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Effects of inspiratory muscle training on inspiratory muscle strength, diaphragm thickness, and exercise capacity in sarcopenic individuals

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Abstract:

BACKGROUND AND AIM: This study aimed to investigate the effects of inspiratory muscle training (IMT) on sarcopenic individuals, specifically on their inspiratory muscle strength, diaphragm muscle thickness, and exercise capacity.

METHODS: Our study included 20 subjects with sarcopenia (16 males, 4 females). The participants were randomly assigned to a training group (TG) (mean age: 72.80±3.01) or a control group (CG) (mean age: 71.5±2.22). To assess the effectiveness of the eight-week IMT, we measured the maximum inspiratory pressure (MIP), diaphragm thickness, pulmonary function test (PFT), and the six-minute walk test (6MWT) before and after the training. Quality of life was evaluated using the Sarcopenia Quality of Life Questionnaire (SarQoL).

RESULTS: Both the MIP and the 6MWT of the TG increased significantly after the IMT program (p=0.001 and p=0.001, respectively). The TG's overall SarQoL score and scores for physical and mental health, functionality, fears, and leisure activities demonstrated significant improvements (p=0.007, p=0.014, p=0.042, p=0.004, and p=0.004, respectively). There was no statistically significant change in diaphragm thickness, PFT parameters (including forced expiratory capacity [FEC], forced expiratory volume in one second [FEV_1], peak expiratory flow [PEF], forced expiratory volume in one second/forced vital capacity [FEV_1/FVC], and forced expiratory flow between 25–75% of vital capacity [FEF25–75]), or other subscales of the SarQoL (p>0.05).

CONCLUSIONS: The IMT program improved inspiratory muscle strength, exercise capacity, and overall quality of life in individuals with sarcopenia. We recommend that rehabilitation programs for sarcopenic individuals include IMT.

Keywords:

Diaphragm thickness, inspiratory muscle training, maximum inspiratory pressure, sarcopenia, six-minute walk test

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Introduction

Sarcopenia, the loss of muscle mass related to aging, was initially considered a phenomenon rather than a disease.[1] However, its prevalence has increased in recent decades.[2] According to the EWGSOP2, sarcopenia is defined as a progressive and widespread skeletal muscle disease associated with falls, fractures, physical disability, with low muscle strength being considered the primary factor.[3]

The loss of muscle strength and mass due to sarcopenia affects not only the skeletal muscles surrounding the axial and appendicular skeleton but also the respiratory muscles.[4,5] A decline in muscle mass and strength in the respiratory muscles eventually leads to impaired respiratory function over time. In a 2021 study, respiratory sarcopenia was defined as a combination of total body sarcopenia, low respiratory muscle mass, and either low respiratory muscle strength or function.[6]

Exercise is a valid and effective element in the treatment of sarcopenia.[7] Numerous studies have demonstrated the positive effects of exercise on muscle strength,[8] muscle mass,[9] and physical performance.[10] While aerobic, balance, and flexibility exercises have been found helpful in treating sarcopenia, progressive resistive exercises are considered the primary treatment method.[11] Although exercises targeting peripheral muscles can increase strength and endurance in respiratory muscles, their effects are limited.[12] Inspiratory muscle training (IMT) is a recommended exercise model that significantly impacts respiratory muscles and is widely used in older populations.[13] IMT involves breathing against external resistance provided by a device and is a low-cost, easy-to-implement method that can be integrated into individual rehabilitation programs. It is reasonable to assume that an IMT program can improve both respiratory and motor functions in elderly individuals diagnosed with sarcopenia, making it a viable option for their rehabilitation.[13]

Although many studies have investigated the effects of IMT on the elderly population, very few have examined its effects on sarcopenic individuals. Moreover, these studies did not use a consensus-based sarcopenia diagnostic algorithm.[14] Therefore, clear conclusions regarding the effects of IMT on the sarcopenic population cannot yet be drawn. The aim of our study was to examine the effects of IMT in sarcopenic individuals diagnosed using the most recent diagnostic criteria from the EWGSOP2. In this context, we applied the IMT program to sarcopenic individuals and aimed to examine its effects on inspiratory muscle strength as the primary outcome. Additionally, we evaluated diaphragm muscle thickness to assess how it is affected as the main respiratory muscle in sarcopenia. We also aimed to observe changes in sarcopenia-specific patient-reported outcomes and exercise capacity following respiratory muscle training in sarcopenic individuals.

Materials and Methods

Subjects

Our study included 20 individuals diagnosed with sarcopenia according to the EWGSOP2 criteria, aged 65 years and older, comprising 16 males and 4 females. Participants were recruited from the Gerontology Clinic at the Istanbul University. They underwent general health examinations, and their demographic information was recorded. Their mental status was assessed using the Mini-Mental Test (MMT).[15] Then the subjects were randomly assigned to either the training group (n=10; eight males and two females; mean age: 72.80±3.01) or the control group (n=10; eight males and two females; mean age: 71.5±2.22). The inclusion criteria were as follows: physical independence in daily activities, full knee range of motion, no musculoskeletal injury in the last six months, and a score of 24 or higher on the Mini-Mental Test. Exclusion criteria included uncontrolled hypertension or diabetes, acute or chronic pathological conditions affecting test performance, significant cognitive impairment or cerebrovascular disease sequelae, and severe orthopedic problems limiting mobility. Istanbul University Istanbul Faculty of Medicine Clinical Research Ethics Committee approved the study (Approval Number: E-29624016-050.99-1373433, Date: 09.11.2022), and the subjects provided written and verbal consent in accordance with the Declaration of Helsinki.

Sarcopenia diagnosis and staging parameters

Sarcopenia was diagnosed based on the EWGSOP2 diagnostic algorithm. Individuals diagnosed with confirmed sarcopenia and severe sarcopenia were included in our study, while individuals with probable sarcopenia were excluded.[3]

Muscle strength: Handgrip strength was measured using a handheld dynamometer (Jamar, Chicago, USA). The results were evaluated based on national cutoff values.[16] Those with handgrip strength (HGS) values below 32 kg for men and 22 kg for women were considered to have low muscle strength.

Muscle mass: Muscle mass and fat-free mass (FFM) were measured using a bioelectrical impedance analysis device (Tanita BC532, Tokyo, Japan). Skeletal muscle mass (SMM) was calculated using the Sergi formula: SMM (kg) =0.566×FFM.[17] The skeletal muscle mass index (SMMI) was then calculated as SMMI = SMM (kg)/body mass index (BMI) (kg/m^2). The BMI was calculated by dividing the patient's weight (in kg) by the square of their height (in meters). According to national data, the threshold values for SMMI (BMI) are 1.049 kg/(kg/m^2) for males and 0.823 kg/(kg/m^2) for females. Patients below these values were considered to have low muscle mass.[17]

Physical performance: Physical performance was assessed using gait speed (GS) and the timed up and go (TUG) test. For GS, walking speed over a distance of 4 meters was measured manually with a stopwatch. Individuals with walking speeds below 0.8 m/s were considered to have low physical performance. For the TUG test, individuals were asked to stand up from a chair without support, walk 3 meters, return, and sit back in the chair. Those taking more than 20 seconds were considered to have low physical performance.[18]

Testing procedures

The evaluation procedures used in our study were applied to all subjects twice: once at the beginning and once at the end of the IMT program.

Inspiratory muscle strength test: Inspiratory muscle strength was measured using the Micro RPM (Micro Medical, UK) to determine maximum inspiratory pressure (MIP) based on the criteria established by the American Thoracic Society (ATS) and the European Respiratory Society (ERS).[19] Participants were instructed to exhale until reaching residual volume and then perform a forceful inhalation. The MIP sustained for one second was recorded in cmH_2O,[20] with measurements repeated three times until the difference between the two measurements was less than 5%.

Pulmonary function tests (PFTs): Pulmonary function tests were conducted in a blinded manner using a spirometer (SN A23-048)/Winspro v.3.1.1 open circuit spirometer, Rome, Italy) to measure forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), peak expiratory flow rate (PEF), forced expiratory flow 25%–75% (FEF25–75%), and the FEV_1/FVC ratio. The measurements were repeated three times, and the most acceptable result was recorded.[21]

Exercise capacity: The six-minute walk test (6MWT) was used to assess individuals' aerobic exercise capacity. The 6MWT is a submaximal exercise test developed by the American Thoracic Society that provides data related to individuals' cardiopulmonary function. It is highly applicable, well-tolerated, and does not require exercise equipment.[22] Perceived exertion and dyspnea before and after the 6MWT were evaluated using the modified Borg scale.[23]

Diaphragm thickness: Diaphragm thickness measurements were performed by the same physician (SD) using a Toshiba Aplio 500 ultrasound device (Toshiba Medical Systems Corporation, Otawara, Japan) in a blinded manner. Imaging was conducted using B-mode with a 9–14 MHz probe. The participant lay supine, and the measurement was taken over the right hemidiaphragm. The ultrasound probe (9–11) was placed on the right mid-axillary line of the intercostal space for measurement. The diaphragm was visualized as a non-echogenic structure between two hyperechogenic lines (the peritoneal membrane below and the pleural membrane above) [Fig. 1]. Diaphragm thickness was determined by measuring the vertical distance between these two hyperechogenic lines. It was measured during three different maneuvers: after deep inspiration (total lung capacity, TLC), during quiescent breathing, and after quiescent expiration (functional residual capacity, FRC). All measurements were performed three times, and the average value was recorded as the diaphragm thickness in millimeters.[5]

Quality of life questionnaire: Quality of life was evaluated using the Sarcopenia Quality of Life (SarQoL) questionnaire, specifically designed for individuals with sarcopenia. The SarQoL has been translated into Turkish, and its reliability and validity have been confirmed.[24]

Inspiratory muscle training (IMT) protocol

The IMT protocol was conducted five days per week for eight weeks using a POWERbreathe device (Medic; HaB International Ltd., Warwickshire, Great Britain). The participants' noses were closed with a clip while they sat upright. Inspiration was performed against a predetermined resistance through an angled mouthpiece.

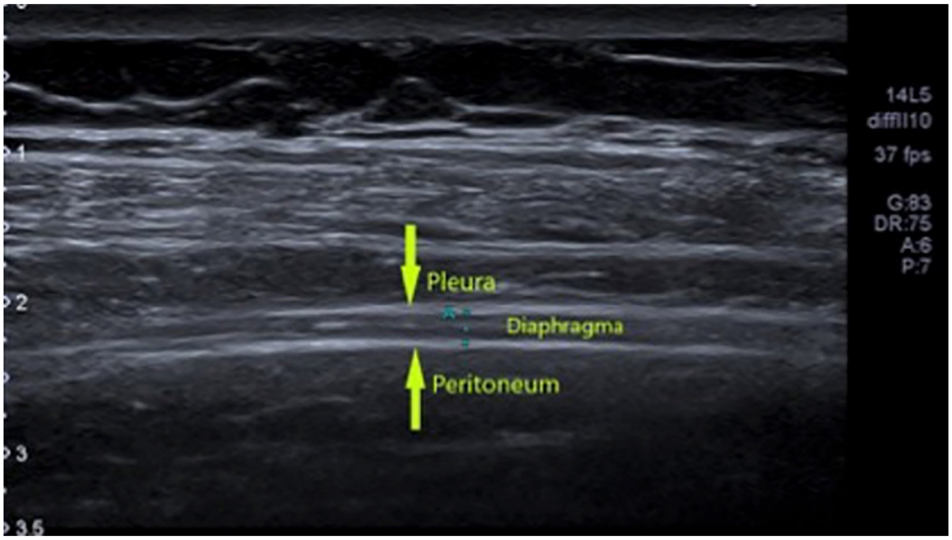

Figure 1: Ultrasound image of diaphragm muscle thickness

Training group

In the first week, the device resistance during inspiration was set as 60% of the MIP value measured in the individual's initial test. There were 10 repetitions, three sets, and two sessions per day. A 1-minute rest was given between sets. The first session was performed approximately two hours after breakfast, and the second session was performed approximately two hours after dinner. In the second week, the device resistance during inspiration was increased to 70% (70% MIP) of the initial MIP value. In the following weeks (weeks 3–8), the resistance level of the device was progressively increased to the level the participants could tolerate during inspiration. The other IMT variables remained unchanged throughout the eight weeks of training.

Control group

The resistance of the device during inspiration was set to 10 cmH_2O. Participants performed 10 repetitions, one set, and one session daily. The placebo protocol was applied two days per week for eight weeks. All sessions in the first week were conducted face-to-face with the physiotherapist (EO). Sessions in weeks 2–8 were completed as a home program. The same physiotherapist monitored the participants via video call during the sessions.

Statistics

The statistical analyses were performed using SPSS version 21 (IBM Corp., Armonk, NY, USA). Categorical variables are expressed as frequencies (n) and percentages (%), while numerical variables are presented as means± standard deviations or medians (25^{th}–75^{th} percentiles). The Shapiro-Wilk test was used to assess whether the data were normally distributed. Chi-square and Fisher's exact tests were used to compare categorical variables, and independent samples t-tests or Mann-Whitney U tests were applied to compare continuous variables between the two groups. Paired samples t-tests or Wilcoxon signed-rank tests were used to assess pre-post differences within each group. Factorial repeated-measures analysis of variance (ANOVA) (general linear model) was used to evaluate differences and interactions of changes between the two groups. A p value of <0.05 indicated statistical significance.

Sample size was calculated using G*Power 3.1. To determine the sample size, the margin of error (α) was set at 0.05; power (1-β) was 0.95; a high effect size (0.8), two groups, and two measurements were assumed. The total sample size was determined to be 18. To account for possible losses during data collection, 20 participants were recruited, with a design effect of 1.1.

Results

There was no significant difference between the anthropometric characteristics of the groups and the results of the tests performed before the IMT program (p>0.05) (Table 1).

Statistically significant changes were observed in the MIP values (Table 2) and the 6MWT results (Table 2) before and after IMT in the training group (p<0.05). When comparing the MIP and 6MWT results before and after IMT, it was found that the training group had significantly greater increases in MIP and 6MWT values than the

Table 1: Anthropometric characteristics of the groups and tests results before inspiratory muscle training (IMT)

	Training group Mean±SD	Control group Mean±SD	p
Age (years)	72.80±3.01	71.5±2.22	0.287
Weight (kg)	70.84±6.14	73.94±6.72	0.649
Height (cm)	153.60±4.62	154.6±5.03	0.296
BMI (kg/m²)	30.02±2.29	30.93±2.31	0.389
MIP (cmH_2O)	47.60±9.33	52.80±12.12	0.297
6MWT (m)	411.60±54.59	410.50±49.53	0.882
SarQol score (total)	59.50±12.50	61.10±15.26	0.801
FEV_1 (L)	1.82±0.30	1.91±0.24	0.509
FVC (L)	2.29±0.32	2.39±0.33	0.518
PEF (L/sec)	4.54±1.51	4.73±0.74	0.726
FEF25–75% (L/sec)	1.96±1.04	1.90±0.47	0.888
FEV_1/FVC (%)	79.68±9.48	80.01±5.06	0.922
DT-Q (mm)	1.96±0.40	1.82±0.14	0.432
DT-FRC (mm)	1.62±0.28	1.65±0.19	0.779
DT-TLC (mm)	2.14±0.37	2.08±0.34	0.696

Results are based on the independent samples t-test. SD: Standard deviation, BMI: Body mass index, MIP: Maximum inspiratory pressure, 6MWT: Six-minute walk test, FEV_1: Forced expiratory volume in the first second, FVC: Forced vital capacity, PEF: Peak expiratory flow, FEF25–75%: Forced expiratory volume between 25% and 75% of FVC, FEV_1/FVC: Ratio of FEV_1 to FVC, DT-Q: Diaphragm thickness during quiescent breathing, DT-FRC: Diaphragm thickness at functional residual capacity, DT-TLC: Diaphragm thickness at total lung capacity

control group ($p<0.05$) (Table 2). However, no significant changes were detected in pulmonary function test (PFT) parameters or diaphragm thickness ($p>0.05$) (Table 3).

According to the SarQoL results, the training group showed significant increases in total score, physical and mental health score, functionality score, leisure activities score, and fear score ($p<0.05$) (Table 4). The locomotion score, body composition score, and activities of daily life score also increased, but not significantly ($p>0.05$) (Table 4).

Table 5 displays the resting dyspnea of the study and control groups before and after inspiratory muscle training. Resting dyspnea showed no significant change in either group ($p>0.05$). The table also shows the exertional dyspnea of the study and control groups before and after inspiratory muscle training. After the training, the study group showed a significant decrease in dyspnea during exertion ($p<0.05$), whereas the control group did not show any significant change in dyspnea during exertion ($p>0.05$).

Discussion

To our knowledge, this is the first randomized controlled study to evaluate an eight-week IMT program in individuals diagnosed with sarcopenia according to the EWGSOP2 criteria. Our study demonstrated that the eight-week IMT program had positive effects on inspiratory muscle strength, exercise capacity, and quality of life in individuals with sarcopenia.

Table 2: Comparison of maximum inspiratory pressure (MIP) and six-minute walk test (6MWT) results before and after the inspiratory muscle training (IMT) program and changes in the results between groups

	Training group			Control group			
	Before IMT Mean±SD	After IMT Mean±SD	Within group p value[1]	Before IMT Mean±SD	After IMT Mean±SD	Within group p value[1]	Between groups p value[2]
MIP (cmH_2O)	47.60±9.33	62.80±12.22	**0.001**	52.80±12.12	53.40±11.72	**0.756**	**0.001**
6MWT (m)	430.60±67.71	454.40±69.18	**0.001**	411.60±54.59	410.50±49.53	**0.882**	**0.011**

[1]: Paired samples t-test, [2]: Factorial repeated measures analysis of variance (ANOVA) (General Linear Model). SD: Standard deviation

Table 3: Comparison of diaphragm thickness before and after the inspiratory muscle training (IMT) program in the training group

	Training group			Control group			
	Before IMT Mean±SD	After IMT Mean±SD	Within group p value[1]	Before IMT Mean±SD	After IMT Mean±SD	Within group p value[1]	Between groups p value[2]
DT-Q (mm)	1.96±0.40	1.91±0.38	**0.480**	1.85±0.14	1.80±0.22	**0.253**	**0.991**
DT-FRC (mm)	1.62±0.28	1.72±0.28	**0.140**	1.65±0.19	1.65±0.19	**0.891**	**0.204**
DT-TLC (mm)	2.14±0.37	2.08±0.35	**0.343**	2.08±0.34	2.07±0.35	**0.712**	**0.455**

[1]: Paired samples t-test, [2]: Factorial repeated measures ANOVA (General Linear Model). SD: Standard deviation, DT-Q: Diaphragma thickness during quiescent breathing, DT-FRC: Diaphragma thickness at functional residual capacity, DT-TLC: Diaphragma thickness at total lung capacity

Table 4: Comparison of Sarcopenia Quality of Life (SarQoL) scores in the training group before and after inspiratory muscle training (IMT)

	Before IMT Mean±SD	After IMT Mean±SD	p
Total score	59.50±12.50	70.73±8.89	**0.007**
PMH	62.42±16.30	73.98±18.49	**0.014**
Locomotion	60.26±18.00	71.94±15.22	0.084
BC	61.94±18.52	70.42±22.87	0.202
Functionality	65.61±14.34	76.98±13.69	**0.042**
ADL	50.67±19.64	63.84±16.88	0.128
LA	38.27±13.68	76.48±19.51	**0.004**
Fears	76.25±19.04	93.75±6.58	**0.004**

Results are based on paired samples t-test. SD: Standard deviation, PMH: Physical and mental health, BC: Body composition, ADL: Activities of daily life, LA: Leisure activities

Respiratory muscle strength is a clinically and prognostically significant factor for older people. An early reduction in respiratory strength leads to a decline in respiratory function or even death. Preserving respiratory strength in elderly individuals is believed to improve pulmonary function and reduce mortality rates.[25] Van der Palen[26] stated that a decrease in maximum inspiratory pressure increases the risk of myocardial infarction and cardiovascular disease-related death. Schoser et al.[27] also showed in their review that MIP predicts long-term outcomes in neuromuscular diseases, including early mortality. Additionally, two studies revealed a significant correlation between low respiratory muscle strength and poor physical performance and quality of life.[28,29] Given its clinical and prognostic importance, studies have also shown that MIP is significantly lower in sarcopenic individuals compared to non-sarcopenic individuals. For these reasons, we selected MIP as the primary outcome in our study.[4,30]

In our study, MIP increased significantly in the training group, while the increase in the control group was not significant (Table 2). IMT has been shown to increase MIP in various studies. A systematic review indicated that IMT increased MIP by an average of 26.3±4.9 cmH_2O.[14] In the same study, the mean MIP of the control group increased by 3.7±4.1 cmH_2O. In another article, 86% of the studies included in the systematic review reported positive effects of IMT on MIP.[13] Additionally, a randomized controlled study have shown the positive effects of IMT on MIP.[31]

However, other studies have shown no positive effects of IMT training programs.[32,33] For example, although MIP increased in the study groups of two different studies, the change was not significant compared to the control groups.[32] Moreover, another study showed no improvement in the IMT group.[34] The individuals in these studies had a higher average age and higher rates of comorbidities.[32] In our study, the sarcopenic individuals did not have comorbidities, which may have affected the positive MIP values observed in the training group after IMT (Table 2).

Diaphragm muscle thickness, another parameter we evaluated in sarcopenic individuals, is a valuable measure for assessing muscle mass and identifying respiratory sarcopenia in older populations. Ultrasound examinations are an essential part of studies in this field.[35] Deniz et al.[5] demonstrated that diaphragm muscle thickness in sarcopenic individuals was significantly lower than in non-sarcopenic elderly individuals. However, studies examining the effects of IMT on diaphragm thickness in the elderly population are limited. Souza et al.[12] reported a significant increase in diaphragm thickness at TLC after an eight-week IMT program, though no significant increase was observed at FRC. Mills et al.[31] found a significant increase in diaphragm thickness measured at residual volume (RV) after the eight-week IMT program, but no significant increase was observed at TLC. In this context, although Nogano et al.[6] recommended ultrasonographic measurements of diaphragm thickness to assess respiratory muscle mass in their respiratory sarcopenia diagnosis algorithm, they were unable to establish the necessary cutoff values due to insufficient studies. Therefore, ad-

Table 5: Comparison of resting and exercise-induced dyspnea in the groups before and after inspiratory muscle training (IMT)

	Training group			Control group		
	Before IMT	After IMT	Within group p value	Before IMT	After IMT	Within group p value
M.B.	Med (Q1-Q3)	Med (Q1-Q3)		Med (Q1-Q3)	Med (Q1-Q3)	
Resting dyspnea (M.B.)	0 (0–0.75)	0 (0–0)	0.180	0 (0–1)	0.5 (0–1)	1.000
Exercise dyspnea (M.B.)	3 (2–4.25)	1 (0.75–2)	**0.007**	1.5 (0.75–3.25)	1.5 (0.75–3)	0.157

Results are based on the Wilcoxon signed-rank test. Med: Median, Q1: Quarter 1, Q3: Quarter 3, M.B.: Modified borg ditional studies are needed to determine the average diaphragm thickness in sarcopenic individuals and to understand the clinical significance of these values.

In our study, after the IMT program, we did not detect a significant change in diaphragm muscle thickness measured during quiescent breathing, FRC, or TLC in the training group (Table 3). We believe that significant deterioration in muscle quality, such as increased myosteatosis and decreased fiber length,[36,37] may be one factor preventing potential diaphragmatic hypertrophy. Furthermore, it should be noted that the studies showing positive effects of IMT on diaphragm thickness were conducted in healthy older individuals. Measuring diaphragm thickness at FRC is considered the most reliable method among diaphragm thickness measurements, as it does not require strenuous effort from the individual.[12] In the training group, diaphragm thickness measured at FRC increased from 1.62±0.28 mm before the IMT to 1.72±0.28 mm after the IMT. However, this difference was not statistically significant. This result may be due to the small sample size or the insufficient duration of the inspiratory muscle training.

An increase in inspiratory muscle strength can result from both structural and functional adaptations. Structural adaptations involve muscle hypertrophy, while functional adaptations occur primarily through neuromuscular adaptation mechanisms.[38] Considering that there was no significant increase in diaphragm muscle thickness after the IMT program, the significant increase in MIP observed in the training group (Table 2) may be attributed to neuromuscular adaptations.

Unlike other pulmonary function tests, the 6MWT is essential for detecting symptoms of non-pulmonary chronic diseases such as cardiovascular diseases, cancer, frailty syndrome, and sarcopenia.[39] For this reason, exercise capacity was evaluated using the 6MWT in our study. The effects of IMT on exercise capacity are controversial. A systematic review by Manifield et al.[40] reported that IMT increased the 6MWT distance by an average of 24.7±22.1 meters. However, this increase was not considered sufficient, and it was suggested that the effect of exercise might be limited. In support of this, Rodrigues et al.[41] did not detect a significant change in the 6MWT after IMT, while Mills et al.[31] reported a significant increase. In our study, the 6MWT distance in the training group increased significantly after the IMT program (Table 2). Moreover, the difference between the training and control groups was also statistically significant.

There is limited information about the physiological processes through which IMT influences exercise capacity. One potential mechanism is an increase in the threshold for stimulating respiratory metaboreflexes. This process can impact exercise capacity by limiting blood flow to the lower extremities, thereby increasing the diaphragm's fatigue threshold.[42] According to Witt et al.,[43] a five-week IMT program can significantly reduce diaphragmatic metaboreflex. Other potential mechanisms include improving cardiac autonomic control (i.e., the balance between sympathetic and parasympathetic activity)[41] or reducing the amount of lactate produced in the blood after exercise.[44]

It is well known that experiencing dyspnea during exercise can decrease one's ability to tolerate physical activity.[2–4] Our research showed that participants in the training group experienced a significant reduction in their perception of exercise-induced dyspnea following IMT (Table 5). This decrease in dyspnea may have positively impacted the participants' exercise capacity, as measured by the 6MWT, in the training group.

The FEV_1, FVC, PEF, FEF 25–75%, and FEV_1/FVC measured by PFTs did not significantly change between the training group and the control group in our study. After reviewing the literature, Rodrigues et al.[41] reported no noteworthy changes in PFT parameters. However, Mills et al.[31] reported increased peak inspiratory flow (PIF) values in their study. In the study by Watsford and Murphy,[20] only a significant increase in FVC was observed. Although the increase in FVC was suggested to be related to an increase in MIP, the relationship was not definitive.[20] Mills et al.[31] suggested that the FVC increase observed by Watsford and Murphy may have been due to a learning effect rather than an adaptation from IMT.

Our study revealed a statistically significant increase in the total SarQoL score, as well as scores for physical and mental health (PMH), functionality, and fears, after IMT in the training group (Table 4). However, the changes in scores for locomotion, body composition, activities of daily living, and leisure activities were not statistically significant (Table 4). This positive change in the quality of life for the training group in our study might be related to physiological adaptations, such as an increase in inspiratory muscle strength and exercise capacity (Table 2), as well as a reduction in perceived exertional dyspnea (Table 5).[45] Psychological factors may have also contributed to the improvement in quality of life we observed. Chang et al.[46] demonstrated a connection between sarcopenia and higher depression levels, regardless of age, sex, cognitive ability, or physical health. Given that exercise is known to positively affect anxiety and depression, the psychological benefits of exercise may have played a role in the improvement in quality of life observed in our study.

Our study identified sarcopenic individuals using the current diagnostic criteria for sarcopenia, the EWGSOP2, but the use of different definitions in previous studies has limited the literature on sarcopenia. Therefore, it is essential that future studies use the most up-to-date diagnostic and classification criteria for sarcopenia. Our research, which focuses on respiratory system structure and function in sarcopenic individuals, is rare but important. Conducting more scientific studies in this area is vital, as worsening respiratory function may predispose individuals to sarcopenia. In addition to decreased muscle mass, sarcopenic individuals may also experience muscle quality disorders. Simultaneous evaluation of muscle mass and quality with ultrasonography can add a new dimension to sarcopenia research. After applying an eight-week IMT program, we observed significant improvements in inspiratory muscle strength, exercise capacity, and quality of life. Furthermore, longer patient follow-up periods in future studies would be valuable to better understand the clinical and prognostic effects of increases in MIP and 6MWT values. As a limitation, although we achieved the targeted sample size, we reached a power of only 26% for the 6MWT. However, we attained high power with 90% for SarQoL and 99% for MIP.

Conclusion

Regular exercise is crucial for treating sarcopenia, but many individuals with this condition experience exercise intolerance or reluctance to engage in physical activity. Severe comorbidities can also present challenges during exercise therapy. However, our study demonstrated that IMT programs offer a low-cost and well-tolerated exercise modality that can produce positive results on important clinical parameters for sarcopenic individuals. We believe that specially designed IMT programs can be safely and effectively integrated into the rehabilitation process for sarcopenic individuals.

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Ethics Committee Approval
The study was approved by the Istanbul University Istanbul Faculty of Medicine Clinical Research Ethics Committee (No: E-29624016-050.99-1373433, Date: 09/11/2022).

Authorship Contributions
Concept – E.Ö., T.Ş., G.M.; Design – E.Ö., S.D., U.S.; Supervision – G.M., T.Ş.; Funding – G.M., T.Ş.; Data collection &/or processing – E.Ö., S.D., U.S.; Analysis and/or interpretation – U.S., S.D.; Literature search – E.Ö., S.D.; Writing – S.D., E.Ö.; Critical review – G.M., T.Ş.

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