement during that time, and not a reduction in improvement for the Yoga group.

3.8 Within-group and change-score analyses

Within-group and change-score analyses. Friedman tests showed significant results for VAS in Yoga (χ^2=36.15, p<0.001, Kendall's W=0.803) and Control (χ^2=52.30, p<0.001, W=0.969), and for ODI in Yoga (χ^2=43.67, p<0.001, W=0.970) and Control (χ^2=54.00, p<0.001, W=1.000). All baseline-to-post comparisons were significant after Holm correction. Because

3.9 Measuring improvement from Day 1 to Day 21

From Day 1 to Day 21, median VAS score improvement was 8 points in the Yoga group and 5 points in the Control group (U=224.5, Holm's p=0.001; r=0.663, 95% CI 0.32-0.93). Improvement in median ODI scores from Day 1 to Day 21 was also significant (p < 0.05). Yoga (U=196.5, Holm's p=0.027; r=0.456, 95% CI 0.10-0.77) and Control (U=196.5, Holm's p=0.027; r=0.456, 95% CI 0.10-0.77) groups showed median improvement of 23 (IQR 4.5) and 16.5 (IQR 5.75) points, respectively. Median percentage improvement in VAS scores was 100% in the Yoga group (n=22) and 68.8% in the Control group. Median improvement in ODI was approximately 95.8% (Yoga group) and 77.6% (Control group). Percentage values are descriptive; low final scores and varying baseline scores may negatively impact interpretation of relative changes.

3.10 Age, yoga-introduction day and outcomes

Age, Yoga-introduction day and sex. In the Yoga group, Age was not significantly correlated with VAS (ρ=0.206) or ODI (ρ=0.349) score improvement. Yoga-introduction day was not significantly related to Day-21 VAS (ρ=-0.258) or ODI (ρ=0.433) scores, VAS (ρ=0.230), and ODI (ρ=-0.081) score improvement. The wide CIs indicate that the absence of statistically significant correlation does not mean that there are no treatment differences for the different ages or Yoga-introduction days.

3.11 Exploratory sex analysis

Exploratory sex analysis was possible for 13 Yoga participants. Median VAS improvement was 8 points for females and 7.5 points for males (U=22.5, p=0.519; r=0.250, 95% CI -0

Tables

Table 1. Demographic and baseline clinical characteristics.

Variable	Yoga (n=15)	Control (n=18)	Test	p	Effect
Age, years	27.6 ± 9.2; median 27 (IQR 8.5); 16-46	31.5 ± 9.6; median 28.5 (IQR 11.75); 22-51	Welch t=-1.19, df=30.30	0.243	Hedges g=-0.405
Sex, Female/Male	9/4; missing=2	9/9; missing=0	Fisher OR=2.25	0.462	—
Day 1 VAS	8 (1); mean 8.20±0.94	8 (2); mean 7.83±1.15	U=159.5	0.359	r_rb=0.181
Day 1 ODI raw total	25 (7.5); mean 24.60±5.08	23 (5.75); mean 23.44±6.24	U=160.5	0.363	r_rb=0.189

Values are mean ± SD or median (IQR) as stated. Sex percentages use complete cases; two Yoga-group sex values were missing. ODI values are raw totals.

Table 2. VAS pain scores over 21 days.

Time	Yoga: median (IQR); mean±SD; 95% CI	Control: median (IQR); mean±SD; 95% CI	p	Holm p	Rank-biserial r (95% CI)
Day 1	8.0 (1.00); 8.20±0.94; 95% CI 7.68-8.72	8.0 (2.00); 7.83±1.15; 95% CI 7.26-8.41	0.359	Not adjusted	0.181 (-0.219, 0.511)
Day 7	3.0 (1.00); 2.60±1.18; 95% CI 1.94-3.26	5.0 (1.75); 5.06±1.06; 95% CI 4.53-5.58	<0.001	<0.001	-0.867 (-0.989, -0.685)
Day 14	2.0 (1.00); 1.47±0.99; 95% CI 0.92-2.02	4.0 (2.00); 4.00±1.19; 95% CI 3.41-4.59	<0.001	<0.001	-0.896 (-0.989, -0.744)
Day 21	0.0 (1.00); 0.80±1.26; 95% CI 0.10-1.50	2.5 (1.00); 2.44±1.10; 95% CI 1.90-2.99	<0.001	<0.001	-0.667 (-0.922, -0.348)

Rank-biserial r is Yoga minus Control; negative values indicate lower outcome scores in Yoga. Day 1 was not included in the post-baseline multiplicity family.

Table 3. Raw ODI disability totals over 21 days.

Time	Yoga: median (IQR); mean±SD; 95% CI	Control: median (IQR); mean±SD; 95% CI	p	Holm p	Rank-biserial r (95% CI)
Day 1	25.0 (7.50); 24.60±5.08; 95% CI 21.79-27.41	23.0 (5.75); 23.44±6.24; 95% CI 20.34-26.55	0.363	Not adjusted	0.189 (-0.185, 0.556)
Day 7	10.0 (3.50); 11.73±3.56; 95% CI 9.76-13.70	17.5 (3.75); 17.00±3.12; 95% CI 15.45-18.55	<0.001	<0.001	-0.726 (-0.945, -0.441)
Day 14	3.0 (3.50); 4.40±3.83; 95% CI 2.28-6.52	11.0 (3.00); 11.78±2.44; 95% CI 10.56-12.99	<0.001	<0.001	-0.878 (-1.000, -0.626)

Time	Yoga: median (IQR); mean±SD; 95% CI	Control: median (IQR); mean±SD; 95% CI	p	Holm p	Rank-biserial r (95% CI)
Day 21	1.0 (1.50); 1.33±1.18; 95% CI 0.68-1.98	5.0 (3.75); 5.06±3.04; 95% CI 3.54-6.57	<0.001	<0.001	-0.778 (-0.967, -0.526)

Rank-biserial r is Yoga minus Control; negative values indicate lower outcome scores in Yoga. Day 1 was not included in the post-baseline multiplicity family.

Table 4. Generalized estimating equation results for longitudinal VAS and ODI trajectories.

Outcome	Term	Estimate	Robust SE	z/Wald	95% CI/df	p
VAS	Control at Day 1	7.833	0.264	29.73	7.317 to 8.350	<0.001
VAS	Yoga-Control at Day 1	0.367	0.353	1.04	-0.325 to 1.058	0.299
VAS	Control change: Day 7	-2.778	0.267	-10.40	-3.301 to -2.254	<0.001
VAS	Control change: Day 14	-3.833	0.286	-13.40	-4.394 to -3.273	<0.001
VAS	Control change: Day 21	-5.389	0.306	-17.63	-5.988 to -4.790	<0.001
VAS	Additional Yoga change: Day 7	-2.822	0.440	-6.41	-3.685 to -1.959	<0.001
VAS	Additional Yoga change: Day 14	-2.900	0.459	-6.32	-3.799 to -2.001	<0.001
VAS	Additional Yoga change: Day 21	-2.011	0.528	-3.81	-3.045 to -0.977	<0.001
VAS	Overall Wald: group	—	—	χ^2=1.08	df=1	0.299
VAS	Overall Wald: time	—	—	χ^2=337.43	df=3	<0.001
VAS	Overall Wald: interaction	—	—	χ^2=52.59	df=3	<0.001
ODI	Control at Day 1	23.444	1.430	16.40	20.642 to 26.247	<0.001
ODI	Yoga-Control at Day 1	1.156	1.911	0.60	-2.590 to 4.901	0.545
ODI	Control change: Day 7	-6.444	1.103	-5.84	-8.607 to -4.282	<0.001
ODI	Control change: Day 14	-11.667	1.421	-8.21	-14.451 to -8.882	<0.001

Outcome	Term	Estimate	Robust SE	z/Wald	95% CI/df	p
ODI	Control change: Day 21	-18.389	1.603	-11.47	-21.530 to -15.248	<0.001
ODI	Additional Yoga change: Day 7	-6.422	1.588	-4.04	-9.535 to -3.309	<0.001
ODI	Additional Yoga change: Day 14	-8.533	1.889	-4.52	-12.235 to -4.832	<0.001
ODI	Additional Yoga change: Day 21	-4.878	2.064	-2.36	-8.924 to -0.832	0.018
ODI	Overall Wald: group	—	—	χ^2=0.37	df=1	0.545
ODI	Overall Wald: time	—	—	χ^2=171.87	df=3	<0.001
ODI	Overall Wald: interaction	—	—	χ^2=35.34	df=3	<0.001

Control and Day 1 are reference categories. Interaction coefficients represent additional change in Yoga beyond contemporaneous Control change. Gaussian GEE used exchangeable working correlation and robust standard errors.

Table 5. Within-group repeated-measures and Holm-adjusted baseline-to-follow-up analyses.

Outcome	Group	Comparison	Statistic	p	Holm p	Effect
VAS	Yoga	Overall four-time-point test	χ^2=36.15	<0.001	<0.001	Kendall W=0.803
VAS	Control	Overall four-time-point test	χ^2=52.30	<0.001	<0.001	Kendall W=0.968
ODI	Yoga	Overall four-time-point test	χ^2=43.67	<0.001	<0.001	Kendall W=0.970
ODI	Control	Overall four-time-point test	χ^2=54.00	<0.001	<0.001	Kendall W=1.000
VAS	Yoga	Day 1 vs Day 7	W=0.0; median Δ=6.0	<0.001	0.002	paired r_rb=1.000
VAS	Yoga	Day 1 vs Day 14	W=0.0; median Δ=7.0	<0.001	0.002	paired r_rb=1.000
VAS	Yoga	Day 1 vs Day 21	W=0.0; median Δ=8.0	<0.001	0.002	paired r_rb=1.000
VAS	Control	Day 1 vs Day 7	W=0.0; median Δ=3.0	<0.001	<0.001	paired r_rb=1.000

Outcome	Group	Comparison	Statistic	p	Holm p	Effect
VAS	Control	Day 1 vs Day 14	W=0.0; median Δ=3.5	<0.001	<0.001	paired r_rb=1.000
VAS	Control	Day 1 vs Day 21	W=0.0; median Δ=5.0	<0.001	<0.001	paired r_rb=1.000
ODI	Yoga	Day 1 vs Day 7	W=0.0; median Δ=11.0	<0.001	0.002	paired r_rb=1.000
ODI	Yoga	Day 1 vs Day 14	W=0.0; median Δ=18.0	<0.001	0.002	paired r_rb=1.000
ODI	Yoga	Day 1 vs Day 21	W=0.0; median Δ=23.0	<0.001	0.002	paired r_rb=1.000
ODI	Control	Day 1 vs Day 7	W=0.0; median Δ=4.5	<0.001	<0.001	paired r_rb=1.000
ODI	Control	Day 1 vs Day 14	W=0.0; median Δ=10.0	<0.001	<0.001	paired r_rb=1.000
ODI	Control	Day 1 vs Day 21	W=0.0; median Δ=16.5	<0.001	<0.001	paired r_rb=1.000

Positive median change denotes improvement. The paired rank-biserial effect was 1.00 because every participant improved from baseline at each listed follow-up; bounded outcomes and score magnitudes must also be considered.

Table 6. Baseline-to-Day-21 absolute and percentage improvement.

Outcome	Yoga absolute improvement	Control absolute improvement	Test	Holm p	r_rb (95% CI)	Median % improvement
VAS	8.0 (2.00); mean 7.40±1.72	5.0 (1.75); mean 5.39±1.33	U=224.5	0.001	0.663 (0.341, 0.922)	100.0% vs 66.7%
ODI	23.0 (8.00); mean 23.27±5.22	16.5 (10.50); mean 18.39±7.00	U=196.5	0.027	0.456 (0.092, 0.767)	94.7% vs 79.4%

Improvement = Day 1 minus Day 21. Positive rank-biserial values favour greater improvement in Yoga. Percentage improvement is descriptive because baseline values and floor effects influence ratios.

Table 7. Spearman correlations within the Yoga group (n=15).

Predictor	Outcome	n	Spearman ρ	Bootstrap 95% CI	p	Interpretation
Age	VAS improvement	15	0.206	-0.392 to 0.679	0.461	Not significant
Age	ODI improvement	15	0.349	-0.227 to 0.775	0.202	Not significant

Predictor	Outcome	n	Spearman ρ	Bootstrap 95% CI	p	Interpretation
Yoga start day	Day 21 VAS	15	-0.258	-0.689 to 0.226	0.354	Not significant
Yoga start day	Day 21 ODI	15	0.433	-0.007 to 0.792	0.107	Not significant
Yoga start day	VAS improvement	15	0.230	-0.341 to 0.727	0.410	Not significant
Yoga start day	ODI improvement	15	-0.081	-0.606 to 0.522	0.774	Not significant

Correlation analyses were exploratory; broad confidence intervals reflect the small sample and restricted yoga-start-day range.

Table 8. Exploratory sex-based baseline-to-Day-21 improvement within the Yoga group.

Outcome	Female: median (IQR); mean±SD	Male: median (IQR); mean±SD	Test	p	r_rb (95% CI)
VAS	n=9; 8.0 (1.00); 7.78±1.39	n=4; 7.5 (2.25); 6.75±2.63	U=22.5	0.519	0.250 (-0.473, 0.889)
ODI	n=9; 23.0 (4.00); 23.00±4.61	n=4; 22.0 (8.25); 22.25±4.92	U=19.0	0.938	0.056 (-0.694, 0.778)

Two Yoga-group participants had missing sex and were excluded. Positive r indicates greater improvement among females. The male subgroup contained four participants.

Figures

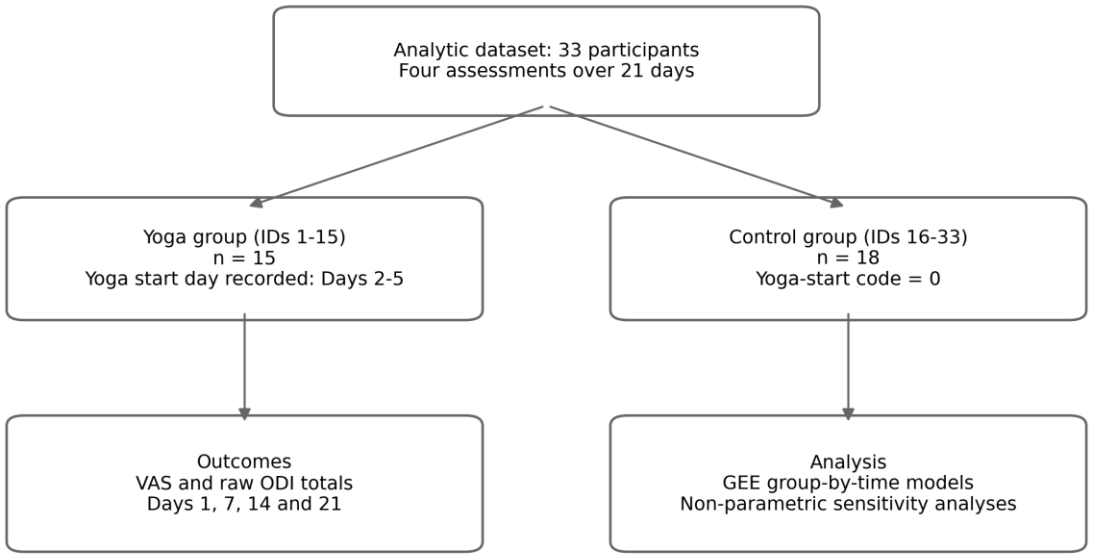

Figure 1. Study design and analytic allocation. The source dataset contained complete VAS and ODI values for all 33 predefined participant IDs; no recruitment or attrition counts were inferred.

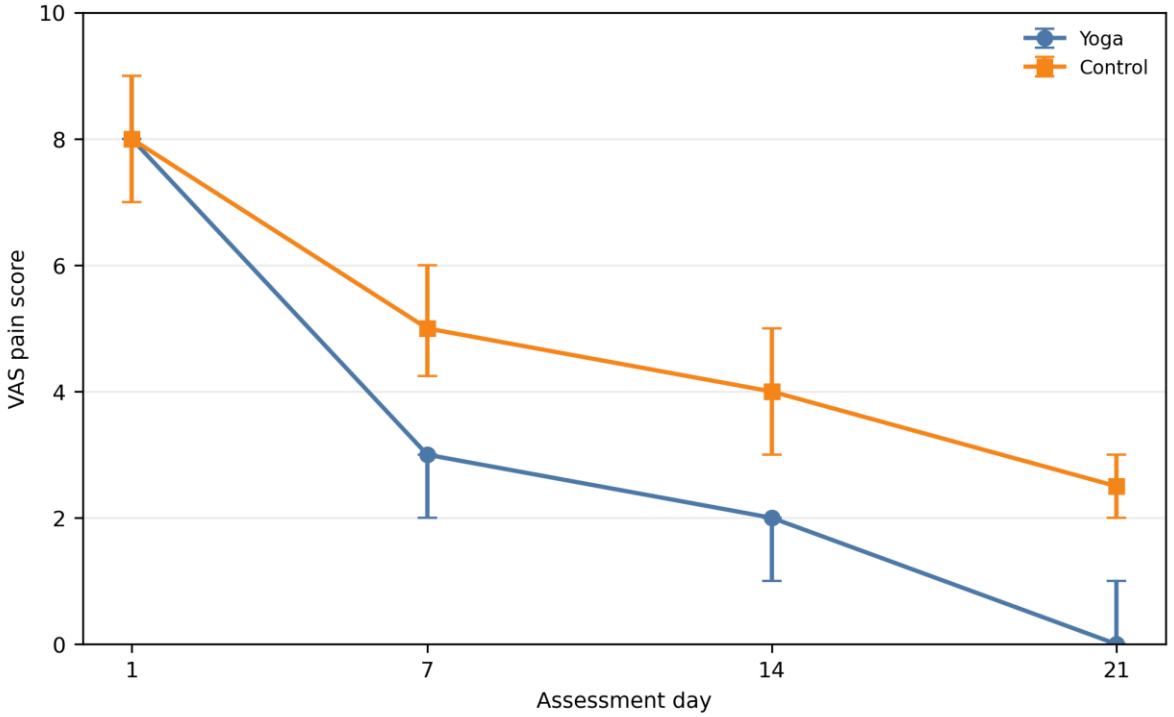

Figure 2. Median VAS pain trajectory with interquartile-range error bars. Lower values indicate less pain. Group separation emerged by Day 7 and persisted through Day 21.

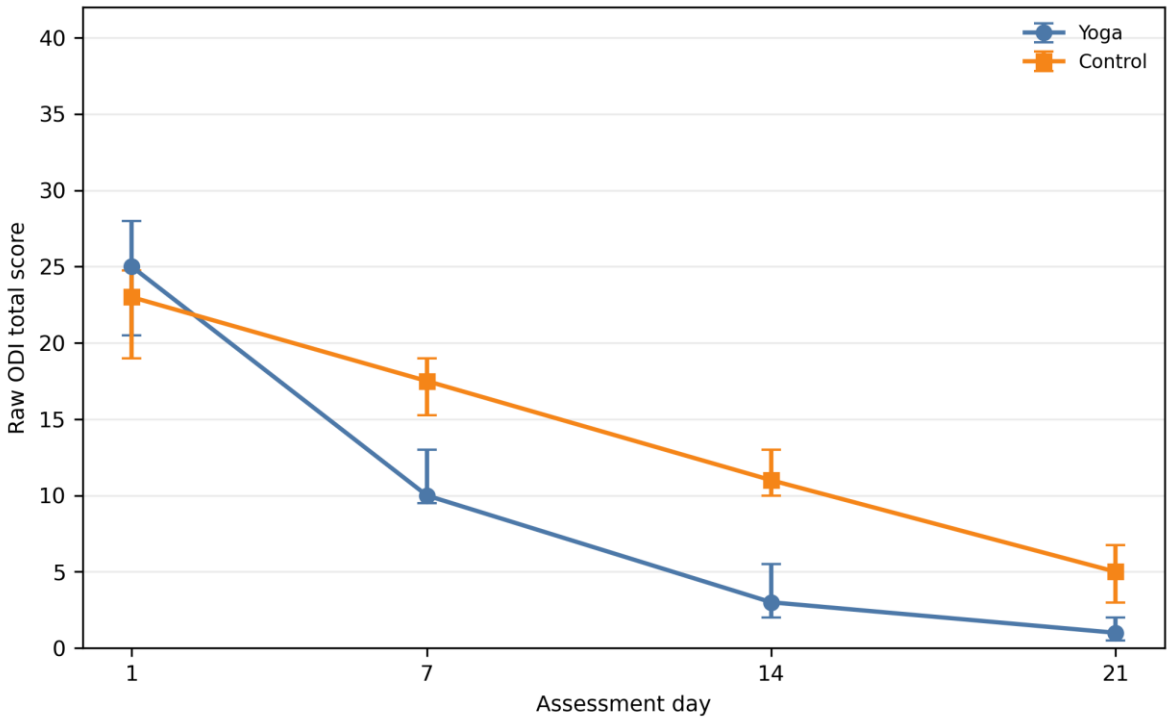

Figure 3. Median raw ODI disability trajectory with interquartile-range error bars. Lower values indicate less disability. Raw totals are shown because an item-level denominator was unavailable.

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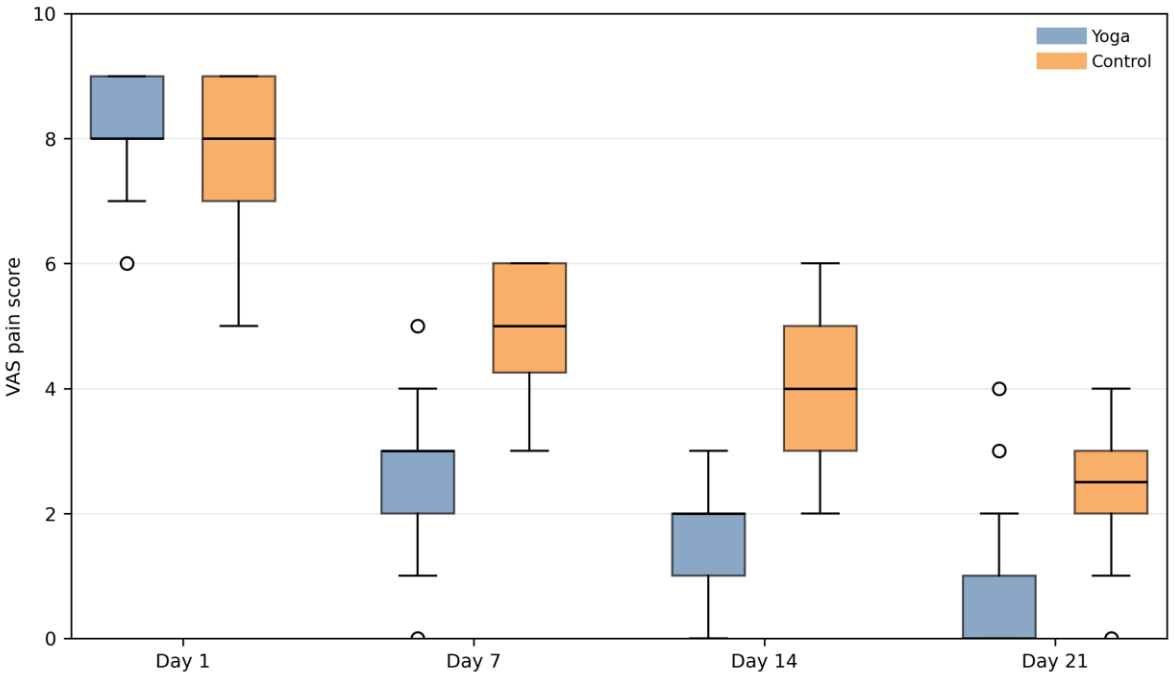

Figure 4. Distribution of VAS scores by group and assessment day. Boxes show the interquartile range, centre lines the median and whiskers the conventional boxplot range.

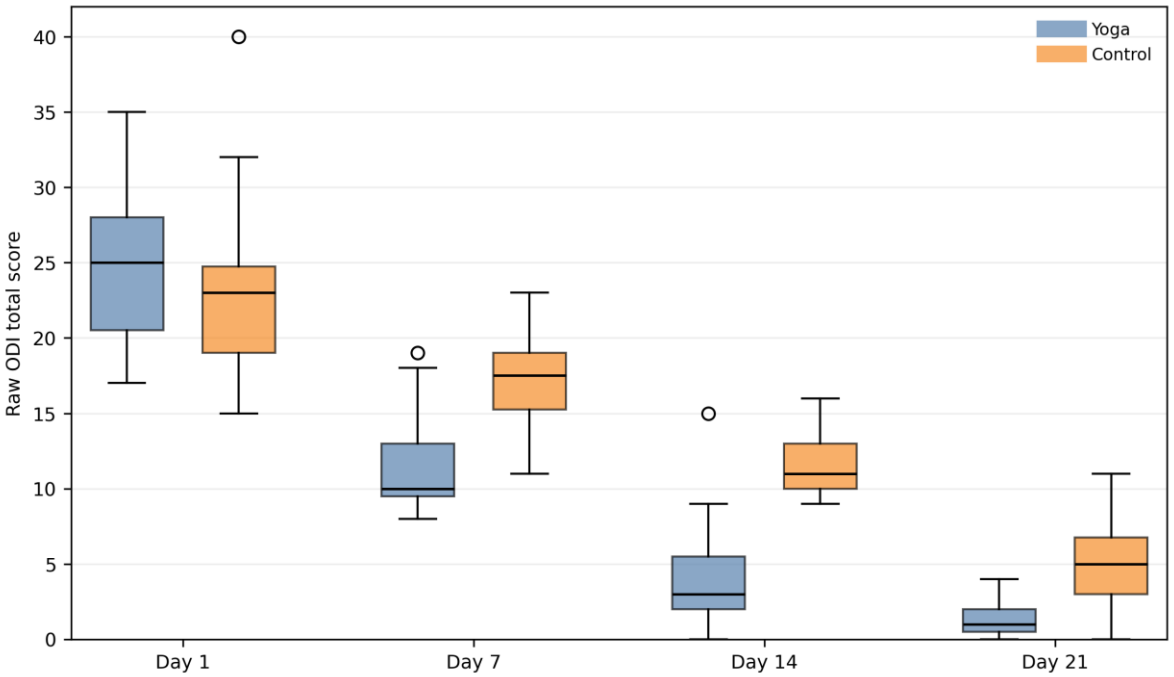

Figure 5. Distribution of raw ODI totals by group and assessment day. Marked clustering at low Yoga-group values is visible on Day 21.

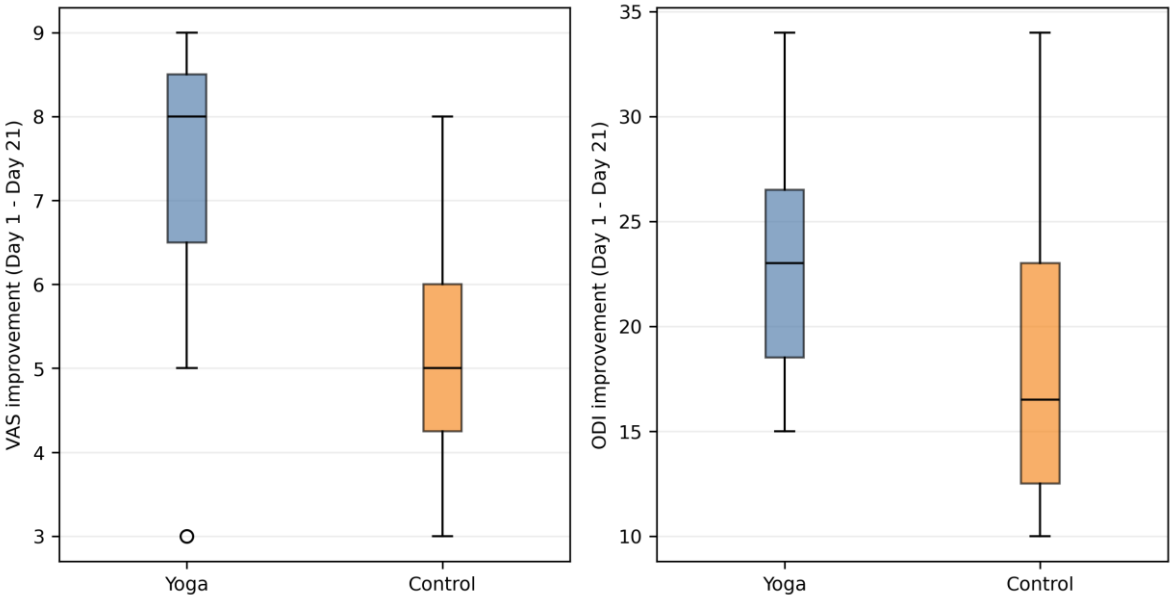

Figure 6. Baseline-to-Day-21 absolute improvement in VAS and ODI. Positive values denote improvement; Yoga displayed larger median improvement for both endpoints.

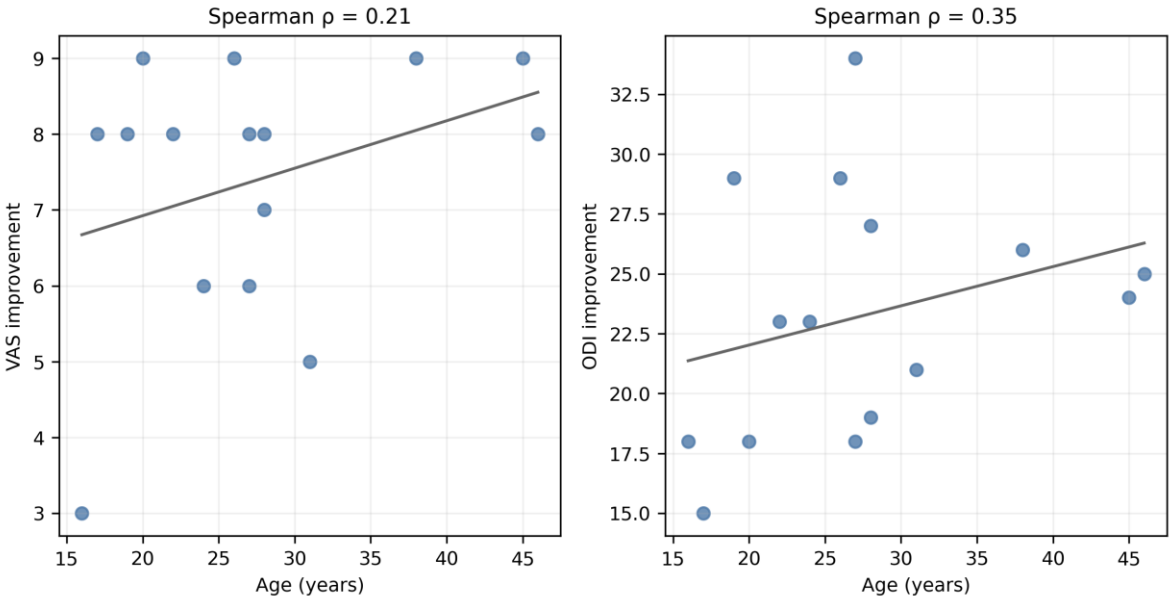

Figure 7. Exploratory relationship of age with VAS and ODI improvement in the Yoga group. Lines are descriptive least-squares trends; inferential results used Spearman correlations.

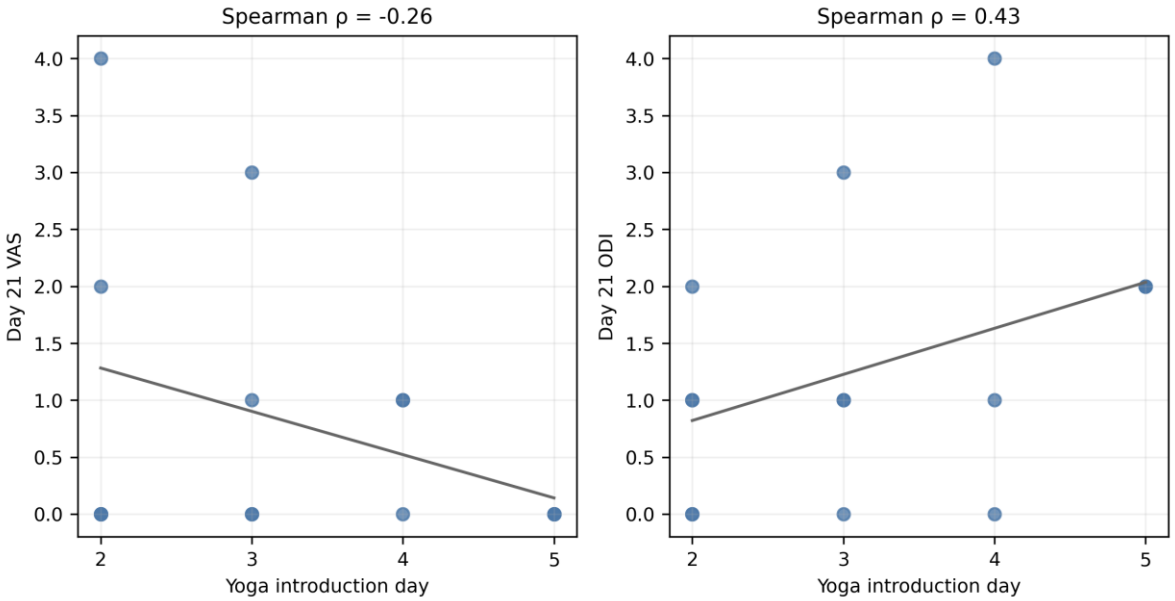

Figure 8. Exploratory relationship of yoga-introduction day with Day-21 VAS and ODI in the Yoga group. The restricted Day-2-to-Day-5 range limits interpretation.

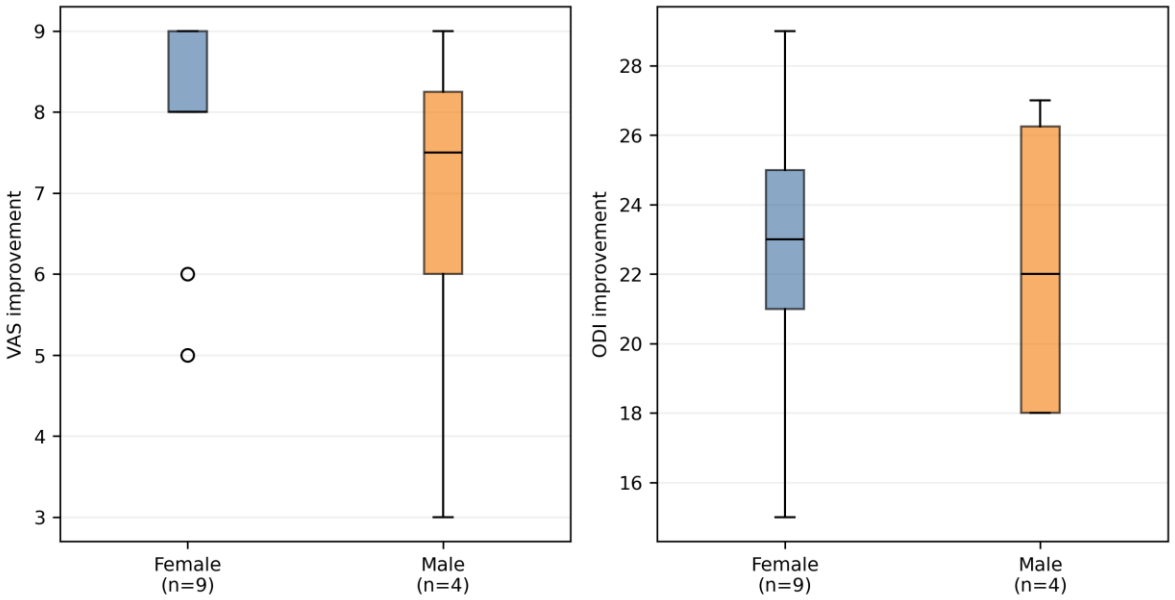

Figure 9. Exploratory sex-based improvement within the Yoga group. Two participants with missing sex were excluded, and the male subgroup was small (n=4).

4. Discussion

This participant-level reanalysis indicates that the Yoga group showed accelerated improvement in both pain intensity and functional disability. There were no significant differences in baseline demographics, VAS, or ODI. Separation between groups was already evident by Day 7, and was greatest by Day 14 for both pain and disability. GEE interaction tests showed that the average change for each group over time was not the same, and that the difference in average change over time could not be explained by a single point comparison. This conclusion was supported by the results of non-parametric tests, which indicated that the post-baseline VAS and ODI difference estimates were large. The Day 21 change-score also supported Yoga, even though the ODI effect was smaller and less precise compared to the other post-baseline effect comparisons.

These findings also support the existing body of research which indicates that exercise programs can reduce Chronic Low Back Pain. Yoga may be an even better option, as it contains all these elements in one program. Yoga can establish a safe environment for movement by promoting patience, postural control, and protective stiffness, and can encourage skilled movement through progressive postures. From a neurophysiological perspective, repeated non-threatening movement may support pain-related fibromyalgia. The present dataset did not measure these mediators, so they remain as explanatory hypotheses rather than demonstrated pathways.

The trajectory aligns with recent yoga-centered literature. A 2022 Cochrane review concluded yoga likely improves back-related function in comparison to no exercise, and yoga may improve back pain, although these findings should be interpreted with caution due to uncertainty and heterogeneity of the included studies [10]. A 2023 overview of reviews reported similar findings, with evidence of potential benefit, although the reviews were methodologically poor and evidence of safety was lacking [11]. A number of recent randomized trials have integrated yoga into virtual, veteran, and integrated care, reporting improvements in pain and/or function [13-15]. These trials have shown longer durations and more fully elaborated specifications than the current 21-day dataset. Thus, the rapid change observed should be treated as a signal that needs further research, not a measure that can be extrapolated to all yoga programs.

The separation of statistical and clinical significance is important here. The VAS and ODI are flexible measures, and their minimal clinically important difference (MCID) is not a fixed constant that applies universally. The scaling of pain measure PSC thresholds are also not fixed, and ODI MCID also varies based on the context of the measure, the framework of the analysis, and the design of the study [21, 22, 23, 24]. The median improvement of the Yoga group reported a raw ODI score of 23 points and 8 points on the VAS, which in comparison to the other groups, was a large improvement and the Control group also reported a large improvement. The magnitude of the change cannot be explained by noise in the measurement system, and the change in the ODI score cannot be interpreted fully without knowledge of the version of the ODI, the sample size of the study, how it was administered, and whether the score was a raw, untitled, or untransformed score.

Attention is warranted for the strong Day-21 floor effect. For the Yoga group, the median VAS was 0 and median ODI was 1. Day-21 floor clustering creates uncertainty and reduces the normal distribution, resulting in undetectable age and treatment effect correlations. This makes the scales unable to discriminate among participants with very low residual symptoms. For this reason and many others, robust GEE with rank-based sensitivity was implemented in the analysis. ODI interaction differences were smaller at Day 21 than at Day 14 for the Yoga group. This was due to a lack of improvement room for the Yoga Group, while the Control Group continued to improve and lower their scores. More studies need to look at longer follow ups, return to activity, recurrence, sleep, medication use, and patient global impression scores to determine if initial improvements extend beyond floor effects.

Age had a weak and statistically insignificant correlation with Yoga improvements. Across the observed 16 – 46-year age range, evidence indicating a lower short-term responsiveness was absent, and the sample was small to assess age invariance. The range Yoga was introduced (Day 2 to Day 5) was also unrelated to the final and total improvement scores. The narrow range fails to provide reasonable evidence that the timing is irrelevant. A better design might randomize the initial exposure or measure cumulative exposure, attendance of sessions, and practice at home. Classifying participants by sex also lacked power; only 4 Yoga participants were male and 2 had no sex recorded. In these cases, non-significant p-values are consistent with no difference or clinically significant differences in either direction.

Several other explanations must be taken into account. To begin with, the source files did not elaborate on how participants were grouped. As a result, if grouping was determined by preference, availability, symptom severity, motivation, or even the clinician's judgment, then a selection bias toward Yoga was likely. Additionally, the comparator was not identified. If the participants were given medication or physiotherapy, or some activity was recommended, or if there was a natural recovery, then the improvement seen may be due to these factors and may be different for each group. In addition, the outcomes in this study were measured by some self-report, and since the participants were likely not blinded to their participation in Yoga, this is also likely to be a source of expectation bias and increased reporting. Furthermore, because the assessment of baseline pain was high, then the improvement could be due to regression to the mean. Lastly, since no data on adherence and fidelity were provided, then there is no way to assess the potential dose-response. While these challenges do not affect the improvement seen, they do affect attributing these solely to Yoga.

The improvement seen in the Control group is of a clinically valuable nature and reinforces the emphasized need for cautious evaluation. The natural improvement of symptoms, standard care, or co-interventions may have been of value. Modern thinking favors a multi-modal, personalized intervention approach, rather than a mutually exclusive model of yoga and standard care. Based on this dataset, and to the best of our ability, we believe that the improvement seen in the Yoga group was beyond improvement seen in the control group. To be able to show the value of this intervention in the future, there needs to be a clear, evidence-based approach for the intervention, where feasible, and subject to standard co-interventions. In addition, there should be blinding of the outcome assessments, and adherence to the interventions would be monitored, with a clear justification of the required sample size for the intervention.

The findings bear practical implications for physiotherapy. In the presence of actively deconditioned patients, of those who are afraid to move and/or who present with neurological signs and 'red flags,' therapeutic exercise will have to include greater supervision. Yoga-inspired movement may be offered to patients as a graded therapeutic exercise, once the patients' irritability, mobility, balance, and comorbidities and preferences are taken into account. Each posture will have to be described in a reproducible program, along with any modifications, instructions for breathing, as well as prescriptions for time and intensity, progression, adverse event procedures, and more. Safety risks may be alleviated through screening, where real-time feedback is still required, especially when integrating virtual/online yoga. Safety risks are also present in other physical interventions. The integration of therapeutic yoga should not replace medical assessment of serious conditions, nor should it delay activity restoration.

Further studies should incorporate the repeated measures design as in the present study and focus on improving design and measures. Subsequent studies of this kind should take into account baseline restriction and other variables including length of symptoms, pharmacotherapy, workplace exposure, psychometrics, and previous yoga attendance. Further studies of this nature are encouraged to justify sample size based on predicted improvement of the primary outcome of concern, rather than a comparison of means for the outcomes measured at the end of the study [27]. Studies of this nature are encouraged to describe adverse events, adherence to the study protocol, in the context of planned outcome measures and responder analyses at a clinically meaningful threshold. Studies of this nature should also incorporate an extended follow-up period to examine the potential for participants to return to work and to assess whether study participants have sustained the effects of the yoga intervention. Acceptability, perceived mechanisms of effect, and barriers to participation would also be measured through qualitative methods. These interventions would elucidate whether the early separation effect is context-specific, a treatment effect of the yoga

intervention, or some combination of the two.

5. Strengths and Limitations

The main strength was having access to participant-level data, meaning that every statistic could be verified independently, unlike studies where verification is done through secondary reports. The design involved four repeated measures and two complementary outcomes and so provided direct assessment of the pain and disability trajectories. Group-by-time GEE models considered the correlation within the participants. Non-parametric sensitivity analyses were utilized when appropriate, considering small samples, scores with limited ranges and floor effects. Effect sizes and confidence intervals were provided, as well as multiplicity-adjusted post hoc results, and the removal of participants' names was done.

The limitations are many. The sample was small, with unequal distribution in the groups. The 21-day follow-up does not provide information on the sustainability of the results. The mechanism of allocation, the context where the participants were recruited from, the duration of the symptoms, the diagnosis procedure, the yoga protocol, the content of the comparator, the medication, co-interventions, adherence, the therapist qualification, and the adverse events were all not reported. Randomization, concealment, and blinding cannot be assumed. Two Yoga participants had missing sex, and analyses by sex had very little power. It was not clear what the ODI version was, and what the ODI was divided by, so values were treated as raw totals with no ability to report them as percentages. Expectation may influence reported outcomes. Day 21 floor effects limit discrimination, and GEE robust inference may be overstated with only 33 clusters. Unmeasured prognostic factors could not be accounted for. Therefore, the analysis should be viewed as a highly rigorous exploratory comparative analysis, and not as definitive causal analysis.

6. Clinical Implications

These findings justify adding overseen yoga into multi-faceted low back pain rehabilitation. The notable feature supporting this was not only a lower Day-21 score, but earlier separation by Day 7, potentially increasing confidence and participation. Red-flag screening, movement tolerance assessment, and the potential for individual modification, should be the initial steps for implementation. Yoga should combine with other elements like education, graded activity and the necessary medications or physiotherapy, and should never be viewed as a substitute for the required interventions. The current research remains inconclusive about the ideal starting day, dose, or posture sequence; however, adherence, symptom worsening, and adverse events should be documented. Also, large-scale, controlled studies should, at a minimum, address which patients gain the most benefit, as well as the long-term sustainability of the benefit.

7. Conclusion

In this 33-participant, longitudinal study, pain as measured by VAS and the ODI, improved for both groups. Over the 21 days, pain and ODI improved more in the Yoga group, with statistically more significant group by time interactions, a large, post-baseline rank-biserial effect, and a greater Day-1 to Day-21 change. Compared to Controls, the Yoga group had lower median Day-21 VAS and ODI, and the Control group showed notable recovery. Age, day of yoga introduction, and sex, showed no statistical correlation with improvements in the Yoga group, but the quality of these analyses was low, and should not be viewed as evidence of the same outcomes across different groups.

The study improves the statistical description of the supplied data; however, the short follow-up period and various floor effects limit its design. The lack of details in study design including group allocation, adherence, treatment protocols,

concurrent care, and ethical considerations, means we can only conclude that the yoga pathway was associated with greater short term improvement compared to the control. Assertive conclusions should be based on a study designed with appropriate constraints, posting an a priori registry that has a standardized yoga intervention, a standardized control, appropriate covariates, safety data, and a longer follow-up period.

Acknowledgements: [Insert acknowledgements, where applicable].

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