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Validity and reliability of 6-minute pegboard and ring test in patients with asthma

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ABSTRACT

Objective: The 6-minute pegboard and ring test (6PBRT) is a test of upper-extremity functional capacity designed for and validated in chronic obstructive pulmonary disease. The aim of this study was to evaluate the validity and reliability of the 6PBRT in asthma patients.

Methods: Thirty-four adults (30 women, 4 men) with well-controlled asthma were included. Unsupported upper-extremity exercise capacity was assessed using 6PBRT, maximal arm exercise capacity using an arm ergometer, handgrip strength using a hand dynamometer, activities of daily living with the London Chest Activities of Daily Living Scale (LCADL), Milliken ADL scale (MAS) and health-related quality of life using the Asthma Quality of Life Questionnaire (AQLQ) and Health Assessment Questionnaire Disability Index (HAQ-DI).

Results: The 6PBRT showed moderate to excellent test-retest reliability with an intraclass correlation coefficient (ICC) value of 0.872 [95% confidence interval (CI) 0.702–0.941]. The 6PBRT was reproducible according to Bland–Altman analysis, with upper and lower limits of agreement of 53.51 and –25.08 rings moved, respectively. The 6PBRT score was significantly correlated with maximum workload ($r=0.514$, $p=0.002$) achieved in the arm ergometer test, change in dyspnea during 6PBRT ($r=-0.402$, $p=0.020$), LCADL-self-care ($r=-0.364$, $p=0.037$), MAS total ($r=0.483$, $p=0.005$), AQLQ-symptom domain ($r=0.420$, $p=0.026$) and HAQ-DI total scores ($r=-0.390$, $p=0.025$).

Conclusions: The 6PBRT can be used as a valid and reliable test to evaluate functional arm exercise capacity in patients with well-controlled asthma.

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6PBRT; asthma; arm exercise endurance; activities of daily living

Introduction

Asthma is a heterogeneous disease characterized by chronic inflammation of the lower airways and associated with airway hyperresponsiveness to a variety of direct or indirect stimuli (1–3). Symptoms due to asthma including wheezing, shortness of breath, coughing, and chest tightness may be episodic or persistent in patients with asthma (2,3).

Patients with asthma often exhibit exercise intolerance, exertional dyspnea, fatigue, limitations in activities of daily living (ADLs), and impaired quality of life (4). Exercise-related respiratory symptoms are known to have adverse effects on ADLs in asthma

and nearly half of patients with asthma avoid physical activities because of these symptoms (5). Accordingly, patients with asthma are prone to physical inactivity, which results in reduced muscle mass, decline in exercise capacity, deconditioning and poorer asthma control (6,7). In addition, prolonged oral corticosteroid use also can lead to peripheral and respiratory muscle weakness in patients with severe asthma (6).

Carter et al. showed that although similar dyspnea and effort perception scores for arms and legs, metabolic demand for arm work increases in obstructive lung disease patients (8). Otherwise, pulmonary function tests, 6-min walk test distance and cardiopulmonary

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exercise tests were not significantly associated with perceived activity limitation in asthma patients (9). There is a need for reliable and practical functional arm test that reflects limitation in ADLs for patients with asthma.

The 6PBRT is shown to be valid and reliable in patients with stable or acute exacerbation of chronic obstructive pulmonary disease (COPD) and in healthy adults (10–12). However, there is no study evaluating arm endurance using the 6PBRT or investigating the validity and reliability of this test in patients with asthma. Because a close relationship was found between 6PBRT score and upper-extremity ADLs in COPD (13) and cardiopulmonary exercise test (CPET) was not found to be associated with activity limitation in patients with asthma (9), we posited that if the 6PBRT is shown to be reliable and valid in asthma patients, it would give chest physicians a practical method with which to understand problems such as exertional dyspnea and fatigue in arm-based tasks and refer patients for pulmonary rehabilitation when necessary. Therefore, this study aimed to evaluate the reliability and validity of the 6PBRT in patients with well-controlled asthma and determine the utility of the test for this patient population.

Materials and methods

Ethics and participants

This study was conducted in the Hacettepe University Faculty of Physical Therapy and Rehabilitation between March 2019 and February 2020. Patients with well-controlled asthma were recruited from the Hacettepe University Faculty of Medicine, Department of Chest Diseases, Division of Adult Allergy & Clinical Immunology. The study was approved by the Hacettepe University Non-Interventional Clinical Research Ethics Committee (March 6, 2018, GO 18/206–24) and is registered at ClinicalTrials.gov (NCT03693664). Written informed consent was obtained from each participant.

Inclusion criteria were being between the ages of 18 and 80 years, having well-controlled asthma with no acute exacerbations in the last 3 months, volunteering to participate in the study, and being ambulatory and cooperative with assessments. Asthma diagnosis was based on the characteristic pattern of respiratory symptoms and variable expiratory flow limitation according to the recent Global Initiative for Asthma (GINA) guideline (3). Asthma control was primarily determined by a chest physician based on asthma symptom control and risk factors for poor asthma outcomes. Asthma control was evaluated using

the Asthma Control Test (ACT). The ACT is a patient-based tool in which the following 5 items are rated according to the last 4 weeks: (1) limitation at work, school, or home, (2) shortness of breath, (3) waking up at night or earlier in the morning due to asthma symptoms, (4) frequency of using rescue inhaler or nebulizer medication, and (5) asthma control. A total score of 20–25 is regarded as well-controlled, 16–19 as not well-controlled, and 5–15 as very poorly controlled asthma (3,14). Patients using inhaled corticosteroid (ICS)-formoterol combination as needed or low-dose ICS and short-acting beta 2 agonist as needed were accepted as receiving step 1 treatment, while patients receiving higher dose ICS and long-acting beta 2 agonist combinations and other add-on therapies like montelukast, tiotropium, biological agents available in Turkey, or oral corticosteroid based on asthma control levels were accepted as receiving step 2–5 treatment according to GINA (3). Exclusion criteria were uncontrolled asthma, any neurological disease or other clinical diagnoses that may affect cognitive status, musculoskeletal and neurological diseases, symptomatic heart disease, previous lung surgery, and malignancy that may affect exercise performance.

To evaluate the validity of the 6PBRT according to maximum workload achieved in the arm ergometry test, the required sample size was calculated based on pilot study data using the Deming regression method. A power analysis program (G*Power, ver. 3.1., Universität Düsseldorf, Düsseldorf, Germany) was used to calculate the sample size. For 90% power to detect a correlation coefficient of at least 0.5 with 5% type I error, the required sample size was 24. Therefore, we determined that the study would be completed with at least 30 patients to allow for drop-outs (15).

Procedure and measurements

In the first evaluation, a detailed medical history including asthma-related symptoms, family history, and clinical findings was taken and pulmonary function test was performed. Initial assessments consisted of handgrip strength measurements, unsupported arm exercise capacity (6PBRT), maximal arm exercise capacity, asthma control, ADLs and health-related quality of life. The 6PBRT was applied before the arm ergometer test during the initial visit for each patients. There was a 30-min interval between the first 6PBRT and arm ergometer test. One week later, the same therapist performed the second 6PBRT test for reliability analysis.

Respiratory muscle strength values (maximal inspiratory pressure-MIP and maximal expiratory pressure-MEP) were measured using a portable electronic mouth pressure device (Micro Medical MicroMPM, United Kingdom). The best value of the three measurements that had no more difference than 10% or 10 cmH₂O was recorded. Measurements were expressed as percentage of the expected value according to the age and gender (16).

Handgrip strength was measured according to the recommendations of the American Hand Therapists Association using a Jamar hand dynamometer (Fabrication Enterprises, New York, USA), a valid and reliable instrument for measuring peripheral muscle strength (17,18). Measurements were performed 3 times for the right and left sides with the patient in sitting position with shoulder in adduction, elbow at 90° flexion, and forearm in neutral position. The highest value on each side was recorded in kg and dominant side strength was used for analysis. Results were expressed as percentage of predicted values based on reference values (18).

Functional arm exercise capacity was assessed using the 6PBRT. During the test, the patient is asked to sit in front of a pegboard and move as many rings as possible from 2 lower pegs placed at shoulder level to the 2 upper pegs (20 cm above) and back down again using both hands simultaneously for a period of 6 min. Participants were familiarized with the test by moving several rings before the real test. During the test, the physiotherapist gave standardized encouragement at 1-min intervals (12). The total number of rings moved in 6 min was recorded as the final score and also expressed as a percentage of predicted value based on reference values. The predicted number of rings moved was calculated using the formula $676.34 - (4.223 \times \text{age})$ (19). Before and after the test, HR and oxygen saturation (SpO₂) were measured using a pulse oximeter (Nonin Model 2500 C, Nonin Medical, Inc., Plymouth, MN, USA), dyspnea and arm fatigue were assessed with the Modified Borg Scale (0–10 points), and systolic (SBP) and diastolic (DBP) blood pressure were measured using an aneroid sphygmomanometer (Erka, Bad Tölz, Germany) (12).

Maximal arm exercise capacity was evaluated using an arm ergometer. The symptom-limited exercise test was performed and used as a criterion for the validity of the 6PBRT. For the arm ergometer test, the patient was seated upright with the crank axle positioned at shoulder height. As in the 6PBRT, the patients' HR, SpO₂, dyspnea, arm fatigue, SBP, and DBP were recorded before and after the arm ergometer test. After initial values were taken, the patient was asked

to start rotating the arm ergometer with a workload of 0 watt (W) and a speed of 60–75 rpm, and the workload was increased by 10 W every 2 min (20). Modified Borg Scale (0–10 points) scores were recorded before each workload increase to assess perceived arm fatigue and dyspnea. HR and SpO₂ values were monitored using a portable pulse oximeter throughout the test. When the patient reached one of the test termination criteria, the test was terminated and the maximum workload reached (in W) and the reason for terminating the test were recorded (20). In addition, we calculated the MET reached at the end of the test for each participant based on The American College of Sports Medicine (ACSM)'s metabolic equations (21).

Activities of daily living were evaluated using the Turkish version of the London Chest Activities of Daily Living Scale (LCADL) questionnaire and Milliken ADL scale (MAS). The LCADL is a valid and reliable measurement of dyspnea during daily activities in chronic lung diseases (22). The LCADL has 15 items in four main components: self-care (drying, dressing the upper body, putting shoes/socks on, and washing hair), domestic activities (making beds, changing sheet, washing windows/curtains, cleaning/dusting, washing up and vacuuming/sweeping), physical activities (walking upstairs and bending), and leisure time (walking in-home, going out socially, and talking). Total score ranges between 0 and 75. Higher scores reflect more significant dyspnea and limitation during daily activities (22).

The MAS is a self-report questionnaire as a measure of arm activity limitation that includes 47 items related with bilateral and unilateral tasks requiring both gross and fine motor skills. The MAS is divided into six sections that represents arm tasks: Meal preparation and eating, personal hygiene, dressing, object manipulation, housecleaning and laundry and other activities. Total score that is derived by summing the total scores of all six sections ranges from 47 to 235. The higher scores indicate less restricted upper limb activities (23).

Health-related quality of life was assessed using the Asthma Quality of Life Questionnaire (AQLQ). The AQLQ is a disease-specific health-related quality of life instrument that assesses the physical and emotional impacts of asthma. This self-applicable questionnaire consists of 32 items within 4 domains: symptoms (11 items), activity limitation (12 items, 5 of which are individualized), emotional functioning (5 items), and environmental exposure (4 items). Based on recall of the last two weeks, each item is

scored on a 7-point Likert-type scale (1=always to 7=not restricted). The overall score is calculated as the mean of all items, with higher scores indicating better quality of life (24).

Health status was evaluated with Health Assessment Questionnaire disability index (HAQ-DI). The HAQ-DI includes 20 items that assess fine movements of the upper extremity, locomotor activities of the lower extremity, and activities that involve both the upper and lower extremities. The HAQ-DI contains eight functional activity categories (dress, arise, eating, walking, hygiene, reach, grip, and activities) and also takes into account the use of aids and devices or any assistance from another person. The total score is calculated as overall score divided by number of responded questions and ranges from 0–3. The total scores of 0 to 1 generally represent mild to moderate difficulty, 1 to 2 represent moderate to severe disability, and 2 to 3 indicate severe to very severe disability (25).

Body awareness was also evaluated with the Turkish version of the Questionnaire (BAQ). The total score ranges from 18–126. Higher scores indicate increased body awareness (26).

Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics 23.0 (SPSS, Chicago, IL, USA). The variables were tested for normal distribution using visual (histograms/probability plots) and analytical methods (Shapiro–Wilk test). Descriptive data were presented as mean and standard deviation (SD) or number and frequencies as appropriate.

Test–retest reliability and reproducibility

Bland–Altman analysis, intraclass correlation coefficients (ICC), and 95% confidence intervals (CI) were analyzed based on a single-measurement, absolute agreement, 2-way mixed-effects model. Values less than 0.50 indicate poor reliability, values between 0.50 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability, and values greater than 0.90 indicate excellent reliability (27). The standard error of measurement (SEM) and the minimum detectable change (MDC) were calculated with the following formulas (28):

$$SEM = SD\sqrt{1 - ICC} \text{ and } MDC = SEM \times 1.96 \times \sqrt{2}$$

(SD: pooled standard deviation).

To evaluate the reliability of 6PBRT, paired t-test and Wilcoxon test were also used to compare normally distributed and non-normally distributed variables, respectively.

Validity

Convergent validity was determined by correlation analysis between the 6PBRT and maximal arm exercise capacity, pulmonary function, handgrip strength, LCADL, MAS, AQLQ domains, HAQ-DI and symptoms during the 6PBRT. Correlations between 6PBRT results and other variables were examined using Pearson's correlation coefficients or Spearman rank test under parametric or non-parametric test conditions, respectively. Correlation coefficients were interpreted as negligible (0–0.25), weak (0.26–0.49), moderate (0.50–0.69), strong (0.70–0.89), and very strong (0.90–1.00) (29). A multiple linear regression analysis with backward elimination was also carried out to identify independent predictors of 6PBRT score and %6PBRT (30). P values less than 0.05 were considered statistically significant.

Results

Demographic and clinical characteristics

A total of 43 patients with well-controlled asthma were assessed for eligibility. Seven patients declined to participate and 2 patients with exacerbation history in the previous 3 months were excluded. Therefore, 34 patients (30 women, 4 men) with a mean age of 43.38 ± 14.72 years were included in this study. The demographic and clinical characteristics of the patients are presented in Table 1.

Reliability and reproducibility

The 6PBRT showed moderate to excellent test–retest reliability with an ICC of 0.872 (95% CI 0.702–0.941). The SEM was 13.16 and MDC was 36.47 (Table 2). There was an increase in the 6PBRT score between the first and second test ($p=0.003$) and the scores were strongly correlated ($r=0.897$, $p<0.001$). Mean 6PBRT scores in both tests were significantly lower than the mean predicted score (246.35 ± 31.16) ($p<0.05$). There were no significant differences in the changes in HR, SpO₂, SBP, DBP, dyspnea, and arm fatigue perception recorded in the first and second 6PBRT ($p>0.05$) (Table 3). Figure 1 represents 6PBRT test–retest reliability and reproducibility in Bland–Altman analysis for 6PBRT scores in patients with

Table 1. Demographic and clinical features of the patients ($n=34$).

	Mean $\pm$ SD	Min–Max
Age (years)	43.38 $\pm$ 14.72	20–74
Body mass index (kg/cm ²)	27.00 $\pm$ 5.50	18.31–37.46
Smoking history (pack-years)	4.10 $\pm$ 7.20	0–30
MMRC (0–4)	0.80 $\pm$ 0.70	0–2
Pulmonary function		
FEV ₁ (%)	96.00 $\pm$ 13.60	86–122
FEV _{1post} (%)	110.50 $\pm$ 10.86	95–126
FVC (%)	100.33 $\pm$ 8.29	90–113
FVC _{post} (%)	110.00 $\pm$ 10.58	100–128
FEV ₁ /FVC	87.50 $\pm$ 14.76	77.70–117
FEV ₁ /FVC _{post}	85.43 $\pm$ 5.11	81–94
FEF _{25–75%} (%)	78.60 $\pm$ 16.38	58–103
FEF _{25–75%} post (%)	105.25 $\pm$ 29.74	69–132
ACT score	21.40 $\pm$ 1.70	0–25
Respiratory muscle strength		
MIP (cmH ₂ O)	76.27 $\pm$ 20.12	38–125
%MIP	89.26 $\pm$ 22.91	44.82–157.46
MEP (cmH ₂ O)	93.24 $\pm$ 20.26	48–147
%MEP	60.06 $\pm$ 13.00	31.79–87.57
Handgrip strength		
Right (kg)	21.50 $\pm$ 6.80	11–40
Right (%)	52.33 $\pm$ 14.42	25.89–88.59
Left (kg)	20.40 $\pm$ 6.84	11–40
Left (%)	49.18 $\pm$ 13.53	27.91–88.59
ADLs		
LCADL-Self-care score	4.76 $\pm$ 3.26	0–14
LCADL-Domestic score	8.58 $\pm$ 5.30	0–21
LCADL-Physical score	3.70 $\pm$ 1.96	0–10
LCADL-Leisure score	2.64 $\pm$ 1.37	0–5
LCADL-Total score	19.55 $\pm$ 10.82	1–49
MAS Total score	219.56 $\pm$ 23.29	149–235
Quality of life		
AQLQ-Activity limitation	50.79 $\pm$ 10.46	28–69
AQLQ-Symptoms	55.60 $\pm$ 14.12	24–76
AQLQ-Emotional function	26.57 $\pm$ 6.89	9–35
AQLQ-Environmental stimuli	13.79 $\pm$ 6.04	4–24
AQLQ-Total score	148.18 $\pm$ 32.20	65–200
HAQ-DI Total score	3.64 $\pm$ 4.72	0–18
BAQ Total score	98.61 $\pm$ 15.37	63–126
	n	%
Daily medications		
None (As-needed)	13	38.3
Short-Acting β 2 Agonists	8	23.5
Long-Acting β 2 Agonists	4	11.8
Inhaled Corticosteroids	9	26.4
Asthma-related variables		
Family history	14	41.2
Childhood asthma	4	11.8
Allergic rhinitis	10	29.4
Sinusitis	1	2.9
Atopy	13	38.2
Smoking status		
Never Smoked	21	61.8
Current Smoker	3	8.8
Ex-smoker	10	29.4

MMRC, Modified medical research council; FEV₁, Forced expiratory volume in one second; FVC, Forced vital capacity; FEF_{25–75%}, Forced expiratory flow between 25% and 75% of FVC; ACT, Asthma Control Test; MIP, Maximal inspiratory pressure; MEP, Maximal expiratory pressure; ADLs, Activities of daily living; LCADL, London Chest Activities of Daily Living Scale; MAS, Milliken ADL Scale; AQLQ, Asthma Quality of Life Questionnaire; HAQ-DI, Health Assessment Questionnaire Disability Index; BAQ, Body Awareness Questionnaire.

asthma. The results showed that 6PBRT was reproducible, with upper and lower limits of agreement of 53.51 and –25.08 rings moved, respectively.

Table 2. Test–retest reliability of the 6PBRT in patients with asthma.

6PBRT	ICC	95% CI	p value	SEM	MDC
	0.872	0.702–0.941	<0.001	13.16	36.47

6PBRT, 6-min pegboard ring test; ICC, Intraclass correlation coefficient; CI, Confidence interval; SEM, Standard error of measurement; MDC, Minimal detectable change.

Validity

6PBRT score was significantly correlated with maximum workload ($r=0.514$, $p=0.002$) during the arm ergometer test and change in dyspnea during the 6PBRT ($r=-0.402$, $p=0.020$). In addition, there was a significant relationship between 6PBRT score and the LCADL-self-care ($r=-0.364$, $p=0.037$), MAS total ($r=0.483$, $p=0.005$), AQLQ-symptom domain ($r=0.420$, $p=0.026$) and HAQ-DI total scores ($r=-0.390$, $p=0.025$). %6PBRT score was also significantly correlated with maximum workload ($r=0.355$, $p=0.040$) and LCADL-leisure score ($r=-0.472$, $p=0.006$). Arm ergometer maximum workload, change in dyspnea during the 6PBRT, LCADL-self care, and AQLQ-symptom domain scores were significant and independent predictors of 6PBRT score ($R^2=0.353$, $F(4-27)=3.142$, $p=0.034$) according to multiple linear regression analysis. In addition, multiple linear regression analysis revealed that arm ergometer maximum workload and LCADL-leisure score were significant and independent predictors of %6PBRT ($R^2=0.372$, $F(2-32)=8.880$, $p=0.001$).

Discussion

To the best of our knowledge, the present study is the first to evaluate test–retest reliability, reproducibility, and validity of the 6PBRT in patients with asthma. Our results showed moderate to excellent test–retest reliability and weak to moderate convergent validity of the 6PBRT through the correlations with the maximal workload achieved in the arm ergometer test, change in dyspnea during the 6PBRT, self-care ADLs, arm activity limitations during ADLs, symptom-related quality of life and general health status. The 6PBRT can be used as a valid and reliable measure of functional arm exercise capacity in patients with well-controlled asthma and two tests should be performed at a 30-min interval to have better scores due to familiarization of the patients (19).

The arm ergometer is a standardized method for evaluating maximal supported arm exercise capacity and endurance (31). However, when choosing test

Table 3. Comparison of 6BPRT results in patients with asthma (within tests and between tests).

6BPRT	Test 1				Test 2				p,z,t
	Median ± SD				Median ± SD				
Number of rings moved	184.08 ± 37.19				193.17 ± 36.40				0.003 ^z
Percentage of predicted (%)	75.53 ± 16.15				79.38 ± 16.84				0.004 ^z
	Pre-test	Post-test	p ^{x,y}	Δ	Pre-test	Post-test	p ^{x,y}	Δ	
	Median ± SD	Median ± SD			Median ± SD	Median ± SD			
Heart rate (bpm)	85.45 ± 12.90	96.69 ± 13.45	<0.001 ^x	11.24 ± 9.86	84.24 ± 17.09	97.78 ± 11.00	<0.001 ^x	13.54 ± 14.67	0.687
Oxygen saturation (%)	96.27 ± 6.18	96.90 ± 1.46	0.340 ^y	0.63 ± 6.27	95.45 ± 3.54	97.06 ± 1.17	0.018 ^y	1.60 ± 3.78	0.654
Systolic pressure (mmHg)	121.13 ± 9.11	130.68 ± 8.63	<0.001 ^y	9.54 ± 7.70	125.00 ± 8.06	132.85 ± 7.83	0.001 ^y	7.85 ± 8.30	<0.001
Diastolic pressure (mmHg)	80.45 ± 9.11	83.86 ± 7.38	0.040 ^y	3.40 ± 7.13	81.19 ± 9.34	85.23 ± 5.80	0.019 ^y	4.04 ± 6.04	0.012
Dyspnea (MBS)	0.36 ± 0.75	1.30 ± 1.66	<0.001 ^y	0.77 ± 1.13	0.83 ± 1.79	2.03 ± 2.58	0.001 ^y	1.19 ± 2.84	0.124
Arm fatigue (MBS)	1.39 ± 1.61	5.84 ± 3.07	<0.001 ^y	4.45 ± 2.89	1.66 ± 2.33	5.96 ± 2.92	<0.001 ^y	4.30 ± 2.99	0.981

^xPaired Student's t-test was performed to compare normally distributed variables within tests (pre- versus post-test).

^yWilcoxon test was performed to compare non-normally distributed variables within tests (pre- versus post-test).

^zPaired Student's t-test was performed to compare normally distributed variables between tests (Test 1 versus Test 2).

¹Wilcoxon test was performed to compare non-normally distributed variables between tests (Test 1 versus Test 2).

Statistically significant results indicated in bold ($p < 0.05$).

6BPRT, 6-min pegboard ring test; MBS, Modified Borg Scale (0–10 point); Δ , Pre- to post-test change.

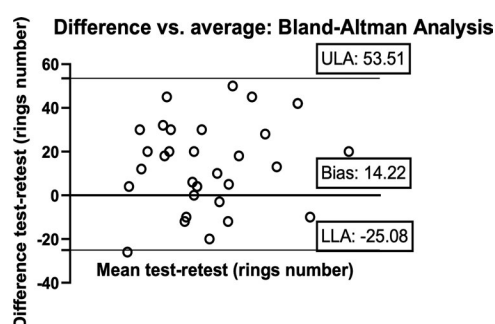


Figure 1. Bland–Altman plots depicting the agreement between 6BPRT tests (tests 1 and 2). ULA, Upper limit of agreement; LLA, Lower limit of agreement.

methods in clinical practice, the patient's tolerance and test features such as ease of application in rehabilitation clinics, reliability, or validity must also be taken into consideration (31). The 6BPRT is a practical test that better reflects performance of ADLs involving arm functions. It is commonly used to assess unsupported arm exercise endurance and upper limb exercise capacity in COPD (31) and was reported to be reliable and valid both in stable patients and those with acute exacerbation of COPD (11,12).

To evaluate the convergent validity of the 6BPRT, we investigated correlations between 6BPRT score and maximal arm exercise capacity, pulmonary function, handgrip strength, LCADL components and total scores, AQLQ total and subdomain scores, MAS and HAQ-DI total scores and perceived dyspnea and arm fatigue during the 6BPRT. There were weak to moderate relationships between 6BPRT and maximal workload in arm ergometer exercise test, LCADL-self-care score, MAS total score, AQLQ-symptom domain, HAQ-DI total score and perceived dyspnea during the 6BPRT. The percentage of predicted 6BPRT values based on normative values were also related with

maximal workload and leisure time ADLs. These findings confirmed the validity of the 6BPRT in the asthma population and its association with ADLs, as in patients with COPD (12,13). Zhan et al. showed that the 6BPRT was a valid test of arm exercise capacity based on its association with respiratory function test parameters in patients with COPD (12). Janaudis-Ferreira et al. (32) and Ozsoy et al. (33) reported that there was a positive correlation between the 6BPRT score and peripheral muscle strength. In another study, 6BPRT score was associated with dyspnea and fatigue during ADLs in hospitalized patients with acute exacerbation of COPD (11). Unlike the findings in COPD, we did not observe a significant relationship between 6BPRT and pulmonary functions or peripheral muscle strength in patients with asthma. Airflow limitation and reduced pulmonary function may affect exercise capacity in patients with COPD (34). The better pulmonary function in our asthmatic patients may explain the absence of an association between these parameters and 6BPRT score. Otherwise, Nyberg et al. demonstrated that the relationship between shoulder muscle endurance and 6BPRT score was significant when controlled for muscle strength (35). Because the 6BPRT requires repetitive unsupported overhead arm movements in which people keep their shoulders flexed at 90°, we believe that the lack of a relationship between handgrip muscle strength and 6BPRT score is an expected finding in accordance with the literature. The 6BPRT score was reported to be weakly and positively associated with ADLs scores in healthy Canadian population (36). Significant associations were also reported between 6BPRT score and arm activity monitor count and score in patients with mild to very severe COPD, and it was concluded that the 6BPRT could be used as a predictive test for upper-extremity ADLs in

pulmonary rehabilitation programs (13). Our study also demonstrated that 6PBRT score was related to maximal workload achieved during tests, dyspnea perception during self-care ADLs, arm activity limitations during ADLs, perceived dyspnea during unsupported arm activity, symptom-related quality of life and health status. Therefore, the 6PBRT may be a valid and useful upper extremity exercise test in well-controlled asthma to provide information regarding predominantly arm-based tasks and dyspnea/fatigue perceptions related to these tasks.

The 6PBRT was reported to have a high test-retest ICC value in healthy individuals (0.91 [0.85–0.94]) (10). Zhan et al. also determined a high correlation between the 6PBRT test and retest scores in their study with COPD patients ($r=0.91$) (12). Recent data also confirmed that the 6PBRT had excellent test-retest reliability (ICC = 0.98) in patients with pulmonary hypertension (37). Our study supported the literature, demonstrating good test-retest reliability in asthma patients with an ICC value of 0.872 (95% CI 0.702–0.941). Otherwise, the 6PBRT retest score was higher than the original test score in our study. Lima et al. also found an increase in retest scores in healthy subjects (10), whereas Zhan et al. reported no difference between 6PBRT test and retest scores in COPD patients (12). Better performance during the second test may be attributed to the learning effect. It was also shown that participants find a more effective way of holding the rings after the first test (10). In our population, the higher score in the second test could also be related to the learning effect similar to healthy individuals. Therefore, two tests should be performed at a 30-min interval to have better scores due to familiarization of the patients.

Despite the statistically significant difference between test-retest 6PBRT scores, the mean difference of 9.09 ± 16.75 was lower than the MDC value, which was 36.47. In the literature, increases in HR, SBP, DBP, and perceived dyspnea and arm fatigue were shown in healthy persons (10) and COPD patients during the 6PBRT (12). Physiological parameters and perceived dyspnea and arm fatigue also increased from before to after both 6PBRTs in the present study. These increases support the ability of the 6PBRT to assess upper extremity exercise capacity because it can increase physiological load.

Reference values for the 6PBRT were reported as 414.85 rings in healthy Brazilian people in the same age group as our study group (19), 404.7 for Canadian adults (36) and 248.88–412.44 rings for women and 291.55–447.11 rings for men according to different age groups in the healthy Indian population (38). Another study reported a score of 128.4 rings in older COPD patients (33), while Zhan et al. reported the mean

number of rings moved as 149 ± 30.9 in the first test and 152 ± 37.1 in the retest in COPD patients (12). We used the same calculation system for the 6PBRT score as described by the developers (12). The reference values reported in healthy populations were scores multiplied by two (19,36). For this reason, we used corrected reference values of 207 and 202, respectively, in our study. The mean numbers of rings moved in both 6PBRT tests in our study were slightly lower (184.04 in the first test and 193.17 in the second test) than predicted values calculated according to reference values in healthy adults (19,36). Otherwise, mean 6PBRT scores of our patients with asthma were better than reported mean scores for COPD patients in the literature (12). This could be attributed to the normal lung function in asthma patients, unlike the irreversible persistent airflow limitation in COPD that limits unsupported arm performance due to higher ventilatory demand during arm tasks (39). Although no correlation was shown between the 6PBRT score and gender (19), it was reported in the literature that men have larger type I fiber areas than women in both upper and lower extremity muscles (40). Because most of our patients were female and 6PBRT performance is mostly related with muscle endurance (36), this would affect the fatigability of muscles and explain the lower arm performance according to reference values. Because the reference values in healthy populations are scores multiplied by two (19,36), this situation should be considered when the patient's upper extremity performance is interpreted according to these reference values.

A limitation of this study was that only patients with well-controlled asthma were included. The lack of data on the responses of patients with uncontrolled asthma limits the generalizability of this study's results. In addition, most of the patients (88.2%) were female, as expected in asthma, and this might limit the usefulness of the test in males. Another limitation was that we didn't perform two 6PBRT tests during first and second visit. Although the most of previous findings related with the 6PBRT didn't implicate any learning effect (12,38), our participants performed better in the second test. This finding demonstrates that two tests should be performed to have better scores due to familiarization of the patients with well-controlled asthma.

The findings of this study showed that 6PBRT has moderate to excellent test-retest reliability, reproducibility, and convergent validity in patients with asthma. Higher 6PBRT scores are associated with greater maximal arm exercise capacity, lower perceived dyspnea during unsupported arm activities and self-care ADLs, less arm activity limitations during ADLs and better health-related quality of life

associated with lower symptom perception and better health status. The 6PBRT is a feasible, easily administrable, valid, reproducible, and reliable measurement of functional arm exercise capacity and can be used in clinical practice for quick assessment for arm performance and perceived dyspnea and arm fatigue during arm activities. The 6PBRT is also useful for chest physicians for determining which patients with well-controlled asthma should be referred to rehabilitation professionals in order to increase their arm performance and decrease symptoms related to arm-based tasks.

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Declaration of interest

None declared.

Trial registration

Clinicaltrials.gov: NCT03693664.

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