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Impact of nutritional status in sarcoidosis patients

Şeyma tunç[1], Pınar yıldız[2], Mehmet ali sungur[3]
[1]Department of Pulmonology, Kastamonu Training and Research Hospital, Kastamonu, Turkey; [2]Department of Pulmonology, University of Duzce, Duzce, Turkey; [3]Department of Biostatistics, University of Duzce, Duzce, Turkey

Abstract. *Background and aim:* Sarcoidosis is a systemic granulomatous disease of unknown etiology, and fatigue is among its most common complaints. The underlying cause of fatigue remains under investigation. Factors such as reduced pulmonary function, impaired respiratory muscle strength, physical deconditioning, and corticosteroid-induced myopathy may contribute to fatigue. The importance of evaluating nutritional status in patients with respiratory system diseases is increasingly recognized. This study aimed to investigate the impact of nutritional assessment on peripheral muscle strength, respiratory muscle strength, and exercise capacity in patients with sarcoidosis. *Methods:* This prospective case-control study included 31 sarcoidosis patients not receiving systemic steroid therapy and 24 age- and sex-matched healthy controls. Participants underwent assessments of functional exercise capacity using the 6-minute walk test (6MWT), respiratory muscle strength via maximal inspiratory (MIP) and expiratory pressures (MEP), peripheral muscle strength via handgrip dynamometry, and pulmonary function testing. Nutritional status was evaluated using the Mini Nutritional Assessment (MNA) questionnaire and body composition analysis via bioelectrical impedance. *Results:* Despite similar pulmonary function and respiratory muscle strength, sarcoidosis patients demonstrated significantly lower 6MWT distances compared to controls. Body mass index (BMI) and fat mass were significantly higher in the sarcoidosis group. Lean mass, soft tissue mass, skeletal muscle mass, total body water, and peripheral muscle strength were similar between the two groups. No significant differences were found between groups in MIP, MEP, or their predicted percentages. Positive correlations were observed between MIP, MEP, and lean body mass, while fat mass was negatively correlated with peak expiratory flow (PEF). *Conclusions:* This study underscores the importance of individualized interventions for fatigue management in sarcoidosis, not only by addressing underlying inflammation but also by incorporating lifestyle modifications, nutritional optimization, and physical rehabilitation. In our findings, BMI and fat mass were significantly higher in sarcoidosis patients compared to controls. These results suggest that further research is warranted to explore the role of fat-related inflammation in the progression and outcomes of sarcoidosis.

Key words: sarcoidosis, nutritional status, respiratory muscle strength, fatigue

Introduction

Sarcoidosis is a systemic granulomatous disease of unknown etiology. While it most commonly affects young to middle-aged non-smoking women, a second incidence peak is known to occur in women over the age of 50. The clinical presentation of sarcoidosis can range from asymptomatic cases to severe multi-organ involvement and even death. Patients frequently present with non-specific symptoms such as generalized fatigue, arthralgia, and reduced exercise capacity (1,2). Several factors may contribute to the limited exercise tolerance observed in these patients, including reduced pulmonary function, decreased respiratory muscle strength, physical deconditioning in a negative feedback cycle, and

Received: 11 March 2025
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Correspondence: Şeyma tunç, MD
Pulmonology Department,
Via Kastamonu Training and Research Hospital
Kastamonu, 37100 Turkey
E-mail: seyma1100@gmail.com
ORCID: 0000-0001-7452-1173

corticosteroid-induced myopathy (3). Some studies have demonstrated that inspiratory and expiratory muscle strength is diminished in patients with sarcoidosis compared to healthy individuals. Kabitz et al. identified inspiratory muscle strength as a strong determinant of both dyspnea and functional exercise capacity (4). A number of studies have reported that the 6-minute walk distance (6MWD) is reduced in the majority of sarcoidosis patients (<400 m). In two studies, the limiting factor was found to be skeletal muscle weakness or reduced peripheral muscle strength (5,6), while Wirnsberger et al. concluded that decreased respiratory muscle strength and endurance time were the primary limiting factors (7). Given the increasing importance of nutritional status in the evaluation of respiratory system diseases, it is plausible to consider that it may play a role in the decline of peripheral muscle strength, respiratory muscle strength, and exercise capacity in sarcoidosis patients. To the best of our knowledge, no study to date has specifically investigated the relationship between nutritional status and respiratory muscle strength or exercise capacity in sarcoidosis. Therefore, the aim of this study is to explore the association between nutritional status—including body composition, biochemical markers, and clinical indicators—and exercise capacity, peripheral muscle strength, and respiratory muscle strength in patients with sarcoidosis.

Material and methods

This prospective case-control study was conducted at the Department of Pulmonary Medicine, Düzce University Faculty of Medicine Hospital, following approval from the Clinical Research Ethics Committee of Düzce University (Approval Date: 16.10.2023; Approval No: 2023/156). Between November 2023 and January 2024, 31 volunteer patients aged 18 to 70 years with stage 1 or 2 pulmonary sarcoidosis, diagnosed according to ATS/ERS/WASOG criteria and not receiving systemic corticosteroid therapy, were recruited from the pulmonary outpatient clinic. To ensure disease severity homogeneity, patients with extrapulmonary involvement or stage 3–4 sarcoidosis were excluded. Additionally, stage 3–4 cases were insufficient in number for meaningful statistical analysis and were mostly receiving systemic corticosteroids, which could potentially influence study outcomes. Exclusion criteria included: presence of uncontrolled cardiac conditions, heart failure, uncontrolled diabetes, malignancy, chronic liver disease, chronic renal failure, unintentional weight loss ≥10% within the past 6 months, hematological disorders affecting serum albumin or lymphocyte count, current use of myopathy-inducing medications, and pregnancy. Healthy controls were selected from individuals presenting to the outpatient clinic with mild upper respiratory tract infections and no chronic diseases. Controls were selected by case design, matching the patient group by sex and age (±3 years). All participants who voluntarily agreed to take part underwent the following assessments, and corresponding data were collected. To evaluate functional exercise capacity, the 6-Minute Walk Test (6MWT) was performed along a 30-meter unobstructed corridor. The test followed the American Thoracic Society (ATS) guidelines. Results provided insight into patients' capacity to perform daily physical activities. Dyspnea severity during activity was assessed using the Modified Medical Research Council (mMRC) dyspnea scale, graded from 0 (no dyspnea during strenuous exercise) to 4 (dyspnea during daily activities). This scale allowed for a more objective evaluation of patients' respiratory symptoms. Respiratory muscle strength was measured using maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) values with an electronic pressure transducer (MicroRPM, Micromedical, Kent, United Kingdom), following ATS/ERS guidelines. A flanged rubber mouthpiece was attached to the device. Patients were instructed to seal their lips tightly around the mouthpiece, exhale or inhale slowly and completely, and then perform a maximal inspiratory or expiratory effort. While seated, MIP was recorded after a full exhalation followed by maximal voluntary inhalation, and MEP was measured after maximal inhalation followed by forceful exhalation. MIP and MEP maneuvers were repeated three times with 30–60 second rest intervals, depending on the patient's tolerance. The highest values and their percentages of predicted values were recorded. Predicted values for MIP and MEP were calculated using the equations proposed by Black and Hyatt. Peripheral muscle strength was assessed via dominant handgrip strength using the Seahan SH5001 hand dynamometer. Measurements were taken with the participant seated, elbow flexed at 90°, close to the torso, and wrist in a neutral position. Participants were instructed to squeeze the

dynamometer with their dominant hand. Measurements were repeated three times at one-minute intervals, and the average of the three readings was recorded. Pulmonary function tests included the measurements of FEV1, FVC, FEV1/FVC ratio, PEF, DLCO, and KCO. Both the absolute values and percentages of predicted values were recorded. Tests were performed using the Jaeger Masterscreen PFT System (CareFusion) according to ATS/ERS standards, in a seated position. Each test was repeated at least three times. Care was taken to ensure that the difference between the best two FVC and FEV1 measurements did not exceed 150 mL, and that expiratory duration was not less than 6 seconds.

Nutritional assessment

To evaluate the participants' nutritional status, the Mini Nutritional Assessment (MNA) questionnaire, a widely used tool for nutritional screening, was administered. The MNA combines a set of verbal questions with anthropometric measurements to assess nutritional status. The MNA score ranges from 0 to 30 and classifies individuals as well-nourished (≥24 points), at risk of malnutrition (17–23.5 points), or malnourished (<17 points). Body composition was assessed using the TANITA Segmental Body Composition Monitor (TANITA-BC418), which operates via bioelectrical impedance analysis. This device was employed to evaluate body components such as bone mass, muscle mass, fat mass, and body water. It provided measurements for body fat percentage, total fat mass, lean body mass and its percentage, and overall muscle mass, offering valuable insights into the nutritional status of the participants. In addition to anthropometric measurements, biochemical parameters were used to further reflect the participants' nutritional status. The Prognostic Nutritional Index (PNI) an indicator of immunonutritional status, was calculated using the following formula: PNI = (10 × serum albumin [g/dL]) + (0.005 × total peripheral lymphocyte count [/mm³]).Serum albumin levels and peripheral lymphocyte counts were used as inputs in this formula to determine the nutritional and immune condition of the individuals.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics version 22. The distribution of numerical variables was assessed using the Shapiro-Wilk test, and homogeneity of variances was examined with Levene's test. For group comparisons, the Independent Samples t-test or Welch's t-test was applied, depending on the homogeneity of variances. Categorical data were analyzed using the Pearson Chi-square test or Fisher's exact test, where appropriate. To investigate the effect of body mass index (BMI) on changes in pulmonary function and respiratory muscle strength between the patient and control groups, a two-way factorial analysis of variance (ANOVA) was employed.

Descriptive statistics for numerical variables were reported as mean ± standard deviation, based on the distribution of data. Categorical variables were summarized as frequencies and percentages. A p-value < 0.05 was considered statistically significant.

Results

The demographic and clinical characteristics of the sarcoidosis patients and healthy controls are presented in Table 1. The groups were comparable in terms of demographic variables such as age and sex.

The mean Body Mass Index (BMI) of the patient group was significantly higher than that of the control group (p = 0.003). Although the respiratory function and respiratory muscle strength test results were similar between the patient and control groups,

Table 1. Comparison of demographic and clinical characteristics of the patient and control groups

	Patient (n=31)	**Control (n=24)**	**p**
Gender, n (%) - Male - Female	 8 (25,8) 23 (74,2)	 6 (25,0) 18 (75,0)	 0,946
Age (years)	48,74±9,89	44,75±7,32	0,104
BMI (kg/m^2)	32,34±5,96	27,65±4,70	**0,003**
Smoking, n (%)	10 (32,3)	12 (50,0)	0,183
Diagnosis, n (%) - Phase 1 - Phase 2	 12 (38,7) 19 (61,3)	 -	 -
MMRC, n (%) - 0 - 1 - 2 - 3	 4 (12,9) 13 (41,9) **8 (25,8)** **6 (19,4)**	 **19 (79,2)** 5 (20,8) 0 (0,0) 0 (0,0)	 **<0,001**

Abbreviations: BMI: body mass index, MMRC: Modified Medical Research Council

Table 2. Comparison of respiratory muscle strength, lung function and exercise capacity between sarcoidosis patients and healthy controls

	Patient (n=31)	Control (n=24)	P
% FEV1	98,03±15,03	98,11±11,72	0,984
% FVC	100,16±16,15	102,13±12,28	0,623
FEV1/FVC Rate (%)	81,64±3,97	81,31±3,92	0,758
% PEF	89,74±15,03	93,67±16,28	0,358
% DLCO	82,97±17,35	78,13±15,37	0,286
% KCO	97,39±16,85	90,08±19,99	0,148
MIP (cmH2O)	72,68±21,48	68,75±19,12	0,484
MEP (cmH2O)	83,87±26,40	85,54±28,08	0,822
6MWT (m)S	393,23±76,43	453,06±56,97	**0,002**

*FVC: forced vital capacity; FEV1: forced expiratory volume in 1st second; PEF: peak expiratory flow; DLCO: carbon monoxide diffusion capacity; KCO(mmol/(min*kPa*L);6MWT:6 minutes walking; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure*

the 6-minute walk distance (6MWD) was significantly shorter in the patient group compared to controls **(**p = 0.002, Table 2**)**. BMI showed a moderate correlation with the 6MWD, but there was no significant interaction effect when examining the combined effect of group (patient vs. control) and BMI on 6MWD (p = 0.627). This indicates that BMI affected 6MWD similarly in both groups. However, the group effect alone on 6MWD was statistically significant (p = 0.011), suggesting that sarcoidosis is associated with reduced exercise capacity independent of BMI.

The mean MNA score in the patient group was significantly lower than that of the control group; however, both groups had average MNA scores ≥24 (patient group: 25.26 ± 2.41; control group: 27.00 ± 1.44), indicating they were considered well-nourished. Fat mass was significantly higher in the patient group compared to controls (p = 0.040). Although the difference in body fat percentage between the groups was not statistically significant, the patient group had a higher fat percentage overall (Table 3).

Among patients with sarcoidosis, DLCO and KCO values were significantly lower in smokers than in non-smokers (p < 0.05). Interestingly, inspiratory and expiratory muscle strength values (MIP and MEP) and their age- and sex-adjusted percentages were significantly higher in smokers compared to non-smokers within the patient group (p = 0.006 and p = 0.040, respectively; see Table 4).

Table 3. Comparison of nutritional assessment and peripheral muscle strength parameters in patient and control groups

	Patient (n=31)	Control (n=24)	p
MNA	25,26±2,41	27,00±1,44	**0,002**
PNI (serum albumin (g/dL)+ [5× lymphocyte count (/mm3)	53,95±5,73	54,53±4,06	0,676
Hand dynamometer (kg)	24,46±10,67	26,20±7,01	0,492
Fat weight (kg)	29,97±10,29	24,60±8,01	**0,040**
Fat percentage (%)	35,27±8,40	33,82±9,89	0,559
Lean mass (kg)	53,54±8,56	50,27±10,00	0,197
Lean mass percentage (%)	63,84±8,92	67,43±7,37	0,118
Mineral percentage (%)	4,38±0,84	4,67±0,61	0,150
Protein percentage (%)	12,94±1,54	13,40±1,52	0,281
Soft muscle (kg)	49,90±7,90	46,80±9,43	0,190
Skeletal muscle mass (kg)	30,30±4,84	28,45±5,66	0,197
Liquid weight (kg)	39,19±6,27	36,80±7,32	0,197
Liquid percentage (%)	47,39±6,14	49,36±5,39	0,219

Abbreviations: MNA: Mini Nutritional Assessment Score; PNI: Prognostic nutritional index

A moderate positive correlation was observed between PNI and KCO in the patient group (r = 0.504; p = 0.004). Additionally, MIP was positively correlated with handgrip strength (r = 0.484; p = 0.006), lean mass (r = 0.510; p = 0.003), lean mass percentage (r = 0.491; p = 0.005), mineral percentage (r = 0.393; p = 0.029), protein percentage (r = 0.393; p = 0.029), soft tissue mass (r = 0.502; p = 0.004), skeletal muscle mass (r = 0.510; p = 0.003), body water (r = 0.412; p = 0.021), and body water percentage (r = 0.432; p = 0.015), while MIP showed a negative correlation with body fat percentage (r = -0.431; p = 0.015). MEP was positively correlated with handgrip strength (r = 0.361; p = 0.046), lean mass (r = 0.412; p = 0.021), lean mass percentage (r = 0.387; p = 0.031), soft tissue mass (r = 0.411; p = 0.022), skeletal muscle mass (r = 0.510; p = 0.003), and body water (r = 0.509; p = 0.003); however, no correlation was observed between MEP and body fat percentage. In the patient group, the 6MWD was positively correlated with handgrip strength

Table 4. Comparison of respiratory parameters according to smoking status in the patient group

	Present (n=10)	Absent (n=21)	p
% FEV1	96,30±9,88	98,86±17,10	0,665
% FVC	100,20±7,77	100,14±19,07	0,991
FEV1/FVC rate (%)	80,95±4,36	81,96±3,84	0,517
PEF (L/s)	96,70±15,19	86,43±14,11	0,075
% DLCO	73,00±14,29	87,71±16,92	**0,025**
% KCO	85,10±15,18	103,24±14,52	**0,003**
MIP (cmH2O)	87,40±15,29	65,67±20,66	**0,006**
MEP (cmH2O)	102,80±27,15	74,86±21,19	**0,004**

Abbreviations: FVC: forced vital capacity; FEV1: forced expiratory volume in 1st second; PEF: peak expiratory flow; DLCO: carbon monoxide diffusion capacity; KCO (mmol/(min*kPa*L); MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure

(r = 0.583; p = 0.001) and lean mass percentage (r = 0.548; p = 0.001) and negatively correlated with fat mass (r = -0.579; p = 0.001) and fat percentage (r = -0.523; p = 0.003). Additionally, fat mass showed a negative correlation with peak expiratory flow (PEF) in the patient group (Table 5).

While a moderate positive correlation was observed between PNI and KCO in the patient group (r = 0.504; p = 0.004), however this correlation was not significant in the healthy control group (r = 0.007; p = 0.974; see Table 6). Comparison of correlation coefficients revealed that the association between PNI and KCO was significantly stronger in the patient group than in the control group (p = 0.029). In both groups, handgrip strength was positively correlated with MIP, MEP, and 6MWD performance, and these correlations were similar between groups (p > 0.05). Moreover, in both groups, MIP and MEP values were positively correlated with lean body mass, soft tissue mass, skeletal muscle mass, and body water, with no significant difference between the groups (Tables 5 and 6).

Discussion

In this study, we aimed to investigate the relationship between nutritional status, respiratory muscle strength, and exercise capacity in patients with sarcoidosis. To the best of our knowledge, this is the first study comparing respiratory muscle strength in sarcoidosis patients and healthy controls who are not on medications associated with myopathy. Our study included a homogeneous sample of patients diagnosed with stage 1 (n=19) and stage 2 (n=12) pulmonary sarcoidosis, compared against age- and sex-matched healthy controls. Respiratory muscle strength was assessed in both groups using MIP and MEP measurements, and in the absence of standardized reference values similar to spirometry parameters, expected values were calculated based on the equations of Black and Hyatt. Our findings revealed no significant differences in MIP and MEP absolute values or percentage-predicted values between groups. Despite comparable pulmonary function test results, the patient group demonstrated significantly shorter 6-minute walk distances compared to controls. Bioelectrical impedance analysis showed that fat mass was significantly higher in the sarcoidosis group, whereas lean mass, soft tissue mass, skeletal muscle mass, total body water, and peripheral muscle strength were similar between the two groups. Most sarcoidosis patients report dyspnea during daily activities. In line with previous literature suggests that exercise capacity is reduced even in early stages of the disease and is often one of the earliest affected physiological parameters. Several studies have demonstrated significantly lower 6MWD values in sarcoidosis patients compared to healthy controls (8,9). For instance, Alhamad (6) and Baughman et al. (5) reported that 73% and 51% of their respective sarcoidosis samples had a 6MWD below 400 meters. Alhamad's study found that 26.9% of patients walked >400 m, 61.5% walked between 300–400 m, and 11.5% walked <300 m. Similarly, in our study, the 6MWD was significantly lower in sarcoidosis patients compared to controls (p = 0.002). However, the prevalence of resting dyspnea in our study was relatively low, likely due to the early-stage nature of our patient cohort. Pulmonary function parameters including FEV1, FVC, FEV1/FVC, PEF, DLCO, and KCO did not differ significantly between the groups. Only 3 patients had FVC <80% of predicted, while DLCO was <80% in 14 patients. These findings are consistent with Baughman et al.'s prospective study of 142 patients, where only 4 had FVC <80% of predicted and DLCO was not measured (5). Another study found that while FVC and DLCO were lower in sarcoidosis patients compared to healthy individuals. However, dyspnea severity was more closely associated with decreased respiratory

Table 5. Correlation of nutritional assessment parameters and respiratory parameters in the patient group

		FEV1	FVC	FEV1/FVC	PEF	DLCO	KCO	MIP	MEP	Six minutes
PNI	r	-0,091	-0,120	0,156	-0,174	0,298	**0,504**	0,079	0,087	0,285
	p	0,625	0,521	0,403	0,349	0,103	**0,004**	0,672	0,643	0,120
MNA	r	0,126	0,024	0,166	0,022	0,185	0,217	-0,168	-0,239	0,101
	p	0,498	0,897	0,373	0,908	0,319	0,241	0,365	0,195	0,588
Hand dynamometer	r	0,037	-0,074	0,174	0,267	0,107	0,093	**0,484**	**0,361**	**0,583**
	p	0,844	0,692	0,350	0,147	0,566	0,617	**0,006**	**0,046**	**0,001**
Fat weight	r	-0,303	-0,175	-0,213	**-0,356**	0,147	0,307	-0,226	-0,168	**-0,579**
	p	0,098	0,345	0,250	**0,050**	0,431	0,093	0,221	0,368	**0,001**
Fat percentage	r	-0,146	-0,010	-0,224	-0,251	0,156	0,226	**-0,431**	-0,308	**-0,523**
	p	0,433	0,957	0,227	0,173	0,403	0,221	**0,015**	0,091	**0,003**
Lean mass	r	-0,292	-0,343	0,039	-0,071	0,017	0,201	**0,510**	**0,412**	0,086
	p	0,111	0,059	0,836	0,704	0,929	0,278	**0,003**	**0,021**	0,644
Lean mass percentage	r	-0,088	-0,276	**0,388**	0,296	-0,318	-0,258	**0,491**	**0,387**	**0,548**
	p	0,636	0,132	**0,031**	0,106	0,082	0,161	**0,005**	**0,031**	**0,001**
Mineral percentage	r	-0,020	-0,148	0,262	0,186	**-0,423**	**-0,428**	**0,393**	0,246	**0,380**
	p	0,914	0,428	0,155	0,317	**0,018**	**0,016**	**0,029**	0,183	**0,035**
Protein percentage	r	0,196	0,066	0,185	0,264	-0,024	-0,102	**0,393**	0,310	**0,537**
	p	0,290	0,725	0,319	0,152	0,898	0,584	**0,029**	0,090	**0,002**
Soft muscle	r	-0,291	-0,340	0,031	-0,075	0,038	0,225	**0,502**	**0,411**	0,082
	p	0,112	0,061	0,867	0,690	0,840	0,223	**0,004**	**0,022**	0,663
Skeletal muscle mass	r	-0,292	-0,343	0,039	-0,071	0,017	0,201	**0,510**	**0,412**	0,086
	p	0,110	0,059	0,836	0,704	0,930	0,279	**0,003**	**0,021**	0,644
Liquid weight	r	-0,292	-0,343	0,038	-0,071	0,016	0,201	**0,509**	**0,412**	0,086
	p	0,111	0,059	0,837	0,704	0,931	0,279	**0,003**	**0,021**	0,645
Liquid percentage	r	0,146	0,010	0,223	0,251	-0,155	-0,225	**0,432**	0,309	**0,522**
	p	0,433	0,958	0,228	0,173	0,405	0,223	**0,015**	0,090	**0,003**

Abbreviations: MNA: Mini Nutritional Assessment Score; PNI: Prognostic nutritional index, FVC: forced vital capacity; FEV1: forced expiratory volume in 1st second; PEF: peak expiratory flow; DLCO: carbon monoxide diffusion capacity; KCO(mmol/(min*kPa*L); MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure

Table 6. Correlation between nutritional assessment parameters and respiratory parameters in the control group

		FEV1	FVC	FEV1/FVC	PEF	DLCO	KCO	MIP	MEP	Six minutes
PNI	r	-0,277	-0,304	-0,095	0,023	-0,078	0,007	-0,145	-0,146	0,232
	p	0,190	0,149	0,658	0,915	0,716	0,974	0,499	0,497	0,276
MNA	r	0,112	0,096	0,005	-0,188	0,095	0,063	0,046	0,046	-0,082
	p	0,601	0,657	0,981	0,380	0,659	0,769	0,832	0,833	0,702
Hand dynamometer	r	-0,154	-0,241	-0,236	0,346	0,320	**0,414**	**0,641**	**0,662**	0,274
	p	0,473	0,258	0,266	0,098	0,128	**0,044**	**0,001**	**0,000**	0,195
Fat weight	r	0,263	0,132	**0,418**	0,160	0,346	0,227	0,156	-0,009	**-0,475**
	p	0,214	0,540	**0,042**	0,455	0,098	0,286	0,467	0,966	**0,019**
Fat percentage	r	0,294	0,197	**0,551**	-0,126	-0,051	-0,145	-0,305	-0,351	-0,193
	p	0,164	0,356	**0,005**	0,556	0,811	0,499	0,148	0,092	0,367
Lean mass	r	-0,048	-0,182	-0,224	**0,404**	**0,416**	**0,464**	**0,649**	**0,495**	-0,169
	p	0,823	0,393	0,293	**0,050**	**0,043**	**0,022**	**0,001**	**0,014**	0,429
Lean mass percentage	r	-0,231	-0,153	**-0,545**	0,107	-0,105	-0,010	0,182	0,279	0,359
	p	0,278	0,477	**0,006**	0,618	0,625	0,963	0,395	0,186	0,085
Mineral percentage	r	0,011	0,072	-0,217	0,010	-0,252	-0,232	0,093	0,157	**0,540**
	p	0,961	0,739	0,309	0,961	0,234	0,275	0,666	0,464	**0,006**
Protein percentage	r	-0,303	-0,230	**-0,611**	0,136	-0,024	0,090	0,198	0,298	0,243
	p	0,150	0,281	**0,002**	0,527	0,910	0,676	0,352	0,157	0,253
Soft muscle	r	-0,058	-0,190	-0,235	**0,405**	**0,419**	**0,469**	**0,644**	**0,493**	-0,177
	p	0,788	0,374	0,270	**0,050**	**0,042**	**0,021**	**0,001**	**0,014**	0,408
Skeletal muscle mass	r	-0,048	-0,182	-0,224	0,404	**0,416**	**0,464**	**0,649**	**0,495**	-0,170
	p	0,824	0,393	0,293	0,050	**0,043**	**0,022**	**0,001**	**0,014**	0,428
Liquid weight	r	-0,048	-0,182	-0,225	0,404	**0,414**	**0,463**	**0,649**	**0,494**	-0,169
	p	0,822	0,394	0,290	0,050	**0,044**	**0,023**	**0,001**	**0,014**	0,430
Liquid percentage	r	-0,232	-0,152	**-0,548**	0,107	-0,108	-0,012	0,182	0,280	0,361
	p	0,276	0,478	**0,006**	0,618	0,616	0,954	0,394	0,185	0,083

Abbreviations: MNA: Mini Nutritional Assessment Score; PNI: Prognostic nutritional index, FVC: forced vital capacity; FEV1: forced expiratory volume in 1st second; PEF: peak expiratory flow; DLCO: carbon monoxide diffusion capacity; KCO (mmol/(min*kPa*L); MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure

muscle strength than with pulmonary function values. MIP and MEP declined more progressively and consistently with worsening dyspnea than did spirometry or DLCO measurements (10). Kabitz et al. (4) also emphasized the association between dyspnea severity and respiratory muscle strength. Although dyspnea symptoms were present in our patient group, their respiratory muscle strength performance was similar to that of the control group. This suggests that in early-stage sarcoidosis patients not using corticosteroids, reduced respiratory muscle strength may not be a primary determinant of dyspnea. This highlights that dyspnea in sarcoidosis is likely multifactorial. The number of studies exploring the impact of respiratory muscle weakness on clinical symptoms in sarcoidosis remains limited. Existing literature suggests that muscle weakness is linked to increased fatigue, perceived dyspnea, decreased exercise capacity, and impaired health status (4,7,10,11). Kabitz et al. (4) reported significantly lower %MIP values in sarcoidosis patients compared to healthy controls (95.2% vs. 124.6%). Another study observed that MIP and MEP values were 37% and 39% lower in sarcoidosis patients than in controls (10). However, Brancaleone et al. (12) reported similar %MIP values in both groups. These discrepancies may be explained by the fact that many of the sarcoidosis patients in these studies were on corticosteroid therapy, which is known to cause myopathy. Spruit et al. (3) found reduced respiratory muscle strength in sarcoidosis patients compared to healthy controls and reported no differences in MIP values between corticosteroid-treated and untreated patients over six months. They also found that peripheral muscle strength was negatively correlated with daily corticosteroid dose and suggested that fatigue in sarcoidosis was more closely related to skeletal muscle weakness than cytokine activity. Another study that included sarcoidosis patients at various disease stages (regardless of treatment status) found significantly reduced MIP and MEP values, as well as reduced quality of life and exercise capacity compared to healthy controls (13). Given the side effects of corticosteroids—commonly used in sarcoidosis—their use may outweigh their benefits. Unlike most previous studies, we compared sarcoidosis patients who were not taking corticosteroids or myopathy-inducing statins to healthy controls and concluded that sarcoidosis alone, particularly in early stages, may not significantly impair respiratory muscle strength. The role of nutrition in the progression and prognosis of respiratory diseases is increasingly recognized. Nutritional status in chronic lung diseases is complex, with both obesity and undernutrition being prevalent. A study on interstitial lung diseases (ILDs) found that most patients were overweight or obese, rather than malnourished. Handgrip strength was found to be associated with lower quality of life. The study emphasized the need for both nutritional interventions and exercise programs to manage weight and prevent muscle loss in ILD patients (14). Similarly, a Dutch study demonstrated that muscle atrophy in sarcoidosis is associated with poor pulmonary function and exercise capacity, underscoring the importance of identifying high-risk patients (15). In our study, we evaluated the nutritional status of sarcoidosis patients using anthropometric, biochemical, and nutritional tools, and examined their relationship with respiratory muscle strength, pulmonary function, and exercise capacity. Our patient and control groups were comparable in terms of age and sex. The mean MNA score was significantly lower in the patient group, though both groups had scores ≥24, indicating normal nutritional status. The mean BMI in the patient group was 32.34±5.96, significantly higher than in the control group ($p = 0.003$), and fat mass was also significantly higher ($p = 0.040$). Skeletal muscle mass, lean body mass, and handgrip strength were similar between groups. Peterson et al. (16) reported strong associations between handgrip strength and respiratory muscle strength (inspiratory, expiratory, and sniff nasal inspiratory pressures). Consistently, our study found positive correlations between MIP and MEP values and handgrip strength in both groups. Furthermore, MIP and MEP values were positively correlated with lean mass, soft tissue mass, skeletal muscle mass, and total body water. In contrast to the control group, fat mass was negatively correlated with PEF in the patient group, while PEF in the control group showed a positive correlation with soft tissue and lean mass. Sarcoidosis is defined in the literature as an autoimmune disease of unknown cause. Studies have proposed a link between increased BMI and autoimmune diseases, with obesity reported to triple the risk of sarcoidosis (17). In a U.S.-based prospective study of 116 healthy women followed for 24 years, a positive association was found between higher BMI and increased risk of developing sarcoidosis (18). Yıldız et al. (19) suggested a potential link between metabolic syndrome and

sarcoidosis risk. In our study, BMI was notably high in the patient group, reinforcing the need for further research on the relationship between adiposity and pulmonary dysfunction in sarcoidosis. The Prognostic Nutritional Index (PNI), which is based on serum albumin and lymphocyte count, reflects immunonutritional status and has been linked to disease activity in autoimmune conditions (20). A study in Turkey reported a median PNI of 52.2 (49–55.5) in 253 sarcoidosis patients, with no significant difference between those with and without metabolic syndrome (21). In our study, the mean PNI was 53.95 ± 5.73, similar to the control group. In conclusion, considering the heterogeneous nature of sarcoidosis, its unknown etiology, and potential for multi-organ involvement, treatment should not only address the underlying inflammation but also include comprehensive and individualized interventions such as lifestyle changes, nutritional support, rehabilitation, and physical exercise programs. Our findings suggest that muscle strength, muscle mass, and fat mass are associated with respiratory muscle performance in sarcoidosis. Preventing obesity and promoting lifestyle modifications may positively impact the quality of life and pulmonary function in sarcoidosis patients. The potential impact of adiposity-related inflammation on disease progression warrants further investigation. More clinical studies focusing on lifestyle interventions, nutrition, and rehabilitation in sarcoidosis patients are urgently needed.

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