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Clinical determinants of the modified incremental step test in adults with non-cystic fibrosis bronchiectasis

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ABSTRACT

Objectives: This study primarily aimed to investigate the clinical determinants of the Modified Incremental Step Test (MIST) in adults with non-cystic fibrosis bronchiectasis (NCFB). A secondary objective was to compare the cardiopulmonary responses after the MIST and Incremental Shuttle Walk Test (ISWT), two commonly adopted symptom-limited maximum field tests in chronic respiratory diseases. **Methods:** Forty-six patients with clinically stable bronchiectasis participated in this cross-sectional study. MIST and ISWT were performed to determine exercise capacity, while disease severity, fatigue, and quality of life were assessed using the Bronchiectasis Severity Index (BSI), the Fatigue Severity Scale (FSS), and St. George's Respiratory Questionnaire (SGRQ), respectively. Quadriceps muscle strength was evaluated using a hand-held dynamometer, walking speed with a wireless inertial sensing device, and the level of physical activity (steps/day) with a pedometer. **Results:** The BSI score, quadriceps muscle strength, daily step count, and the SGRQ total score explained 61.9% of the variance in the MIST ($p < 0.001$, $R^2 = 0.67$, $AR^2 = 0.619$). The BSI score ($r = -0.412$, $p = 0.004$), quadriceps muscle strength ($r = 0.574$, $p = 0.001$), daily step count ($r = 0.523$, $p < 0.001$), walking speed ($r = 0.402$, $p = 0.006$), FSS score ($r = -0.551$, $p < 0.001$), and SGRQ total score ($r = -0.570$, $p < 0.001$) correlated with the MIST. The patients achieved higher heart rates (HR), HR%, desaturation, dyspnea, and leg fatigue in the MIST compared to the ISWT ($p < 0.05$). **Conclusions:** Disease severity, quadriceps muscle strength, physical activity level, and quality of life were determinants of MIST. The advantages of the MIST, including higher cardiopulmonary response than ISWT and greater portability, which facilitates its use in various settings, make MIST the preferred choice for investigating symptom-limited exercise capacity in patients with NCFB.

Keywords: bronchiectasis, exercise capacity, step test, physical activity, walking speed, quality of life.

INTRODUCTION

Bronchiectasis is a chronic and progressive respiratory disease in which functional exercise capacity, quality of life, and the ability to perform daily living activities are impaired, together with pulmonary and extrapulmonary involvement.[1,2] In bronchiectasis, chronic sputum, fatigue, dyspnea symptoms, and a decline in peripheral muscle strength and endurance negatively impact functional exercise capacity.[3,4]

The most common field walking tests used to evaluate functional exercise capacity in bronchiectasis patients are the 6-minute walk test (6MWT) and the incremental shuttle walk test (ISWT).[5] Step tests offer advantages due to their greater portability compared to walking tests and the requirement for less space during application, making them suitable for use in any given environment.[6] Step tests can be either self-paced or externally paced, like the 6MWT and the ISWT. They can also be conducted with a constant or incremental workload, similar to cycle ergometer and treadmill protocols.[6] The Modified Incremental Step Test (MIST) is a symptom-limited maximum field step test that evaluates exercise capacity with gradually increasing step rates.[7] This test is reliable and responsive to pulmonary rehabilitation in individuals with stable chronic respiratory disease.[8] In bronchiectasis, MIST was assessed in only one study, and the MIST number of steps (NOSs) was highly correlated with pulmonary function, 6MWT distance, and heart rate.[7] The ISWT, the most commonly used maximum field walking test, and the MIST are valid for measuring maximum exercise capacity and have demonstrated maximum cardiopulmonary responses in individuals with bronchiectasis.[7,9] Therefore, exercise tolerance duration, cardiopulmonary stress, and effort perception in patients with bronchiectasis are comparable using the ISWT and MIST.

The determinants of exercise capacity in bronchiectasis have been previously investigated in a few studies. While the predictors of ISWT were reported as being age, body composition, respiratory function, shortness of breath, and physical activity in daily life in one study,[9] age and gender were also described in another.[10] Saint

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George's Respiratory Questionnaire (SGRQ) symptom and activity scores and high-resolution computed tomography (HRCT) score were identified as predictors of the 6MWT.[11] Although the factors limiting exercise capacity in bronchiectasis are multifactorial, they have not been explicitly studied. Considering all this information, exploring the determinants of exercise capacity in subjects with bronchiectasis is essential. In recent years, the significance of the MIST, a step test for evaluating exercise capacity in individuals with chronic pulmonary diseases, has increased; however, no studies in the literature have investigated its clinical determinants. MIST provides new opportunities to assess exercise capacity, prescribe exercise training, and reassess exercise program outcomes in environments where established field walking tests are impractical.[8] Identifying clinical and functional variables that explain MIST in bronchiectasis may serve as potential indicators for benefiting from pulmonary rehabilitation programs.

Therefore, the primary objective of this study was to determine which factors influence exercise capacity measured by MIST using different clinical and functional parameters, including disease severity, muscle strength, physical activity level, walking speed, and quality of life assessment in individuals with non-cystic fibrosis bronchiectasis (NCFB). The secondary aim was to compare the results obtained with the MIST and ISWT.

METHODS

This descriptive, cross-sectional study involved patients diagnosed with bronchiectasis who were followed up at the Department of Chest Diseases of Dokuz Eylül University, in Izmir, Turkey, between September 2019 and March 2021. The study protocol received approval from the Ethics Committee of Dokuz Eylül University (2019/18-21), and written informed consent was obtained from from all subjects. The study included individuals diagnosed with NCFB, confirmed by HRCT, who were clinically stable (no antibiotic use for four weeks) and had not participated in any regular pulmonary rehabilitation programs. Those with serious cardiac problems, neurological or orthopedic diseases, and/or malignancies were excluded.

The physical and sociodemographic characteristics of the subjects were recorded. HRCT images were obtained from their clinical records. A pulmonary function test (Sensor Medics Vmax 22, SensorMedics, Inc., Anaheim, CA, USA) was performed to measure forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC), and the test was carried out following the recommended guidelines of the American Thoracic Society and the European Respiratory Society.[12]

The assessment of dyspnea perception was conducted using the Medical Research Council (MRC) dyspnea scale, a categorical scoring system ranging from 0 to 5 points. This scale involves choosing the statement most aptly representing the degree of dyspnea from five different statements about dyspnea.[13]

Disease severity was evaluated using the Bronchiectasis Severity Index (BSI). The BSI is a valid tool for identifying patients at an increased risk of future mortality, hospitalization, and exacerbations. It comprises eight parameters, which include age, body mass index (BMI), forced expiratory volume in 1s (FEV1), previous hospital admissions, the frequency of exacerbations, the score on the modified Medical Research Council (mMRC) dyspnea scale, colonization status (*Pseudomonas aeruginosa* or other organisms), and the extent of radiological findings; higher BSI scores indicate greater disease severity. According to the BSI score, disease severity can be categorized as mild (0 – 4 points), moderate (5 – 8 points), or severe (≥ 9 points).[14]

The MIST was used, as previously described, to assess exercise capacity.[7] The step test commenced at a rate of 10 steps/min, with one-step increments introduced every 30 seconds. The step rate progressed at regular intervals through auditory stimuli previously recorded on a disc.[7]

The ISWT was also administered to evaluate exercise capacity.[15] The test was conducted in an empty and quiet 10-m corridor, and walking speed was guided by an audio signal, which started at 0.5 m/s and increased progressively.

Two MISTs and ISWTs were carried out on the same day, with a resting period of at least 30 minutes between them. The second tests were performed once the participants' vital signs had returned to baseline levels to ensure consistent clinical conditions for each patient in both tests. The highest NOSs in the MIST[7] and the best distance in the ISWT were recorded.[5] Oxygen saturation and heart rate values (pulse-oximetry - Beurer PO30 Pulse Oximeter, Germany), dyspnea (Modified Borg Scale), and fatigue (Rated Perceived Exertion (RPE) Scale) were assessed before and after the tests. The tests were stopped when the participant declared inability to continue, the researcher observed that the participant was not suitable to continue the test, two consecutive beeps were missed, or SpO_2 < 80%. The reasons for stopping the tests, the total NOSs, and the test completion time were registered. The maximum heart rate (HRmax) was determined using the formula [220 – age], and the HRmax% reached at the end of the tests was calculated.[16]

Walking speed was evaluated using a wireless inertial sensing device (G-Sensor-BTS Bioengineering-S.p.A., Italy) attached to the subject's waist with a semi-elastic belt at the L4-L5 level.[17] The participants were instructed to walk along an 8-m pathway at a self-selected speed, and the walking speed was recorded in m/s.

A hand-held dynamometer (Lafayette Instrument Co., Lafayette, IN, USA) was utilized to assess quadriceps muscle strength. The measurement involved an isometric knee extension exercise at 90° of knee flexion, repeated three times, with the best value recorded in Newtons (N).[18] Percentages of muscle strength were calculated based on reference values.[19]

The level of physical activity (steps/day) was evaluated using a pedometer (CW-700, Digi-walker Pedometer, Yamax-Corp., Tokyo, Japan), a practical and suitable device for patients with bronchiectasis.[20] The pedometer was worn on the belt on the dominant side at the midline of the thigh for seven consecutive days, except during showering or swimming. The total step count in a week, walking distance (kilometers), activity duration (hours), and calories expended (kcal) were obtained from the pedometer, and the daily average values of these parameters were calculated.[21]

The Fatigue Severity Scale (FSS) was used to estimate the fatigue level of the participants.[22] In the FSS, scores ≥ 4 points indicate the presence of severe fatigue. St. George's Respiratory Questionnaire[23] was utilized to assess quality of life, as the SGRQ allows for comparisons with previous studies,[11,23] and there is strong evidence supporting its validity, internal reliability, and reproducibility.[24] The Turkish versions of the FSS and SGRQ have been validated and are cpnsidered reliable.[25,26]

Statistical analysis was performed using IBM SPSS software, version 24.0 (SPSS Inc., Chicago, IL, USA). All variables were expressed as mean ± standard deviation, frequency, and percentage when appropriate. The normality of distribution was assessed using the Skewness-Kurtosis test and histograms. When applicable, the correlation between MIST NOSs and the variables was determined via Pearson/Spearman correlation analyses. The correlation coefficients were interpreted as weak for r = 0.2-0.3, moderate for r = 0.3-0.5, and strong for r ≥ 0.5.[27] Statistical significance was set at $p < 0.05$. The paired t-test was used to compare the test results in the ISWT and MIST. Categorical data across the exercise tests were compared with the Chi-square test.

An enter regression model was developed to identify the determinants of MIST. Independent variables showing a significant correlation with MIST were included in the model. Model fit was assessed using appropriate residual and goodness-of-fit statistics.

Based on a similar study in which the predictors of ISWT were previously determined,[10] the sample size was calculated as 46 patients, considering an expected effect size of 0.727, an alpha of 0.05, and a statistical power of 0.95, using G*Power software, version 3.1.

RESULTS

A total of 48 subjects who met the inclusion criteria participated in the study. Forty-six were evaluated, and their data were analyzed (Figure 1). Twenty-six (56%) participants were female, while 20 were male. Their demographic and clinical characteristics are shown in Table 1.

The classification of disease severity among the individuals was as follows: 30 (65.2%) had mild, 10 (21.7%) had moderate, and six (13.1%) had severe bronchiectasis. The patients achieved 35% of quadriceps muscle strength as a percentage of predicted values. In addition, 25 (54.3%) patients reported experiencing severe fatigue.

Correlations between the patients' MIST NOSs and their clinical parameters can be observed in Table 2. The MIST NOSs showed a strong correlation with the ISWT distance ($r = 0.788$, $p < 0.001$), quadriceps muscle strength ($r = 0.574$, $p = 0.001$), daily number of steps ($r = 0.523$, $p < 0.001$), walking distance ($r = 0.629$, $p < 0.001$), total energy expenditure ($r = 0.528$, $p < 0.001$), FSS score ($r = -0.551$, $p < 0.001$), SGRQ total score ($r = -0.570$, $p < 0.001$), SGRQ activity score ($r = -0.541$, $p < 0.001$), and SGRQ impact score ($r = -0.525$, $p < 0.001$). Meanwhile, the MIST NOSs exhibited a moderate correlation with FEV1 (pred%) ($r = 0.456$, $p = 0.001$), FVC (pred%) ($r = 0.403$, $p = 0.005$), BSI ($r = -0.412$, $p = 0.004$), the 8-m walking speed ($r = 0.402$, $p = 0.006$), and activity duration ($r = 0.378$, $p = 0.001$).

A multiple linear regression model was used to identify the determinants of the MIST NOSs (Table 3). Our findings indicate that the BSI score ($p = 0.004$), quadriceps muscle strength ($p = 0.002$), pedometer daily number of steps ($p = 0.039$), and SGRQ total score ($p = 0.003$) explained the variance in the MIST NOSs by 61.9% [$F = 13.190$, $p < 0.001$, $R^2 = 0.67$, $AR^2 = 0.619$].

ISWT and MIST performance, physiological responses, and the exercise perception of the patients are presented in Table 4. No differences were observed in resting values of HR, dyspnea, or leg fatigue between the ISWT and MIST ($p > 0.05$). SpO_2 at rest was significantly higher before MIST than ISWT ($p = 0.038$, 96.58 ± 1.32 vs. 96.26 ± 1.55, respectively). Changes in HR, dyspnea, and leg fatigue parameters during the MIST were significantly higher compared to the ISWT ($p < 0.001$). While 64% of HRmax was reached in the ISWT, 82% was reached in the MIST. Three participants

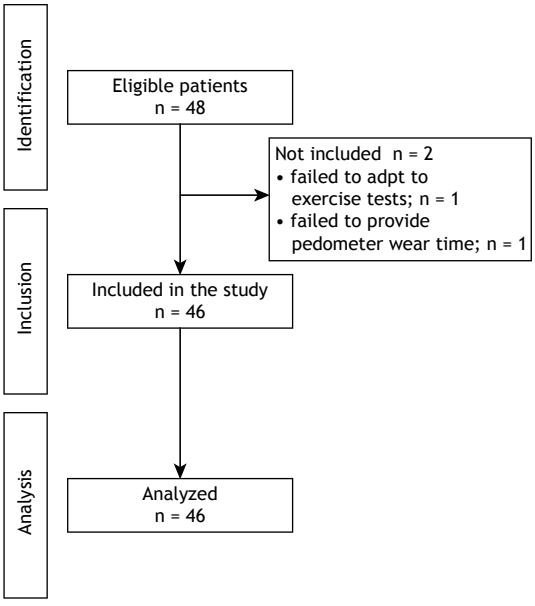

Figure 1. Study enrollment flowchart.

Table 1. Demographic and clinical features of individuals with bronchiectasis.

Variables	Mean (SD)	Range
Age (years)	59.30 (7.72)	41 - 74
Body weight (kg)	73.98 (12.59)	48 - 97
Body mass index (kg/m^2)	27.93 (4.41)	20.20 - 37.90
Fat-free mass (kg)	51.12 (10.29)	30.80 - 74.40
Disease duration (years)	13.43 (11.36)	1 - 50
Smoking history (pack-years)	10.28 (21.25)	0 - 120
Etiology, n (%)		
Idiopathic	16 (35)	-
Post-infectious problems	12 (27)	-
Autoimmune diseases	9 (19)	-
Respiratory disease (asthma, COPD)	9 (19)	-
Other reasons (toxic inhalation)		
Medication use, n (%)		
Inhaled bronchodilator	21 (45.65)	-
Inhaled corticosteroid	7 (15.21)	-
Mucolytics	4 (8.69)	-
Antihypertensive	10 (21.73)	-
Glucose-lowering medication	4 (8.69)	-
Lipid-modifying medication	2 (4.34)	-
FEV1 (pred%)	75.58 (19.13)	27 - 110
FVC (pred%)	81.04 (17.89)	41 - 118
MRC score	1.71 (0.54)	1 - 3
BSI score	4.5 (2.68)	2 - 12
8-m gait speed (m/s)	1.16 (0.16)	0.86 - 1.63
Quadriceps (N)	122.54 (24.46)	77.47 -180.44
Number of steps (steps/day)	6,418.74 (2,225.30)	2,813.00 -11,479.00
Walking distance (km/day)	3.94 (1.58)	1.54 - 7.48
Energy expenditure (kcal/day)	260.16 (117.76)	92.94 -626.47
Total physical activity duration (min/day)	67.8 (21.00)	31.2 - 112.8
Fatigue Severity Scale score	5.45 (3.22)	2.25 - 12.75
SGRQ total	32.36 (12.40)	9.36 - 63.67
SGRQ symptom	40.86 (16.53)	0.00 - 76.23
SGRQ activity	44.02 (15.79)	11.16 - 79.79
SGRQ impact	22.51 (14.28)	4.51 - 64.09

N = 46 subjects; values shown as mean (SD); MRC = Medical Research Council Dyspnea Scale; BSI = Bronchiectasis Severity Index; SGRQ = St. George's Respiratory Questionnaire; FEV1 = Forced Expiratory Volume in 1s; FVC = Forced Vital Capacity.

(6%) in the ISWT and 27 (59%) in the MIST reached HRmax and completed the tests. Changes in SpO_2 between rest and exercising ≥4% were considered desaturation. All subjects showing desaturation in the ISWT also exhibited desaturation in the MIST.

DISCUSSION

This study is the first to investigate the determinants of exercise capacity with the MIST in individuals with bronchiectasis using different clinical and functional parameters. Disease severity, peripheral muscle strength, physical activity level, walking speed, fatigue, and quality of life were found to be related to the MIST NOSs. Disease severity, peripheral muscle strength, physical activity level, and quality of life were identified as determinants of MIST. Also, patients achieved higher HR, HR%, desaturation rates, dyspnea, and leg fatigue in the MIST compared to the ISWT.

Corroborating the findings of previous studies, we noted a decrease in exercise capacity in the ISWT in subjects with bronchiectasis.[10,28–31] Only one study evaluated exercise capacity with the MIST in individuals with bronchiectasis. Although the HR values, mean NOSs, and test duration during peak exercise herein were similar to those reported in a previous study,[7] the SpO_2 (%) and dyspnea scores differed. These discrepancies may be attributed to the better respiratory function of the subjects in the present study. Disease severity was not evaluated in the previous study,[7] hindering our ability to make comparisons.

To our knowledge, no studies in the literature have explored the relationship between MIST and ISWT results in individuals with bronchiectasis. Considering that both tests are valid for measuring maximum exercise capacity in subjects with bronchiectasis and elicit maximum cardiopulmonary responses, it is possible to compare patient performance in both

Table 2. Univariate analysis of the variables and the MIST number of steps.

Variables	MIST NOSs	
	r	*P*
Age (years)	-0.290†	0.050
Gender	0.008‡	0.957
Height (m)	0.137†	0.364
Body weight (kg)	0.100†	0.508
Body mass index (kg/m^2)	0.024†	0.873
Fat-free mass (kg)	0.195†	0.195
Disease duration (years)	-0.193‡	0.198
Smoking history (pack-years)	0.092‡	0.542
FEV1 (pred%)	0.456†	0.001*
FVC (pred%)	0.403†	0.005*
BSI score	-0.412 ‡	0.004*
ISWT distance (m)	0.788†	<0.001*
8-m gait speed (m/s)	0.402†	0.006*
Quadriceps (N)	0.574†	<0.001*
Number of steps (steps/day)	0.523†	<0.001*
Walking distance (km/day)	0.629†	<0.001*
Energy expenditure (kcal/day)	0.528†	<0.001*
Total physical activity duration (min/day)	0.378†	0.001*
Fatigue Severity Scale score	-0.551‡	<0.001*
SGRQ total	-0.570†	<0.001*
SGRQ symptom	-0.190†	0.206
SGRQ activity	-0.541†	<0.001*
SGRQ impact	-0.525‡	<0.001*

N = 46 subjects; ISWT = Incremental Shuttle Walk Test; MIST = Modified Incremental Step Test; MRC = Medical Research Council Dyspnea Scale; BSI = Bronchiectasis Severity Index; SGRQ = St. George's Respiratory Questionnaire; FEV1 = Forced Expiratory Volume in 1s, FVC = Forced Vital Capacity; NOSs = Number of steps; * $p < 0.05$; †Pearson r, ‡Spearman rho.

tests. The HRmax% value achieved in the MIST was higher compared to the ISWT (82% vs. 64%), with more participants reaching HRmax (n = 27 vs. n = 3) and completing the test. Although the ISWT is widely used in studies involving bronchiectasis patients,[3,10] based on these results, the MIST is more effective at increasing heart rate than the ISWT. The increase in the MIST at more frequent intervals may have accelerated the heart rate in patients with higher functional capacity. Therefore, the MIST may be a more useful exercise test than the ISWT for individuals with high functional capacity. Moreover, the step test has an advantage over the walking test in terms of portability and applicability in smaller spaces, making it suitable for situations lacking adequate space for the maximum walking field test.

Fatigue is observed in 74% of patients with bronchiectasis,[32] resulting in impaired exercise tolerance.[11] The FSS score showed a strong correlation with the MIST NOSs, consistent with the results obtained in a previous study[11] that reported an association between physical fatigue and reduced exercise tolerance in bronchiectasis. Due to the continuous vertical displacement of the body during the step test, the workload of the muscles increases, causing fatigue and desaturation.[33] While fatigue is not reported as a limitation in walking tests, it is considered as a limiting symptom in tests involving stairs or step activities.[34] More subjects in the MIST ended the test due to leg fatigue than in the ISWT. Studies involving bronchiectasis have shown that quadriceps muscle strength decreases and affects exercise capacity.[4,28,30] In the present study, quadriceps muscle strength strongly correlated with exercise capacity and can be a predictor of exercise capacity. Desaturation has been observed in step tests in studies analyzing different pulmonary diseases.[35,36] Here, desaturation was observed more in individuals with different levels of disease severity in the MIST compared to the ISWT, indicating that the step test is more sensitive to desaturation. This finding is consistent with another study[33] in which desaturation was more prevalent in the MIST than in the cardiopulmonary exercise test (CPET) in patients with COPD.[33]

Individuals with bronchiectasis often perceive dyspnea, which significantly affects exercise capacity.[4,9] While dyspnea was reported as the primary reason for ending the MIST, this was not reported in the ISWT. More subjects ended the test due to leg fatigue in the MIST than in the ISWT. When the responses to the two exercise tests were evaluated regarding leg fatigue and dyspnea, the step test was identified as the most symptom-limiting test according to the participants. Hence, this test better reflects the cardiopulmonary responses and symptoms in the face of increased workload. Exercise tests applied at an incremental rate

Table 3. Multiple linear regression analysis of variables associated with the MIST number of steps.

Independent variables	B	SE	95% CI	t	p
Constant	86.932	49.436	-13.092 to 186.895	1.758	0.087
BSI score	-6.028	1.971	-10.015 to 2.041	-3.058	0.004*
Quadriceps (N)	8.447	0.2504	3.381 to 13.512	3.381	0.002*
Number of steps (steps/day)	0.006	0.003	0.00 to 0.012	2.138	0.039*
SGRQ total	-1.75	0.551	-2.865 to -0.635	-3.174	0.003*

*p < 0.05; t = statistical test; B = unstandardized regression coefficient; SE = standard error; BSI = Bronchiectasis Severity Index; SGRQ = St. George's Respiratory Questionnaire.

Table 4. Variables at Peak Exercise in the ISWT and MIST.

Variables	ISWT	MIST	95% CI	p
Outcome	401.67 (73.65) meters	152.93 (55.00) steps	-	-
Time, min	6.86 (0.80)	8.36 (2.02)	-116.42 to -6.92	< 0.001*
SpO_2, %	95.45 (3.69)	95.13 (3.83)	-0.87 to 0.22	0.238
Δ SpO_2	- 0.8 (3.12)	1.45 (3.03)	-1.20 to -0.10	0.021*
Δ SpO_2 ≥ 4%, n	4 (2 moderate, 2 severe)	7 (1 mild, 4 moderate, 2 severe)	-	< 0.001*
Heart rate, beats/min	102.06 (16.35)	132.02 (19.90)	24.29 to 35.62	< 0.001*
Heart rate, % maximum predicted	63.60 (10.54)	82.15 (11.70)	21.97 to 10.90	< 0.001*
Dyspnea	1.67 (1.30)	3.21 (1.47)	1.05 to 2.03	< 0.001*
Leg fatigue	6.85 (6.52)	12.19 (2.76)	-11.17 to -9.67	< 0.001*
Reasons for ending the test				
SpO_2 < 80%, n (%)	-	2 (4.34)	-	-
Leg fatigue, n (%)	4 (8.69)	15 (32.60)	-	-
Dyspnea, n (%)	-	4 (8.69)	-	-
Leg fatigue and dyspnea, n (%)	-	7 (15.21)	-	-

N = 46 subjects; ISWT = Incremental Shuttle Walk Test; MIST = Modified Incremental Step Test; values expressed as mean (SD) * p < 0.05 between tests.

or workload in healthy individuals are recommended to last 8-12 minutes.[37] The mean duration of the MIST was 8.36 minutes, while that of the ISWT was 6.86 minutes. This result meets the recommended minimum time to observe the maximum cardiopulmonary responses during peak exercise, which is 8 minutes, indicating that the step test is well-tolerated.

We found that high BSI scores are moderately associated with a decrease in exercise capacity, and that the BSI score is a determinant of MIST. A limited number of studies have evaluated the effect of disease severity on exercise capacity in bronchiectasis. One previous study reported that patients with moderate-to-severe disease significantly achieved lower walking distance values than those with mild bronchiectasis.[38] In the present study, as the distribution of participants according to disease severity classification was not homogeneous, no comparisons were made between groups in terms of exercise capacity. However, a moderate negative correlation was found between disease severity and exercise capacity, consistent with the literature.

The decrease in walking speed in subjects with chronic lung disease is associated with general health status and reflects the multisystemic effects of the disease besides impairments in pulmonary function.[39] In COPD, walking speed has been associated with exercise capacity.[39,40] The only study evaluating walking speed in bronchiectasis found no relationship between 4-meter gait speed and sedentary behavior duration.[38] In this study, we assessed walking speed in bronchiectasis using an objective device and found a moderate correlation between walking speed and exercise capacity.

Furthermore, we identified a relationship between physical activity level and the MIST NOSs in bronchiectasis, with the former being a determinant of MIST. The daily step count of the participants was less than the minimum value of 7,000 steps/day.[21] Our results support studies that reported that the physical activity level of subjects with bronchiectasis decreased and is associated with exercise capacity.[28–30]

The strong association between the MIST and SGRQ activity, impact, and total scores is consistent with previous studies investigating the relationship between exercise capacity and SGRQ in bronchiectasis.[11,23] The SGRQ symptom domain assesses the frequency, severity, and duration of symptoms, while the activity domain analyzes the physical limitations and impairments associated with respiratory symptoms.[23] Therefore, there may be a lack of correlation between the SGRQ symptom domain and exercise capacity, given the disease severity was mild/moderate. In addition, the correlation between the SGRQ activity score and the MIST in our study may be explained by the low levels of physical activity in our patients. It is not unexpected that the SGRQ total score is a predictor of MIST. However, our study supports the view that

physical limitations, as well as respiratory signs and symptoms, are clinically relevant when assessing exercise capacity in patients with mild-to-moderate bronchiectasis.

The present study had some limitations. Firstly, gas exchange parameters could not be measured during the exercise tests due to equipment requirements. During the step test, which is favored in clinical practice due to its ease of use and low cost, the participants reached the maximum predicted heart rates, estimated using the formula [220 – age], and the exercise test was considerably successful. We compared the ISWT and MIST test responses, but not gas exchange parameters. Secondly, both maximum tests were performed on the same day. However, sufficient rest intervals were provided between tests. The tests were conducted a second time when the participants' vital signs returned to baseline levels to ensure the same clinical conditions were maintained for each patient in both tests. Finally, we used a pedometer to assess physical activity levels instead of an accelerometer, which offers a more precise measurement of physical activity intensity. Nevertheless, both accelerometers and pedometers are viable tools for assessing physical activity in individuals with bronchiectasis by tracking daily step counts.[20]

In conclusion, disease severity, quadriceps muscle strength, physical activity levels, and quality of life were independently related to exercise capacity. Although the ISWT is one of the most widely used field tests, the MIST can be preferred to evaluate the exercise capacity of patients with bronchiectasis due to its advantages in generating greater cardiopulmonary responses and requiring less space than the ISWT. Exercise intensity can be calculated, and exercise prescription can be planned by estimating the workload[6] or oxygen consumption[33] with the number of steps taken, which is one of the MIST outcome parameters.

AUTHOR CONTRIBUTIONS

MMB: Investigation, Conceptualization, Methodology, Formal analysis, Writing - Original Draft, Writing - Review & Editing; SS: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing, Supervision; AT: Conceptualization, Methodology, Formal analysis, Writing - Review & Editing; BOK: Conceptualization, Methodology, Formal analysis, Writing - Review & Editing; DG: Conceptualization, Methodology, Resources; CS: Conceptualization, Methodology, Writing - Review & Editing, Resources, Supervision.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

REFERENCES

1. Polverino E, Goeminne PC, McDonnell MJ, Aliberti S, Marshall SE, Loebinger MR, et al. European Respiratory Society guidelines for the management of adult bronchiectasis. Eur Respir J. 2017;50(3):1700629. https://doi.org/10.1183/13993003.00629-2017.
2. Pasteur MC, Bilton D, Hill AT. British Thoracic Society Bronchiectasis non-CF Guideline Group. British thoracic society guideline for non-CF bronchiectasis. Thorax. 2010 Jul 1;65(SUPPL. 1):i1-58. https://doi.org/10.1136/thx.2010.136119.
3. Lee AL, Cecins N, Holland AE, Hill CJ, McDonald CF, Burge AT, et al. Field Walking Tests Are Reliable and Responsive to Exercise Training in People With Non-Cystic Fibrosis Bronchiectasis. J Cardiopulm Rehabil Prev. 2015;35(6):439-45. https://doi.org/10.1097/HCR.0000000000000130.
4. Ozalp O, Inal-Ince D, Calik E, Vardar-Yagli N, Saglam M, Savci S, et al. Extrapulmonary features of bronchiectasis: muscle function, exercise capacity, fatigue, and health status. Multidiscip Respir Med. 2012;7(1):3. https://doi.org/10.1186/2049-6958-7-3.
5. Holland AE, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. Eur Respir J. 2014;44(6):1428-46. https://doi.org/10.1183/09031936.00150314.
6. De Andrade CH, De Camargo AA, De Castro BP, Malaguti C, Dal Corso S. Comparison of cardiopulmonary responses during 2 incremental step tests in subjects with COPD. Respir Care. 2012;57(11):1920-6. https://doi.org/10.4187/respcare.01742.
7. Camargo AA, Lanza FC, Tupinambá T, Corso SD. Reproducibility of step tests in patients with bronchiectasis. Braz J Phys Ther. 2013;17(3):255-62. https://doi.org/10.1590/S1413-35552012005000089.
8. Burge AT, Rodrigues JC Jr, Abramson MJ, Cox NS, Bondarenko J, Webb E, et al. Application of the Modified Incremental Step Test for Pulmonary Rehabilitation. Phys Ther. 2021;101(5):pzab044. https://doi.org/10.1093/PTJ/PZAB044.
9. De Camargo AA, Amaral TS, Rached SZ, Athanazio RA, Lanza FC, Sampaio LM, et al. Incremental shuttle walking test: a reproducible and valid test to evaluate exercise tolerance in adults with noncystic fibrosis bronchiectasis. Arch Phys Med Rehabil. 2014;95(5):892-9. https://doi.org/10.1016/j.apmr.2013.11.019.
10. Yildiz S, Inal-Ince D, Calik-Kutukcu E, Vardar-Yagli N, Saglam M, Arikan H, et al. Clinical Determinants of Incremental Shuttle Walk Test in Adults with Bronchiectasis. Lung. 2018;196(3):343-9. https://doi.org/10.1007/s00408-018-0094-x.
11. Lee AL, Button BM, Ellis S, Stirling R, Wilson JW, Holland AE, et al. Clinical determinants of the 6-Minute Walk Test in bronchiectasis. Respir Med. 2009;103(5):780-5. https://doi.org/10.1016/j.rmed.2008.11.005.
12. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J. 2005;26(2):319-38. https://doi.org/10.1183/09031936.05.00034805.
13. Bestall JC, Paul EA, Garrod R, Garnham R, Jones PW, Wedzicha JA. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. Thorax. 1999;54(7):581-6. https://doi.org/10.1136/thx.54.7.581.
14. Chalmers JD, Goeminne P, Aliberti S, McDonnell MJ, Lonni S, Davidson J, et al. The bronchiectasis severity index. An international derivation and validation study. Am J Respir Crit Care Med. 2014;189(5):576-85. https://doi.org/10.1164/rccm.201309-1575OC.
15. Cartlidge MK, Smith MP, Bedi P, Donaldson S, Clarke A, Mantoani LC, et al. Validation of the Incremental Shuttle Walk Test as a Clinical End Point in Bronchiectasis. Chest. 2018;154(6):1321-9. https://doi.

org/10.1016/j.chest.2018.09.019.

16. Fox EL, Bowers RW, Foss ML. The physiological basis of physical education and athletics. William C. Brown Publication: Philadelphia; 1988:734. p. 435. Disponível em: https://books.google.com.tr/books/about/The_Physiological_Basis_of_Physical_Educ.html?id=b0NOAQAAIAAJ&redir_esc=y.
17. Awotidebe TO, Ativie RN, Oke KI, Akindele MO, Adedoyin RA, Olaogun MO, et al. Relationships among exercise capacity, dynamic balance and gait characteristics of Nigerian patients with type-2 diabetes: an indication for fall prevention. J Exerc Rehabil. 2016;12(6):581-8. https://doi.org/10.12965/jer.1632706.353.
18. Bohannon RW. Test-Retest Reliability of Hand-Held Dynamometry During a Single Session of Strength Assessment. Phys Ther. 1986;66(2):206-9. https://dx.doi.org/10.1093/ptj/66.2.206.
19. Andrews AW, Thomas MW, Bohannon RW. Normative Values for Isometric Muscle Force Measurements Obtained With Hand-held Dynamometers. Phys Ther. 1996;76(3):248-59. https://doi.org/10.1093/ptj/76.3.248.
20. O'Neill B, McDonough SM, Wilson JJ, Bradbury I, Hayes K, Kirk A, et al. Comparing accelerometer, pedometer and a questionnaire for measuring physical activity in bronchiectasis: a validity and feasibility study? Respir Res. 2017;18(1):16. https://doi.org/10.1186/s12931-016-0497-2.
21. Tudor-Locke C, Craig CL, Brown WJ, Clemes SA, De Cocker K, Giles-Corti B, et al. How many steps/day are enough? For adults. Int J Behav Nutr Phys Act. 2011;8:79. https://doi.org/10.1186/1479-5868-8-79.
22. Krupp LB, LaRocca NG, Muir-Nash J, Steinberg AD. The fatigue severity scale. Application to patients with multiple sclerosis and systemic lupus erythematosus. Arch Neurol. 1989;46(10):1121-3. https://doi.org/10.1001/archneur.1989.00520460115022.
23. Wilson CB, Jones PW, O'Leary CJ, Cole PJ, Wilson R. Validation of the St. George's Respiratory Questionnaire in bronchiectasis. Am J Respir Crit Care Med. 1997;156(2 Pt I):536-41. https://doi.org/10.1164/ajrccm.156.2.9607083.
24. Spinou A, Fragkos KC, Lee KK, Elston C, Siegert RJ, Loebinger MR, et al. The validity of health-related quality of life questionnaires in bronchiectasis: a systematic review and meta-analysis. Thorax. 2016;71(8):683-94. https://doi.org/10.1136/thoraxjnl-2015-207315.
25. Polatli M, Yorgancioğlu A, Aydemir Ö, Yilmaz Demirci N, Kirkil G, Atiş Nayci S, et al. St. George solunum anketinin Türkçe geçerlilik ve güvenilirliği. Tuberkuloz ve Toraks. 2013;61(2):81-7. Disponível em: https://toad.halileksi.net/wp-content/uploads/2022/07/st-george-solunum-anketi-toad.pdf.
26. Armutlu K, Korkmaz NC, Keser I, Sumbuloglu V, Akbiyik DI, Guney Z, et al. The validity and reliability of the Fatigue Severity Scale in Turkish multiple sclerosis patients. Int J Rehabil Res. 2007;30(1):81-5. https://doi.org/10.1097/MRR.0b013e3280146ec4.
27. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2. ed. New York: Academic Press; 2013. 567 p.
28. De Camargo AA, Boldorini JC, Holland AE, De Castro RA, Lanza FC, Athanazio RA, et al. Determinants of Peripheral Muscle Strength and Activity in Daily Life in People With Bronchiectasis. Phys Ther. 2018;98(3):153-161. https://doi.org/10.1093/ptj/pzx123.
29. José A, Ramos TM, De Castro RA, De Oliveira CS, De Camargo AA, Athanazio RA, et al. Reduced Physical Activity With Bronchiectasis. Respir Care. 2018;63(12):1498-1505. https://doi.org/10.4187/respcare.05771.
30. Cakmak A, Inal-Ince D, Sonbahar-Ulu H, Bozdemir-Ozel C, Ozalp O, Calik-Kutukcu E, et al. Physical activity of patients with bronchiectasis compared with healthy counterparts: A cross-sectional study. Heart Lung. 2020;49(1):99-104. https://doi.org/10.1016/j.hrtlng.2019.09.004.
31. Probst VS, Hernandes NA, Teixeira DC, Felcar JM, Mesquita RB, Gonçalves CG, et al. Reference values for the incremental shuttle walking test. Respir Med. 2012;106(2):243-8. https://doi.org/10.1016/j.rmed.2011.07.023.
32. King PT, Holdsworth SR, Freezer NJ, Villanueva E, Holmes PW. Characterisation of the onset and presenting clinical features of adult bronchiectasis. Respir Med. 2006;100(12):2183-9. https://doi.org/10.1016/j.rmed.2006.03.012.
33. Dal Corso S, De Camargo AA, Izbicki M, Malaguti C, Nery LE. A symptom-limited incremental step test determines maximum physiological responses in patients with chronic obstructive pulmonary disease. Respir Med. 2013;107(12):1993-9. https://doi.org/10.1016/j.rmed.2013.06.013.
34. Dreher M, Walterspacher S, Sonntag F, Prettin S, Kabitz HJ, Windisch W. Exercise in severe COPD: is walking different from stair-climbing? Respir Med. 2008;102(6):912-8. https://doi.org/10.1016/j.rmed.2008.01.002.
35. Hadeli KO, Siegel EM, Sherrill DL, Beck KC, Enright PL. Predictors of oxygen desaturation during submaximal exercise in 8,000 patients. Chest. 2001;120(1):88-92. https://doi.org/10.1378/chest.120.1.88.
36. Dal Corso S, Duarte SR, Neder JA, Malaguti C, De Fuccio MB, De Castro Pereira CA, et al. A step test to assess exercise-related oxygen desaturation in interstitial lung disease. Eur Respir J. 2007;29(2):330-6. https://doi.org/10.1183/09031936.00094006.
37. Ross RM. ATS/ACCP statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med. 2003;167(10):1451. https://doi.org/10.1164/ajrccm.167.10.950.
38. McKeough ZJ, Large SL, Spencer LM, Cheng SW, McNamara RJ. An observational study of self-reported sedentary behaviour in people with chronic obstructive pulmonary disease and bronchiectasis. Braz J Phys Ther. 2020;24(5):399-406. https://doi.org/10.1016/j.bjpt.2019.05.005.
39. Karpman C, Benzo R. Gait speed as a measure of functional status in COPD patients. Int J Chron Obstruct Pulmon Dis. 2014;9:1315-20. https://doi.org/10.2147/COPD.S54481.
40. DePew ZS, Karpman C, Novotny PJ, Benzo RP. Correlations between gait speed, 6-minute walk distance, physical activity, and self-efficacy in patients with severe chronic lung disease. Respir Care. 2013;58(12):2113-9. https://doi.org/10.4187/respcare.02471.