

ORIGINAL ARTICLE

Effects of yoga-based and conventional physiotherapy programs on functional, respiratory, and psychosocial outcomes in stage II sarcoidosis: A randomized controlled trial

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ABSTRACT

Background and aim: Sarcoidosis, a multisystemic granulomatous disease, presents with various clinical symptoms such as deterioration in respiratory functions, decreased exercise capacity, fatigue, sleep disorders, anxiety-depression, and consequently reduced quality of life. A standard rehabilitation protocol has not been defined for sarcoidosis, and due to the nature of the disease, holistic approaches are crucial in this group, which is known to have multisystem involvement. Therefore, this study aims to contribute to the development of future rehabilitation protocols by comparing the effectiveness of yoga and conventional physiotherapy programs delivered via telerehabilitation, in addition to standard aerobic training, in sarcoidosis patients with pulmonary involvement.

Methods: Thirty-four Stage II sarcoidosis patients were included in this study, and the participants were randomly divided into two groups (conventional physiotherapy, n=16, yoga, n=18). Before and after the 8-week programs, participants completed the following questionnaires: Fatigue Assessment Scale (FAS), Hospital Anxiety and Depression Scale, Pittsburgh Sleep Quality Index (PSQI), and St. George Respiratory Questionnaire (SGRQ). Furthermore, the 6MWT, Body Oxygen Level Test (BOLT), spirometric measurements, DLCO, Maximum inspiratory pressure (MIP), and dyspnea (mMRC score) measurements.



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Results: Programs significantly improved exercise capacity, inspiratory muscle strength, fatigue (FAS), dyspnea, PSQI scores, anxiety-depression levels, quality of life (SGRQ), and BOLT time in both groups. While similar improvements were observed overall in intergroup comparisons, the increase in MIP and BOLT time was more pronounced in the conventional physiotherapy group. Neither program resulted in significant changes in spirometric parameters or DLCO values.

Conclusions: This study found that both 8-week telerehabilitation-based yoga and conventional physiotherapy programs were effective for patients with Stage II sarcoidosis. The similar effects observed between yoga and conventional physiotherapy suggest that yoga, a holistic mind-body approach, may be an effective alternative in the treatment of sarcoidosis.

Key words: sarcoidosis, yoga, physiotherapy, telerehabilitation, exercise

Introduction

Sarcoidosis is a multisystem disease of unknown cause, typically affecting the respiratory system, characterized by the formation of immune granulomas that can affect multiple organs and systems, with varying clinical manifestations depending on the organs involved. It occurs most frequently in young and middle-aged adults. Despite a low mortality rate, sarcoidosis often progresses to a chronic disease with associated morbidity (1,2). Pulmonary involvement, seen in 95% of patients, results in limited lung capacity and decreased inspiratory muscle strength, which are essential factors contributing to increased dyspnea, decreased walking distance, and exercise capacity. In addition to respiratory muscle weakness, skeletal muscle dysfunction is also frequently observed. Dyspnea and fatigue are the most common symptoms and, along with psychosocial consequences, significantly reduce quality of life (3-5). According to guidelines published by the European Respiratory Society (ERS), a 6- to 12-week pulmonary rehabilitation (PR) program (low-level evidence) is recommended to alleviate fatigue in patients with sarcoidosis who have fatigue and no contraindications to exercise (6). Although structured exercise and pulmonary rehabilitation programs have demonstrated improvements in exercise capacity, dyspnea, and quality of life in patients with sarcoidosis, the optimal disease-specific prescription remains unclear (7,8).

Yoga is a holistic exercise approach targeting both physical and psychosocial domains, combining asanas, pranayama (breathing techniques), and meditation, and is considered suitable for cardiopulmonary rehabilitation programs because it regulates autonomic function by increasing vagal nerve activation (9). Yoga-based interventions have been shown to improve lung function, six-minute walk distance (6MWD), and quality of life in patients with chronic respiratory diseases (11-12). There is increasing evidence that pranayama and slow/deep diaphragmatic breathing practices increase autonomic nervous system regulation, vagal tone, and heart rate variability, and reduce anxiety, stress, and depression (13-15).

A pulmonologist routinely monitors patients with sarcoidosis, and if the disease doesn't progress during this period, pharmacological treatment may not be initiated. The basis of pharmacological therapy is corticosteroids and immunosuppressive medications. However, long-term cortisone use has been reported to have side effects and may even cause the disease to relapse (6,16). Therefore, non-pharmacological approaches, particularly rehabilitation and breathing-based techniques, can play a complementary role. The existing literature on non-pharmacological interventions in sarcoidosis is limited, and no study has yet examined the efficacy of yoga-based rehabilitation.

This study aims to compare the effectiveness of telerehabilitation-based yoga and conventional physiotherapy programs without assuming superiority of

either intervention, in addition to standard aerobic training, over 8 weeks in patients with Stage II sarcoidosis with pulmonary involvement, and to examine multidimensional effects, particularly on pulmonary function, exercise capacity, fatigue, and quality of life. Furthermore, given the nature of the disease in this group, which is known to involve multiple systems, holistic approaches are crucial; in this regard, our study aims to contribute to the development of future rehabilitation protocols.

Material and Methods

Study design and setting

This study was conducted at a single tertiary care center and was designed as a randomized, open-label, controlled trial comparing two different exercise approaches in patients with sarcoidosis.

This randomized controlled trial was conducted between June 2024 and July 2025. Participants were recruited from June 2024 to May 2025, followed by an 8-week intervention period. The final post-intervention assessment was completed in July 2025.

Registration and ethics

The study is registered at ClinicalTrials.gov as NCT06848608. Ethical approval was received from the Clinical Research Ethics Committee (November 22, 2023; no: 148); all participants provided written informed consent.

Participants/eligibility criteria

The participants were individuals diagnosed with Sarcoidosis by a pulmonologist and followed at a sarcoidosis outpatient clinic. The study was initially planned to include individuals with radiologically diagnosed stages II, III, and IV sarcoidosis. However, only patients with stage II sarcoidosis met the inclusion criteria and completed the intervention process. Therefore, statistical analyses and outcome evaluations were conducted only on patients with Stage II sarcoidosis.

Inclusion criteria

Diagnosis of sarcoidosis classified as Stage II, III, or IV according to the Scadding criteria confirmed by a pulmonologist, presence of pulmonary involvement, presence of fatigue symptoms, no use of systemic corticosteroids or other immunosuppressive medication within the past 12 months, and no use of antidepressant medication within the past 6 months.

Exclusion criteria

Refusal to participate in the study; cognitive impairment interfering with communication or the ability to follow instructions; anemia; diabetes mellitus; pregnancy; major cardiovascular disease; recent fractures; diagnosed osteoporosis; neurological or orthopedic conditions that could interfere with participation in or the outcomes of the intervention.

The sample size was calculated using G* Power 3.1 with an effect size of 0.25, a margin of error of 0.05, and a 95% confidence level. A total of 32 participants were targeted, with a minimum of 16 per group (17,18). Between June 2024 and May 2025, a total of 426 patients attended the relevant clinic. Of these, 166 declined to participate. The remaining 260 patients were screened for eligibility by the physician; 80 did not meet the inclusion criteria, and 124 met the exclusion criteria. Consequently, 56 eligible participants were referred to the physiotherapist conducting the study and randomized. To account for potential dropouts, 56 patients with sarcoidosis were ultimately enrolled. A total of 56 eligible participants were randomized (1:1) to the yoga or conventional physiotherapy group using a computer-generated randomization sequence (random.org, Random Integer Generator).

During the 8-week intervention period, 22 participants withdrew for various reasons, as detailed in the CONSORT flow diagram (Figure 1). Data from the remaining 34 participants who completed the final assessments were analyzed. The interventions were well tolerated, and no intervention-related adverse events were observed. The reasons for withdrawal were mainly motivational, logistical, or due to unrelated medical conditions; therefore, these withdrawals were not classified as adverse events. Because these

participants did not complete the post-intervention assessments, no end-of-study data were available for them.

Measurements

Initial assessments for all participants were conducted face-to-face at the sarcoidosis outpatient clinic. After the baseline evaluation, each participant received individualized, one-on-one instruction on the exercise program specific to their allocated group. At the end of the 8-week intervention period, final assessments were conducted face-to-face with all participants, in accordance with the study protocol. Demographic and clinical characteristics, including age, sex, height, weight, body mass index (BMI), medical history, and current medications, were recorded for all participants.

Outcome measures

The primary outcome of the study was functional exercise capacity assessed by the six-minute walk distance (6MWD).

Secondary outcomes included respiratory muscle strength (MIP), pulmonary function parameters (FEV₁, FVC, FEV₁/FVC, DLCO), body oxygen level test (BOLT), dyspnea severity (mMRC), fatigue (FAS), psychological status (HAD), sleep quality (PUKI), and health-related quality of life (SGRQ).

- Fatigue Assessment Scale (FAS)

FAS, a single-dimensional, ten-question questionnaire measuring physical and psychological fatigue, aims to assess fatigue status (19). Saydam and Selçuk conducted the scale's validity and reliability in Turkish in 2019 (20).

- Pulmonary Function Testing

Pulmonary function testing was performed using a spirometer (Spiro USB, CareFusion USA) according to ATS/ERS criteria (21).

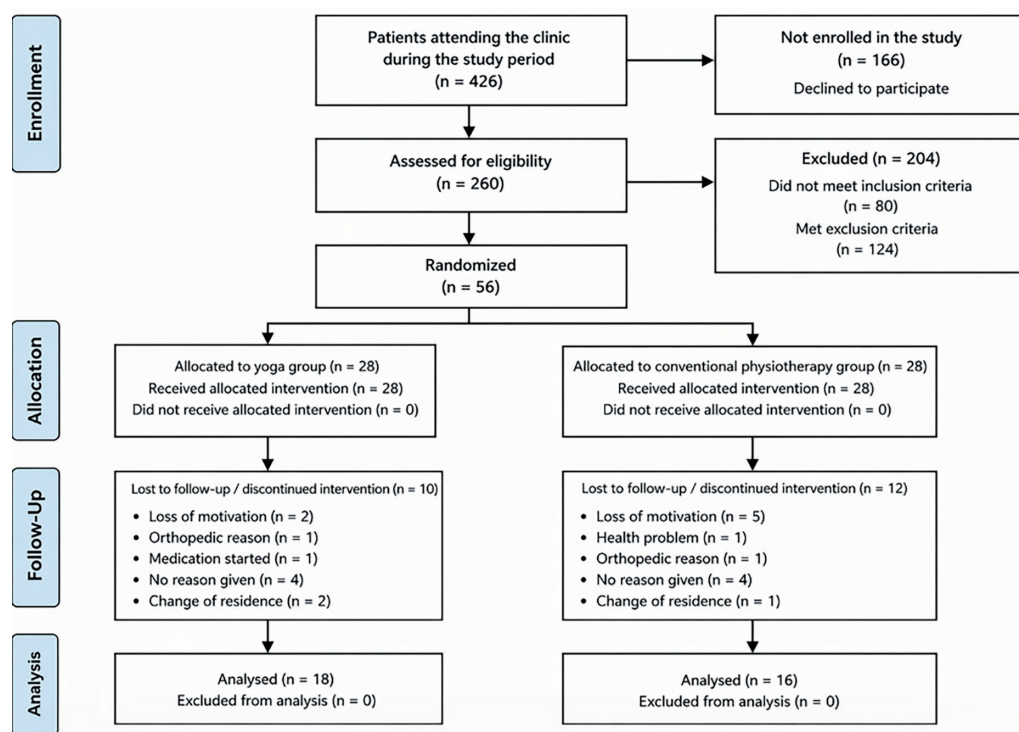


Figure 1. CONSORT flow diagram of participant screening, randomization, follow-up, and analysis.

- Diffusing Capacity of the Lungs for Carbon Monoxide (DLCO)

This test, which measures gas exchange in the lungs, evaluates alveolar surface area, membrane integrity, and pulmonary capillary blood flow. DLCO values were expressed as a percentage of the expected value for sex, height, and age (22).

- Exercise Capacity

Exercise capacity was determined using a 6-minute walk test (6MWT) performed according to the ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories (ATS) criteria (23). Exercise testing is frequently used in patients with sarcoidosis to monitor the clinical course of the disease, guide medical treatment, and evaluate treatment effectiveness (24-26).

- Modified Medical Research Council Dyspnea Scale (mMRC)

Patients were asked to select the mMRC grade (0-4) that best described their breathlessness (27).

- Quality of Life Assessment / St. George's Respiratory Questionnaire (SGRQ)

Health-related quality of life in patients with chronic respiratory diseases was assessed using the SGRQ (28).

- Hospital Anxiety and Depression Scale (HADS)

HADS was used to assess anxiety and depression levels in the patients. Zigmond and Snaith developed the scale, and its validity and reliability in Turkish were established by Aydemir et al. It includes anxiety and depression subscales (29,30).

- Pittsburgh Sleep Quality Index (PSQI)

The PSQI is an index developed by Buysse et al. in 1989 to assess sleep quality over one-month in clinical studies (31). The validity and reliability studies of the scale in our country were conducted by Ağargün et al. in 1996 (32).

- Body Oxygen Level Test (BOLT)

BOLT was used to assess the participants' pulmonary capacity. BOLT is a breath-holding test performed after a normal exhalation that

measures the time until the first urge to breathe, reflecting breathing control mechanisms and tolerance to carbon dioxide accumulation. Breath-holding tests such as BOLT are considered practical tools for evaluating the reflex regulation of the cardiorespiratory system (33). Furthermore, the literature reports significant correlations between exercise tolerance and cardiopulmonary function across various respiratory diseases, and these findings have been clinically useful and reliable (34-36).

- MIP (Maximum Inspiratory Pressure)

Respiratory muscle strength was measured using the Respiratory Pressure Meter (RP Check) (MD Diagnostics Ltd. RP Check MIP & MEP) intraoral pressure measurement device according to ATS/ERS criteria (37). Each test was repeated at least three times, and care was taken to ensure that the difference between the two best-measured values was no more than 5%. The highest value was taken, and the interpretation of the MIP data was based on the measurement methodology described by Black and Hyatt (38). Expected % MIP values were calculated using regression models from the literature based on age and gender (39).

Missing data were minimal in the final analysis set. One participant had missing spirometry and DLCO data, and one participant had missing DLCO data. Rather than excluding these participants entirely, each outcome was analyzed using only the available data. No imputation was performed.

Intervention program

Following an initial assessment in the hospital, all patients received information and education on accessing online sessions, which would continue for 8 weeks. Both groups received aerobic training consisting of free walking three days per week, performed at an individually determined walking speed based on the six-minute walk test results. Yoga and conventional physiotherapy protocols were implemented separately for each group, as outlined in Supplementary 1, which

details session structures, exercise progressions, and breathing techniques.

Conventional physiotherapy group program

Exercise practices were taught individually to each patient by a physiotherapist in the hospital. Exercises were performed two days a week for eight weeks as part of a group-based, supervised, and standardized telerehabilitation program. The remaining three days of the week were recorded in an exercise diary, each lasting approximately 45 minutes.

The program included:

- Warm-up exercises
- Resistance training for the lower and upper extremities
- Pursed-lip breathing exercises
- Diaphragmatic breathing exercises
- Thoracic expansion exercises (File S1).

Yoga group program

In this group, pranayama techniques and asanas were taught to patients one-on-one in the hospital by a certified yoga instructor and expert physiotherapist. The group-based, supervised, and standardized telerehabilitation program was conducted two days a week for eight weeks, with the remaining three days self-paced at home. Patients kept an exercise diary to monitor their progress. The program lasted approximately 45 minutes.

The program includes:

Pranayamic techniques: Nadi Shodhana Pranayama, Ujjai Pranayama, Bhramari Pranayama, Sukha Pranayama, Kapalabhati (See Suppl. File 1).

Asanas: The yoga flow was created by a certified yoga instructor and certified physical therapist. This flow was taught to patients individually, with written and visual instructions to help them maintain the exercises. It was stated that patients should breathe through their noses whenever possible, focus their attention on their breath, and perform all stretching movements on exhalation. The asanas used in the yoga flow are: Sukhasana, Bhadarajasana, Marjaryasana- Bitilasana, Bhujangasana,

Kapotasana, Hasta uttanasana, Virabhadrasana I, Setu Bandha Sarvangasana, Navasana (See Suppl. File 1)

Meditation: standardized 10-minute meditation technique (File S1).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed with the Kolmogorov-Smirnov test. A p-value < 0.05 was considered statistically significant. Parametric tests (paired samples t-test, independent samples t-test, and two-way mixed model ANOVA) were applied to normally distributed variables, with Bonferroni correction for multiple within-group comparisons. Non-normally distributed ordinal variables were analyzed using the Wilcoxon signed-rank test and Mann-Whitney U test, while categorical variables were evaluated using the chi-square test.

Results

A total of 34 individuals with sarcoidosis were included in the study (yoga group, n=18; conventional physiotherapy group, n=16). No statistically significant difference was found between the groups in terms of age (47.67 ± 9.63 years and 49.12 ± 13.84 years, respectively) and mean BMI (28.22 ± 5.45 kg/m² and 31.12 ± 5.88 kg/m², respectively) ($p > 0.05$). When sociodemographic variables such as gender, education level, occupational distribution, and smoking history (packs/year, duration of smoking, duration of quitting) were examined, the groups were homogeneous across all variables (all $p > 0.05$).

Consequently, the study groups were similar (homogenous) at baseline in terms of basic demographic characteristics, anthropometric measurements, and smoking history.

No statistically significant improvement in spirometric parameters or DLCO values was observed after the intervention ($p > 0.05$, Table 1).

Pre-intervention values for BOLT measurements were not statistically significant in independent intergroup comparisons ($p=0.247$). A significant

Table 1. Within- and between-group comparisons of respiratory and physical performance parameters before and after intervention.

	Conventional Physiotherapy (Mean ± SD)	Yoga (Mean ± SD)	Between-Group Comparison		Group-Time Interaction		
Variable			t ^a	p ^a	F	p	η ²
FVC Pre	3.14 ± 1.25	3.02 ± 0.79	0.120	0.732	0.099	0.755	0.003
FVC Post	3.06 ± 1.26	2.97 ± 0.76	0.071	0.792			
Within-group comparison (tb)	t =1.340 p =0.256	t =0.642 p=0.429					
FEV1 Pre	2.41 ± 0.89	2.35 ± 0.55	0.062	0.805	0.049	0.827	0.002
FEV1 Post	2.3 ± 0.97	2.26 ± 0.51	0.035	0.853			
Within-group comparison (tb)	t =4.930 p=0.034*	t=4.430 p=0.044*					
FEV1/FVC Pre	77.09 ± 7.61	78.35 ± 7.24	0.234	0.632	0.409	0.527	0.013
FEV1/FVC Post	75.69 ± 8.43	78.4 ± 12.38	0.519	0.477			
Within-group comparison (tb)	t =0.698 p=0.410	t =0.001 p=0.973					
PEF Pre	5.14 ± 2.02	5.03 ± 1.65	0.028	0.868	4.018	0.054	0.115
PEF Post	4.2 ± 2.21	5.06 ± 1.67	1.604	0.215			
Within-group comparison (tb)	t =6.964 p=0.013*	t =0.007 p=0.935					
DLCOcSB Pre	6.66 ± 2.48	6.17 ± 1.1	0.564	0.458	0.322	0.574	0.011
DLCOcSB Post	6.66 ± 2.2	6.33 ± 1.57	0.253	0.619			
Within-group comparison (tb)	t =0.001 p=0.989	t =0.764 p=0.389					
DLCOcSB % Pred Pre	72 ± 13.15	74.33 ± 11.75	0.28	0.601	0.037	0.849	0.001
DLCOcSB %Pred Post	74.43 ± 11.71	76.22 ± 16.39	0.12	0.732			
Within-group comparison (tb)	t =1.327 p=0.258	t =1.032 p=0.318					
BOLT Pre	14.38 ± 4.44	16.17 ± 4.41	1.389	0.247	7.979	0.008*	0.200
BOLT Post	20.5 ± 5.18	18.33 ± 3.9	1.928	0.175			
Within-group comparison (tb)	t=36088 p=0.001*	t =5.08 p=0.031*					
6MWD (m) Pre	463.84 ± 80.44	475.56 ± 42.56	0.291	0.593	0.191	0.665	0.006
6MWD(m) Post	498.56 ± 74.99	504.78 ± 41.77	0.092	0.764			
Within-group comparison (tb)	t=14.363 p=0.001*	t=11.447 p=0.002*					

Abbreviation: SD: Standard Deviation, Pre: before intervention (baseline), Post: after intervention, DLCOcSB: single-breath diffusing capacity for carbon monoxide, corrected for hemoglobin (used as DLCO in the text), % pred: % of predicted value, FVC: Forced Vital Capacity, FEV1: Forced Expiratory Volume in one second, PEF: Peak Expiratory Flow, 6MWD: 6-Minute Walk Test, m: meter, F: two-way mixed ANOVA, t, t² : paired samples t-test, t² : independent samples t-test, η²: eta squared effect size, *p < 0.05 indicates statistical significance

difference was found in both groups compared with pre-intervention ($p=0.001$ for conventional physiotherapy; $p=0.031$ for the yoga group). According to the two-way mixed-model ANOVA, the time $\times$ group interaction was significant in favor of the conventional physiotherapy group. The calculated effect size for these results was $\eta^2 = 0.200$, indicating a medium-to-large effect (Table 1).

Pre-treatment mean 6MWT distance was 463.84 ± 80.44 meters in the conventional physiotherapy group and 475.56 ± 42.56 meters in the yoga group; there was no significant difference between the groups ($t = 0.291$, $p = 0.593$). Post-treatment distances increased to 498.56 ± 74.99 meters and 504.78 ± 41.77 meters, respectively. In the within-group analyses, a significant increase was found after treatment in both groups (conventional: $t = 14.363$, $p = 0.001$; yoga: $t = 11.447$, $p = 0.002$). However, the group $\times$ time interaction was not significant ($F = 0.665$, $p = 0.191$, Table 1).

No significant difference was observed between the groups in pulse, SpO_2 , and blood pressure responses measured before and after the 6MWT; clinically minor changes were observed (all $p>0.05$, Table 1).

Baseline MIP (cmH_2O) values were 64.44 ± 16.92 in the conventional physiotherapy group and 67.50 ± 18.73 in the yoga group, and no significant

difference was found between the groups ($t=0.248$, $p=0.622$). When the pre and post-intervention values were compared between groups, a significant increase in MIP measurements was observed (conventional: $p=0.001$, yoga: $p=0.002$). According to the results of two-way mixed model ANOVA, the change over time between the groups was significant ($F=6.801$, $p=0.014$), with the difference favoring the conventional physiotherapy group. The calculated effect size ($\eta^2 = 0.175$) represents a medium effect (Figure 2).

Pre-intervention mean MIP (%) values were found to be 70.56 ± 15.76 in the conventional physiotherapy group and 78.67 ± 20.61 in the yoga group. When the baseline values were compared between the groups, no significant difference was found ($t=1.630$, $p=0.211$). In intra-group comparisons, a significant increase was observed in both the conventional physiotherapy ($p=0.001$) and the yoga group ($p=0.001$) compared to the pre-intervention level. The results of the two-way mixed-model ANOVA showed that the levels of change over time differed significantly between the two groups ($F = 5.695$, $p = 0.023$), with the difference favoring the conventional physiotherapy group. According to this result, the calculated effect size ($\eta^2=0.151$) indicates a moderate clinical effect (Figure 3).

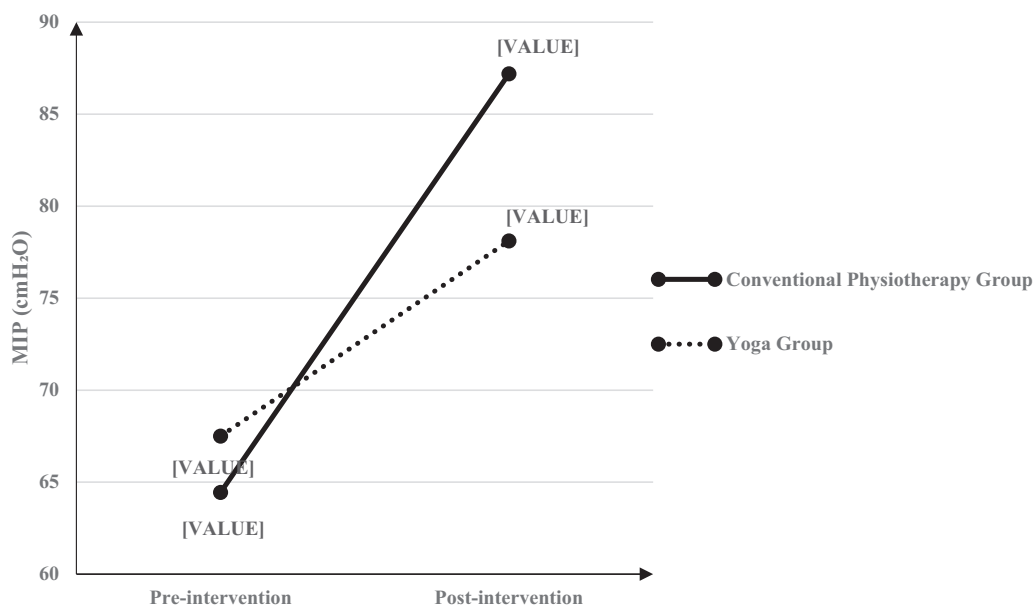


Figure 2. Change in MIP (cmH_2O) before and after the intervention.

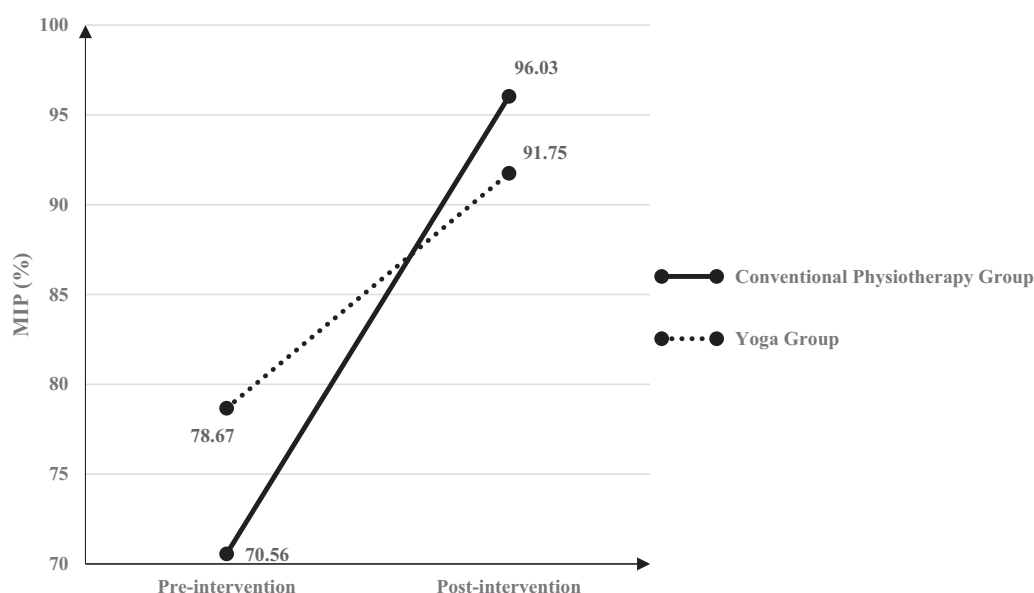


Figure 3. Change in MIP (%) before and after the intervention.

After the intervention, significant decreases in physical, mental, and total FAS scores were observed in both groups. However, the two-way mixed ANOVA revealed no time-by-group interaction on any subscales ($p > 0.05$, Table 2).

According to SGRQ scores, significant decreases were observed in both groups across the symptom, feeling, activity, and total subscales. However, in the two-way mixed ANOVA, no significant differences were found among the groups on any subscale ($p > 0.05$, Table 2).

According to the HADS, significant decreases were found in the anxiety subscale only in the yoga group and in the depression subscale only in the conventional physiotherapy group. However, according to the two-way mixed model ANOVA, no time $\times$ group interaction was found in either the anxiety or depression subscales ($p > 0.05$, Table 2).

A significant decrease in PSQI scale scores was observed in both groups. However, the two-way mixed ANOVA results showed no significant differences among groups on any subscale ($p > 0.05$, Table 2).

MMRC dyspnea scores decreased in both groups after the intervention. Median values decreased from 2 to 1 in the conventional physiotherapy and yoga

groups, and the difference between the groups was not statistically significant ($p > 0.05$).

To assess potential attrition bias, baseline characteristics of completers and non-completers were compared. Most variables were similar between groups, although DLCO % predicted was significantly higher in non-completers (see Suppl. File 1, Supplementary Table S1).

Discussion

Our study aimed to compare the effectiveness of yoga and conventional physiotherapy programs delivered via telerehabilitation, in addition to standard aerobic training, over 8 weeks in 34 sarcoidosis patients with pulmonary involvement.

A review of the literature reveals no clinical studies using yoga in sarcoidosis, and existing research is mainly limited to mindfulness-based approaches (40,41). Therefore, our study is the first single-center, randomized controlled trial comparing yoga and conventional physiotherapy interventions delivered via telerehabilitation in sarcoidosis patients.

The fact that 79.4% ($n=27$) of the cases were female is consistent with the “female predominance” reported in many epidemiological studies (42,43). The

Table 2. Comparison of pre- and post-intervention anxiety, depression, sleep quality, quality of life, and fatigue levels within and between groups.

Variable	Conventional Physiotherapy		Yoga	Between-Group Comparison		Group-Time Interaction		
	Mean $\pm$ SD			t ^a	p ^a	F	p	η^2
FAS (physical) Pre	15.88 $\pm$ 4.27		13.78 $\pm$ 4.01	2.18	0.150	1.042	0.315	0.032
FAS (physical) Post	11.69 $\pm$ 3.2		10.72 $\pm$ 3.18	0.777	0.385			
Within-group comparison (t ^b)	t = 26.930	p = 0.001*	t = 16.131	p = 0.001*				
FAS (mental) Pre	13.69 $\pm$ 5.12		10.44 $\pm$ 4.22	4.097	0.051	1.776	0.192	0.053
FAS (mental) Post	10.13 $\pm$ 3.22		8.61 $\pm$ 3.96	1.472	0.234			
Within-group comparison (t ^b)	t = 14.236	p = 0.001*	t = 4.242	p = 0.048*				
FAS (total score) Pre	29.56 $\pm$ 8.93		24.22 $\pm$ 7.3	3.679	0.064	1.86	0.182	0.055
FAS (total score) Post	21.81 $\pm$ 6.3		19.33 $\pm$ 5.85	1.416	0.243			
Within-group comparison (t ^b)	t = 25.782	p = 0.001*	t = 11.542	p = 0.002*				
SGRQ (symptoms) Pre	42.4 $\pm$ 18.51		25.94 $\pm$ 12.37	9.481	0.004*	3.641	0.065	0.102
SGRQ (symptoms) Post	27.17 $\pm$ 14.01		18.96 $\pm$ 11.26	3.581	0.068			
Within-group comparison (t ^b)	t = 23.436	p = 0.001*	t = 5.538	p = 0.025*				
SGRQ (impact) Pre	40.25 $\pm$ 21.05		32.12 $\pm$ 17.56	1.505	0.229	0.436	0.514	0.013
SGRQ (impact) Post	25.48 $\pm$ 12.4		20.42 $\pm$ 12.57	1.387	0.248			
Within-group comparison (t ^b)	t = 19.07	p = 0.001*	t = 13.462	p = 0.001*				
SGRQ (activity) Pre	45.67 $\pm$ 15.91		31.79 $\pm$ 18.96	5.270	0.028*	0.005	0.942	0.001
SGRQ (activity) Post	34.33 $\pm$ 16		20.84 $\pm$ 16.28	5.903	0.021*			
Within-group comparison (t ^b)	t = 8.400	p = 0.007*	t = 8.803	p = 0.006*				
SGRQ (total) Pre	42.64 $\pm$ 17.51		33.53 $\pm$ 14.07	2.827	0.102	0.130	0.721	0.004
SGRQ (total) Post	29.66 $\pm$ 14		22.06 $\pm$ 11.22	3.082	0.089			
Within-group comparison (t ^b)	t = 18.062	p = 0.001*	t = 15.854	p = 0.001*				
HADS (anxiety) Pre	9.63 $\pm$ 4.92		8.28 $\pm$ 4.25	0.733	0.398	0.845	0.365	0.026
HADS (anxiety) Post	8.06 $\pm$ 5.48		5.56 $\pm$ 3.71	2.486	0.125			
Within-group comparison (t ^b)	t = 2.897	p = 0.098	t = 9.891	p = 0.004*				
HADS (depression) Pre	7.69 $\pm$ 3.32		6.17 $\pm$ 3.31	1.781	0.191	2.161	0.151	0.063
HADS (depression) Post	5.31 $\pm$ 3.93		5.22 $\pm$ 3.37	0.005	0.943			
Within-group comparison (t ^b)	t = 11.251	p = 0.002*	t = 2.002	p = 0.167				
PSQI Pre	6.44 $\pm$ 2.53		6.33 $\pm$ 3.27	0.011	0.919	0.183	0.671	0.006
PSQI Post	3.75 $\pm$ 2.49		4 $\pm$ 2.2	0.097	0.758			
Within-group comparison (t ^b)	t = 19.942	p = 0.001*	t = 16.911	p = 0.001*				

SD: standard deviation, Pre: before intervention (baseline), Post: after intervention, FAS: Fatigue Assessment Scale, SGRQ: St. George's Respiratory Questionnaire, HADS: Hospital Anxiety and Depression Scale, PSQI: Pittsburgh Sleep Quality Index, F: two-way mixed ANOVA, t^a: paired samples t-test, t^b: independent samples t-test, η^2 : eta squared effect size, *p < 0.05 indicates statistical significance.

gender distribution between the groups was similar ($p=0.147$). Although BMI appeared lower in the yoga group than in the conventional physiotherapy group, the difference was not statistically significant ($p=0.145$). It is known that BMI can affect functional capacity and clinical course in patients with sarcoidosis; therefore, similar pre-intervention distributions are essential for comparability of results. The fact that BMI values were above the “overweight” range in both groups is consistent with studies indicating a higher prevalence of obesity and overweight in sarcoidosis patients compared to the normal population (44,45).

In a randomized controlled trial conducted among patients with sarcoidosis, a 12-week structured exercise program resulted in significant improvements in dyspnea, fatigue, 6MWD, inspiratory muscle strength, oxygenation, and SGRQ total/sub-scores (8). Furthermore, telerehabilitation approaches have reported promising long-term effects on physical activity and functionality in advanced sarcoidosis (46). A review of the existing literature reveals that studies on non-pharmacological treatments for sarcoidosis are limited. While relatively few studies have focused on COPD, several studies in patients with bronchiectasis, pulmonary arterial hypertension, and asthma have shown that yoga reduces dyspnea and fatigue and increases pulmonary function and exercise capacity (8,47–50). Crucially, no study has evaluated the effectiveness of yoga-based rehabilitation in sarcoidosis.

Fatigue is one of the most common and disabling symptoms in sarcoidosis patients, with a reported prevalence between 50% and 80% (51). ERS treatment guidelines recommend PR in patients with significant fatigue (6). In this study, the decrease in FAS scores in both groups exceeded the threshold for clinically significant change (MCID ≈ 4 points) (52).

While both the conventional physiotherapy (–7.75 points) and the yoga group (–4.89 points) were found to reduce fatigue to a clinically significant level, no significant difference was observed between the groups. A decrease in FAS was reported after 4 weeks of multidisciplinary PR (53). Furthermore, a 2025 study comparing single- and double-leg cycling training in pulmonary sarcoidosis reported that both protocols significantly

reduced fatigue (54). In this respect, our findings are consistent with the literature on exercise and PR.

In our study, although small changes were observed in some spirometric parameters, no significant improvement was observed. Similarly, no significant improvement in DLCO values was observed. This result is consistent with the literature, indicating that short- to medium-term rehabilitation programs do not significantly improve classical spirometry parameters, and that changes are often explained by measurement variability and effort dependence (55,56). These findings suggest that the functional and symptomatic benefits of PR in sarcoidosis may occur independently of structural lung parameters.

Prolongation of BOLT duration indicates pulmonary control and suggests improved carbon dioxide tolerance (57). In our study, both groups showed an increase in BOLT scores. This increase was significantly more pronounced in the conventional physiotherapy group. This result suggests that conventional physiotherapy may be more effective in improving respiratory control. The current literature contains no studies using BOLT as an assessment parameter in sarcoidosis patients. However, studies in COPD (58) and asthma (59) patients use breath-hold duration as an indicator of respiratory control. For example, the Buteyko breathing technique has been reported to increase breath-hold duration, although it does not change spirometric values (59). The significant increase in BOLT durations, despite no change in spirometry values in our study, is consistent with this literature.

Although a sarcoidosis-specific MCID for the 6MWT has not yet been defined, the increase of 34.7 m in the conventional group in our study exceeded the 30 m threshold, thereby achieving clinical significance relative to the ATS/ERS reference values. Although the increase in the yoga group was below the threshold at 29.2 m, it is still considered clinically relevant because it is close to the threshold. Lingner et al. (60), in a study of 296 patients with sarcoidosis, demonstrated that a 3-week exercise program improved the 6MWT by almost 40 m, in addition to enhancing quality of life, dyspnea, fatigue, anxiety, and depression. These results were also reported by Guber et al. (61), who conducted a 12-week study in 52 individuals with sarcoidosis, and are consistent with our research.

Although the MCID for sarcoidosis has not been defined for the SGRQ total score, the accepted threshold for COPD is 4. In our study, the decrease in the SGRQ total score was approximately 11–13 points in both groups, suggesting that the improvement in SGRQ is clinically significant.

Both groups showed significant improvements in psychological parameters (anxiety in the yoga group and depression in the conventional physiotherapy group). The lack of a significant difference between the groups suggests that the two interventions provided similar psychological benefits.

The literature supports that yoga practice incorporating pranayama provides significant improvements in anxiety and stress scores (62, 63). The improvement in depression scores favoring conventional physiotherapy and anxiety scores favoring the yoga group may be related to the different mechanisms of action of the interventions. Methods that rapidly affect vagal modulation and autonomic regulation, such as pranayama exercises and yoga, may be more effective on anxiety associated with high arousal and shallow breathing patterns, while a conventional physiotherapy program focused on aerobic and resistance exercise may have a stronger effect on depression associated with low arousal and decreased energy through behavioral activation and increased neurochemical release (64,65).

These findings suggest that yoga modules can be safely integrated into the PR, especially for patients with anxiety problems; however, further studies are needed to clarify the effects.

The current literature has not identified any published studies directly investigating the effects of conventional physiotherapy or yoga on sleep quality in sarcoidosis patients. However, large-scale studies in sarcoidosis have reported a high rate of poor sleep (66,67). In our study, significant improvements in PSQI scores were observed in both the conventional physiotherapy and yoga groups. This improvement in both groups indicates the effects of the 8-week yoga and conventional physiotherapy programs implemented through telerehabilitation on general physiological and psychological well-being. There was no significant difference between the groups ($p>0.05$). This suggests that both programs provide similar levels of improvement. The improvement in PSQI scores, which was

accompanied by the simultaneous decrease in anxiety and depression scores observed in our study, indicates that sleep quality is related to psychological well-being. Similarly, the literature has shown that lower anxiety and depression scores improve sleep quality, while poor sleep quality negatively impacts depression and anxiety scores (68,69). These results suggest that yoga and conventional physiotherapy practices support individuals not only physiologically but also psychologically, contributing indirectly to sleep quality.

A detailed examination of the mean MIP (cmH_2O) in our study reveals an increase of approximately 20 cmH_2O . A review of the literature found no value associated with a minimal clinically significant change in MIP in sarcoidosis. However, a 2023 study reported an MCID of approximately 13.5 $\text{cm H}_2\text{O}$ for MIP in COPD (70). Another COPD study reported the value as approximately 17.2 $\text{cm H}_2\text{O}$ (71). Therefore, based on our MIP ($\text{cm H}_2\text{O}$) results, it can be argued that an increase of this magnitude (approximately 20 $\text{cm H}_2\text{O}$) may positively influence 6MWT performance and perceived dyspnea by enhancing respiratory muscle capacity. Similarly, % MIP increased in both groups, indicating not only greater inspiratory muscle strength but also values exceeding age- and sex-predicted norms.

In conclusion, both interventions implemented in our study demonstrated clinically significant improvements in inspiratory muscle strength, as measured in absolute (cmH_2O) and predicted (%) terms. These findings support the notion that breathing-based interventions that do not include device-based inspiratory muscle training (IMT) can also improve respiratory muscle strength. Future, longer-term studies comparing the effects of different breathing exercises (e.g., IMT, pranayama, diaphragmatic breathing) would be beneficial for clarifying the clinical significance of this difference.

Dyspnea is a common symptom in daily life among patients with sarcoidosis, and studies have reported that inspiratory muscle weakness is the primary cause of dyspnea in this condition (25, 26). Naz et al. (2018) reported that a structured exercise program without IMT improved dyspnea perception, functional capacity, and quality of life in patients with sarcoidosis (8). In our study, inspiratory muscle strength improved

significantly in both groups. Therefore, it is consistent with our findings that the decrease in mMRC scores observed in our study coincided with the increase in inspiratory muscle strength.

Our study had some limitations. Although the initial protocol targeted patients with Stage II–IV sarcoidosis, all included participants were Stage II. This limits generalizability to more advanced stages; however, spontaneous remission rates decrease with radiographic stage (reported as 55–90% in Stage I, 40–70% in Stage II, and 10–20% in Stage III) and usually occur within the first 1–2 years after diagnosis (3,72,73). In our study, 32 of the 34 patients (94.1%) had been followed for more than 1 year, and 28 (82.4%) for more than 2 years, with a diagnosis of sarcoidosis, making it highly unlikely that the findings could be attributed to spontaneous remission. The fact that the sample consisted solely of Stage II cases limits the generalizability of the findings to Stages III and IV. However, the homogeneous stage distribution in our study increased internal validity. Future studies that conduct subgroup analyses by stage, including Stages III–IV, are recommended. In addition, the exclusion of patients using systemic corticosteroids or other immunosuppressive medication within the past 12 months reduced treatment-related heterogeneity and potential pharmacological confounding; however, it may limit the generalizability of the findings to sarcoidosis patients receiving active pharmacological treatment.

Although sarcoidosis has a high female prevalence, the significantly lower number of male participants in our study limits the generalizability of the findings to men. A more balanced gender distribution is recommended in future studies.

When comparing the two interventions, conventional physiotherapy demonstrated greater improvements in inspiratory muscle strength and BOLT scores, whereas yoga-based rehabilitation showed comparable benefits in psychosocial and quality-of-life outcomes. These findings suggest that the two approaches may provide complementary therapeutic effects rather than a clear superiority of one intervention over the other.

Conclusion

According to this study's results, both 8-week telerehabilitation-based yoga and conventional physiotherapy programs were effective approaches for patients with Stage II sarcoidosis with pulmonary involvement. Fatigue, BOLT scores, exercise capacity, quality of life, anxiety-depression scores, sleep quality, MIP scores, and dyspnea perception significantly improved in both groups. Additionally, benefits were observed in the conventional physiotherapy group for depression, MIP, and BOLT scores, and in the yoga group for anxiety scores. However, no significant improvements were observed in spirometric measurements or diffusion capacity parameters in either group.

In patients with multisystem involvement, such as in sarcoidosis, holistic approaches are increasingly important given the disease's nature. The similar effects of yoga and traditional physiotherapy treatments administered via telerehabilitation for both groups may make yoga, a holistic approach, an effective alternative for sarcoidosis patients. Our study may contribute to the development of future sarcoidosis protocols in this direction.

Ethic Approval: SBU Süreyyapaşa Chest Diseases and Thoracic Surgery Hospital Clinical Research Ethics Committee; Protocol No. 148; 2023.

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Authors' Contribution: Ş.Y. conceived and designed the study, collected and analyzed the data, performed the interventions, interpretation of the findings, and drafted the manuscript. M.K. and S.A.E. referred eligible patients and contributed to clinical evaluation. Z.D.T. supervised the study as the research advisor, provided scientific guidance throughout the study, contributed to the study design, and interpretation of the findings, and critically revised the manuscript.

Declaration on the Use of AI: The authors declare that no artificial intelligence (AI)-assisted technologies were used in the

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Appendix

Supplementary file

A supplementary file with detailed descriptions of the intervention protocol is available online.

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