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Original Article

Comparative Analysis of Functional Capacity Improvements Through 6MWD Testing Across Different Respiratory Conditions: Implications for Targeted Pulmonary Rehabilitation

Sneha Chacko*, Gaurang Shah

Department of Pharmacology L. M. College of Pharmacy, Ahmedabad, Gujarat, INDIA, INDIA.

ABSTRACT

Background: The 6-Min Walk Distance (6MWD) test is widely used to assess functional capacity in respiratory patients, but response patterns across different respiratory conditions remain poorly understood. **Materials and Methods:** 115 patients (29 Asthma, 46 COPD, 40 ILD) underwent 6MWD testing before and after pulmonary rehabilitation. Changes in distance, heart rate, and oxygen saturation were analyzed across diagnostic groups. **Results:** Mean 6MWD improved from 363.90 m to 375.26 m post-rehabilitation. Asthma patients showed the most significant improvement (30 m increase), followed by COPD (8 m increase), while ILD patients showed minimal change. Heart rate and SpO_2 changes during testing showed no significant differences pre- and post-rehabilitation (p>0.05). Diagnostic category significantly influenced improvement patterns (p<0.05). **Conclusion:** The effectiveness of pulmonary rehabilitation on functional capacity varies significantly across respiratory conditions, with asthma patients showing the most marked improvements. These findings suggest the need for condition-specific rehabilitation protocols and indicate that 6MWD improvements may not be a universally appropriate primary outcome measure across all respiratory conditions.

Keywords: 6MWD, Pulmonary Rehabilitation, Asthma, COPD, ILD.

Correspondence:

Ms. Sneha Chacko

Assistant Professor, Department of Pharmacology L. M. College of Pharmacy Ahmedabad, Gujarat, INDIA.

Email: saumyasneha@gmail.com

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INTRODUCTION

The 6-Min Walk Distance (6MWD) test is becoming a crucial assessment parameter when evaluating patients' functional ability with respiratory diseases (Holland *et al*., 2014a; Singh *et al*., 2014). Very much like habitual tasks 6MWD, a submaximal workout test, provides significant insights into patients' practical restrictions and therapeutic effects (Dantes *et al*., 2019; Singh *et al*., 2014). Although pulmonary rehabilitation is widely implemented in several clinics, uncertainty persists regarding the influence of various respiratory impairments on test results, along with patterns of response (Candemir, 2018; Spruit *et al*., 2015).

The effectiveness of pulmonary rehabilitation in increasing exercise capacity, decreasing symptoms, and improving quality of life has been established in many pulmonary conditions (Mccarthy *et al*., 2015; Spruit *et al*., 2013). The degree of such changes and the underlying mechanisms, however, are likely to differ widely according to the primary pathophysiology involved in respiratory disease (McNamara *et al*., 2019). In contrast to the progressive airflow limitation in Chronic Obstructive Pulmonary Disease (COPD) or the restrictive ventilatory defects and gas exchange abnormalities in Interstitial Lung Disease (ILD), asthma represents a relatively unique pathophysiological state of reversible airflow limitation and airway hyperresponsiveness (Gloeckl *et al*., 2013; Raghu *et al*., 2015). These pathophysological differences have thrown into question the validity of standardized approaches to rehabilitation and the selection of outcome measures in different diagnostic groups (Dowman *et al*., 2014; Neder *et al*., 2019). While the 6MWD test has been established for multiple respiratory illnesses, it might reiterate diverse physiologic limitations and compensatory mechanisms among patients with ILD, COPD and asthma (Andrianopoulos *et al*., 2015; Bahmer *et al*., 2017).

Here, we aim to fill this knowledge gap by providing an evidence-based comparison of the functional capacity improvements to the 6MWD test across a heterogeneous cohort of asthmatic, COPD and ILD patients participating in a standardized pulmonary rehabilitation program. Through

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the analysis of variations in walking distance, changes in heart rate responses and changes in oxygen saturations through the course of exercise, we aim to identify physiological response patters specific to condition, which may inform a more tailored approach to rehabilitation. Understanding these differences might help develop more tailored rehabilitation approaches and matching outcomes based on diagnostic category (Holland *et al.*, 2014b; Spruit *et al.*, 2013).

MATERIALS AND METHODS

Study Design and Participants

This was a prospective cross-sectional study from June 2022 to June 2024 done at Sparsh Chest Disease Centre. Patients were recruited based on inclusion and exclusion criteria. All participants were enrolled in a standardised pulmonary rehabilitation program. The study protocol was approved by the institutional ethics committee (GCSMC/EC/Research project/ APPROVE/2022 /352) and all participants provided written informed consent prior to enrolment.

6 Min Walk Distance Test Protocol

The 6MWD Test was carried out in compliance with guidelines laid down by the American Thoracic Society (ATS). Tests were conducted on a flat and straight 30 m walking course in an enclosed hallway. Participants were given standardized instructions urging them to walk as far as possible during this 6 min interval, while they could build in rest periods if needed. Consistent verbal encouragement was given at intervals standardized to the advice of the ATS in order not to influence test performance by investigator attitude. Each participant conducted the 6MWD Test twice. Once before the start of respiratory rehabilitation (pre-rehabilitation) and once after completing it (post-rehabilitation).

Pulmonary Rehabilitation Program

Each participant went through an eight-week standard pulmonary rehabilitation program It consisted of supervised exercise twice a week Each session ran for 1 hr and included:

Aerobic conditioning: 30 min on the treadmill at levels of intensity tailored to each person so they correspond 60-80% heart rate control for that individual's heart rate intensity.

Resistance training: Using arms and legs strengthening exercises such as free weights and resistance bands.

Flexibility exercises: 10 min of stretching major muscle groups.

Educational components: Weekly sessions addressing disease management, breathing techniques, and energy conservation strategies.

Throughout the program, exercise intensity was progressively increased depending on each person's tolerance to it. All sessions were run by experienced physiotherapists with qualifications in pulmonary rehabilitation.

Statistical analysis

Statistical analyses were conducted using version 25.0 of IBM SPSS software (Armonk, N.Y., USA: IBM Corp.). The Shapiro-Wilk test was used to determine whether the data distribution was normal. For every variable, descriptive statistics were calculated; continuous data were shown as means and standard deviations, while categorical data were shown as frequencies and percentages.

RESULTS

Demographic characteristics of participants of the study (n=115) by diagnostic group are shown in Table 1. There were 29 patients with asthma, 46 with COPD, and 40 with ILD. The majority of participants were female in all of the diagnostic categories, with females accounting for 75.9% (n=22) asthma patients, 82.6% (n=38) of COPD patients, and 72.5% (n=29) of ILD patients. In the analysis of the age distribution of study participants, the bulk of the recruited population in the asthma, COPD and ILD cohorts were in the 51-60 years age bracket (34.5%, 50.0% and 47.5% respectively). None of the individuals diagnosed in any category were under the age of 30 years. Distribution of BMI by classification was variable between groups. In asthmatics, the same proportions were identified as having healthy weight (18.5-24.9 kg/m²) or pre-obesity (25-29 kg/m²). Within the group with COPD, 34.8% (n=16) were classified as normal weight and 30.4% (n=14) as overweight. The largest portion of ILD patients were pre-obese (42.5%, n=17), followed by healthy weight (32.5%, n=13). Severe obesity (BMI ≥40 kg/m²) was uncommon among all groups (n=1 in ILD group).

Table 2 shows the 6MWD parameter changes after pulmonary rehabilitation among asthma patients (n=29). The distribution of heart rates at baseline showed a significant shift post-rehabilitation (p100 bpm), 19 being in the normal heart range (60-100 bpm) at baseline compared to 2 and 27 respectively after rehabilitation. Baseline SpO_2 was unchanged, all patients remained normal (88-92%) pre- and post-rehabilitation (p=1.0).

At the end of 6MWD, no statistically significant changes in heart rate distribution were noted post rehabilitation (p=0.271). There was a small increase in number of patients with bradycardia (0 to 2) and normal heart rate (from 4 to 5) with corresponding decrease in number of patients with tachycardia (from 25 to 22). Notably, end-test SpO_2 was improved with borderline significance (p=0.053) with every patient achieving normal levels at end-test following rehabilitation compared to pre-rehabilitation when 2 and 3 patients had hypoxia (85-88%) and severe hypoxia (<85%) during exercise, respectively.

Almost walking distance showed a non-significant trend toward improvement (p=0.126), with the number of patients reaching normal distance (≥400m) increased from 7 to 11. The lowest saturation measurements showed the greatest improvement with a highly significant decrease in oxygen desaturation events ($p<0.000002$). After rehabilitation, 27 patients (51%) had normal saturation during the test compared to only 21 patients before rehabilitation, and severe hypoxia was observed in only 1 patient as opposed to 6 patients before rehabilitation.

Table 3 gives the analysis of the 6MWD parameters before and after pulmonary rehabilitation in COLD patients (n=46) all baseline measurement showed that SpO_2 distribution after rehabilitation (p=1.0 for both parameters) still had no significant change without any different heart rates. By contrast our patients at their worst could still maintain normal oxygen saturation each time before and after rehabilitation. As the analysis shows, from 35 patients experienced tachycardia to 40 patients and one patient developed bradycardia post-rehabilitation; this was not apparent before rehabilitation. Even more impressively, end-test SpO_2 showed significant improvement (p=0.004). All 46 patients maintained normal oxygen saturation post-rehabilitation compared to pre-rehabilitation, when 4 patients experienced hypoxia and 2 patients experienced severe hypoxia. Walking distance analysis demonstrated a significant improvement following rehabilitation (p=0.013). The number of patients able to make good distance (≥400m) doubled from 8-16. The most striking change, however, was in lowest saturation measurements during the test. Oxygen desaturation underwent a highly significant reduction ($p<0.001$). Post-rehabilitation, 38 patients kept normal saturation throughout the test compared with just 18 pre-rehabilitation.

Table 4 presents the changes of the 6MWD parameter after pulmonary rehabilitation in ILD patients (n=40). Heart rate distributions in baseline showed an almost non-significant increase from those patients tending toward supraventricular tachycardia (p=0.053). Baseline SpO_2 was consistent before and after intervention, and it remained that the entire group of subjects had 88-92% per cent saturation. (p=1.0) There were no significant changes in end-test heart rate distribution after rehabilitation (p=0.573), with all 3 groups that existed before intervention being maintained simultaneously afterwards. On the other hand, end-test SpO_2 showed a significant inferior change over time (p=0.010). After rehabilitation, fewer patients had normal saturation (18 versus 27 pre-rehabilitation) and more experienced hypoxia (7 versus 2) or even severe hypoxia (15 versus 11). Two. There was no statistically significant change in walking distance after rehabilitation (p=0.740). Only a marginal increase was seen from before to after the intervention with respect percentage of people who achieved a normal distance at baseline from 13 to 14. In spite of the overall distance walked remaining largely unchanged, however, lowest saturation measurements during the test did show a statistically significant shift in distribution (p=0.016). Post-rehabilitation, more people had severe hypoxia during test (27 versus 22 pre-rehabilitation), fewer moderate

Table 1: Demographic Details.

Parameters	ASTHMA (n=29)	COPD (n=46)	ILD (n=40)
Gender			
Male	7	8	11
Female	22	38	29
Age (Years)			
Below 30	0	0	0
31-40	5	3	6
41-50	8	6	9
51-60	10	23	19
61-70	5	14	5
Above 71	1	0	1
BMI (kg/m^2)			
Underweight (<18.5)	0	0	1
Healthy (18.5-24.9)	10	16	13
Overweight (greater than or equal to 25)	2	8	5
Pre-obese (25-29)	10	14	17
Obese class 1 (30-34)	3	7	2
Obese class 2 (35-39)	4	1	1
Obese class 3 (greater than or equal to 40)	0	0	1

Table 2: Effects of Pulmonary Rehabilitation on 6MWD Parameters in Asthma Patients (*n*=29).

6 Min Walk Test Recording of Asthma Patients (*n*=29)					
Parameters			**Pre**	**Post**	***p* value**
Baseline	HR Group	Bradycardia (Below 60)	0	0	0.000000004556067412
		Normal Range (60-100)	19	27	
		Tachycardia (Above 100)	10	2	
	SpO_2 Group	Normal* (88-92)	29	29	1
		Hypoxic (88-85)	0	0	
		Severly Hypoxic (less than 85)	0	0	
End of test	HR Group	Bradycardia (Below 60)	0	2	0.2712958233
		Normal Range (60-100)	4	5	
		Tachycardia (Above 100)	25	22	
	SpO_2 Group	Normal* (88-92)	24	29	0.053
		Hypoxic (88-85)	2	0	
		Severly Hypoxic (less than 85)	3	0	
Serial 6MWD	Distance Group	<400	22	18	0.1258119093
		Normal	7	11	
	Lowest Saturation Group	Normal* (88-92)	21	27	0.000001160491812
		Hypoxic (88-85)	2	1	
		Severly Hypoxic (less than 85)	6	1	

hypoxias (5 versus 11). The number of people who kept normal saturation throughout test also increased slightly from 7 to 8.

DISCUSSION

The results of this study demonstrate the heterogeneous nature of improvements in functional exercise capacity following pulmonary rehabilitation in people with various respiratory diseases. Asthmatics had the highest 6MWD mean improvement of 30 m and patients with COPD had more modest improvement (8 m), and ILD patients exhibited little change in walking distance. At the same time, these differential responses speak to the importance of the underlying pathophysiological interpretation towards both the understanding of our data as well as the development of intervention protocols.

Improved responsiveness in asthma patients fits with prior studies noting that exercise limitations may be more fully reversible in this population than with other chronic lung diseases (Carson *et al*., 2013; Tan *et al*., 2017). The traditional pathophysiology of asthma (with characteristics of reversible airflow obstruction and airway hyperresponsiveness) could allow for greater improvements in exercise capacity with interventions aimed at both the elements affecting respiratory mechanics and systemic deconditioning (Cordova-Rivera *et al*., 2018; Trevor *et al*., 2015). Moreover, asthma patients in our cohort were younger than the COPD or ILD patients, which might have also contributed to the greater physiological reserves they possessed.

In light of this, the modest gains achieved in COPD patients (of 8 m) were below the widely accepted Minimal Clinically Important Difference (MCID) threshold of the 6MWD of 25-30 m in COPD populations (Spruit *et al*., 2015). However, in our study, we discovered considerable advances in mean exercise oxygen saturation patterns in this group and a significant transition from moderate to severe hypoxia during testing for patients that transitioned from hypoxia to normal (Polkey *et al*., 2013; Singh *et al*., 2014). Increasing aerobic capacity with no greater mobility increase implies that during exercise, pulmonary rehabilitation has most likely improved ventilation-perfusion matching and oxygen utilization in diagnosed COPD patients (Gloeckl *et al*., 2013; Neder *et al*., 2019).

The minimal improvement in 6MWD noted in patients with ILD should be interpreted with caution. ILD is defined as a heterogeneous group of disorders characterized by lung parenchymal inflammation and fibrosis, leading to restrictive ventilatory defects and severe gas exchange abnormalities. However, the ILD patients reported a greater degree of oxygen desaturation following rehabilitation (Dantes *et al*., 2019; Raghu *et al*., 2015). Such paradoxical responses are indicative of the complex pathophysiology of exercise limitation in ILD, and highlight the fact that "one size" pulmonary rehabilitation may not be appropriate for this patient group (Dowman *et al*., 2014; Vainshelboim, 2016).

It is important to mention that there were no significant differences in heart rate parameters in any of the diagnostic

Table 3: Pre and Post Pulmonary Rehabilitation 6MWD Outcomes in COPD Patients (*n*=46).

6 Min Walk Test Recording OF Copd Patients (*n*=46)					
Parameters			**PRE**	**POST**	***p* value**
Baseline	HR Group	Bradycardia (Below 60)	0	0	1
		Normal Range (60-100)	33	33	
		Tachycardia (Above 100)	13	13	
	SpO_2 Group	Normal* (88-92)	46	46	1
		Hypoxic (88-85)	0	0	
		Severly Hypoxic (less than 85)	0	0	
End of test	HR Group	Bradycardia (Below 60)	0	1	0.01212482834
		Normal Range (60-100)	11	5	
		Tachycardia (Above 100)	35	40	
	SpO_2 Group	Normal* (88-92)	40	46	0.004
		Hypoxic (88-85)	4	0	
		Severly Hypoxic (less than 85)	2	0	
Serial 6MWD	Distance Group	<400	38	30	0.01326565341
		Normal	8	16	
	Lowest Saturation Group	Normal* (88-92)	18	38	0
		Hypoxic (88-85)	12	6	
		Severly Hypoxic (less than 85)	16	2	

Table 4: Analysis of 6MWD Parameters Pre and Post Pulmonary Rehabilitation in ILD Patients (*n*=40).

6 Min Walk Test Recording of Ild Patients (*n*=40)					
Parameters			**Pre**	**Post**	***p* value**
Baseline	HR Group	Bradycardia (Below 60)	0	0	0.05280751142
		Normal Range (60-100)	30	24	
		Tachycardia (Above 100)	10	16	
	SpO_2 Group	Normal* (88-92)	40	40	1
		Hypoxic (88-85)	0	0	
		Severly Hypoxic (less than 85)	0	0	
End of test	HR Group	Bradycardia (Below 60)	1	1	0.5728434234
		Normal Range (60-100)	6	4	
		Tachycardia (Above 100)	33	35	
	SpO_2 Group	Normal* (88-92)	27	18	0.01036782914
		Hypoxic (88-85)	2	7	
		Severly Hypoxic (less than 85)	11	15	
Serial 6MWD	Distance Group	<400	27	26	0.7402692788
		Normal	13	14	
	Lowest Saturation Group	Normal* (88-92)	7	8	0.01615601322
		Hypoxic (88-85)	11	5	
		Severly Hypoxic (less than 85)	22	27	

groups. Improvements in exercise capacity following pulmonary rehabilitation may have a cardiovascular component, with reports of increases in stroke volume and cardiac output. Physiological adaptations were previously attributed to improved walking distance in several trials, but our results show these changes, especially in asthma patients, can be explained by improved ventilatory efficiency, reduced dynamic hyperinflation and/or peripheral muscle function rather than cardiovascular adaptations as previously suggested (Langer *et al*., 2014; Spruit *et al*., 2015).

The meaningful effect of diagnostic category on improvement patterns ($p<0.05$) reinforces the necessity for condition-specific approaches to rehabilitation design and outcomes. We believe our data better describes the role of the 6MWD test and reveal that its clinical applicability in COPD is not necessarily shared with other respiratory disorders (Dowman *et al*., 2014; Holland *et al*., 2014a). This is of clinical and research significance as introduced a potential break in the one size fits all approach commonly observed in pulmonary rehabilitation settings.

Some limitations need to be recognized. One limitation of the study is that the ILD cohort consists of multiple specific ILD conditions with differing prognoses and responses to treatment, which are heterogeneous within each diagnostic category and may have biased the results (Raghu *et al*., 2015). Furthermore, there may not have been an ideal standardized rehabilitation protocol designed for each diagnostic category that was applied in this study. The subsequent studies should aim to develop condition-specific rehabilitation protocols tailored to the specific pathophysiological limitations of each respiratory condition (Dowman *et al*., 2014; Spruit *et al*., 2013).

This last point is particularly critical if clinical services are to maximize the potential response of patients with different diagnoses to pulmonary rehabilitation as characterized by an improvement in the clinical outcome. Overall, the promising improvements seen in patients with asthma demonstrate that exercise-based interventions may be particularly beneficial in this cohort, whereas the diminished response in patients with ILD suggests that different and/or tailored approaches may be more appropriate for this group. These findings add to the increasing amount of evidence for next steps into tailored pulmonary rehabilitation strategies based on underlying pathophysiology rather than one-size-fits-all protocols across all chronic respiratory conditions (McNamara *et al*., 2019; Spruit *et al*., 2015).

CONCLUSION

According to the new study, there are different patterns of improvement in functional capacity by respiratory disease after pulmonary rehabilitation. Patients with asthma showed the greatest gains in 6MWD (an average of 30 m more), while those of COPD had modest increases for walking distance (8 m up), and ILD patients hardly changed. This verifies the view that pulmonary rehabilitation was effective for improving functional capacity of different underlying respiratory diseases was markedly different in these groups of patients.

Despite this fact, significant changes in oxygen saturation parameters materialized across the different diagnostic groups-however the patterns were quite distinct. Asthma and COPD patients both produced noticeable increases ($p<0.000002$) in minimum saturation readings during testing, but those with ILD showed signs that end-test SpO_2 fell extremely off ($p<0.010$). Whether in these two different oxygenation parameters-from heart rates to SpO_2 and saturation-we find that when looking at responses people still reflect the physiology specific to their disease in each very case.

In the meantime, responses of heart rate showed less consistent patterns by group a point which might suggest that improvements in walking distance are hardly to do with the central cardio-vascular system itself and rely more on peripheral muscle function than efficient ventilation. In particular, it is worth noticing that the changes in oxygen saturation patterns of 6MWD as an outcome parameter whose acceptance needs to be reconsidered for all respiratory conditions.

These findings underscore the need for pulmonary rehabilitation programs to have specific goals tailored to the different conditions of patients and suggest that 6MWD improvements may not be a universally appropriate primary outcome measure across all respiratory disease. The profound differences in response patterns between patients with asthma, COPD, and ILD highlight the need for rehabilitation efforts tailored to the specific pathophysiological peculiarities of each illness. For future research, the focus should be placed firmly on developing and validating condition-specific rehabilitation protocols in order to optimize functional outcomes for patients with different respiratory problems.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

COPD: Chronic Obstructive Pulmonary Disease; **ILD:** Interstitial Lung Disease; **SpO_2:** Oxygen Saturation; **6MWD:** 6-Minute Walk Distance; **ATS:** American Thoracic Society; **IBM-SPSS:** International Business Machines Corporation-Statistical Package for Social Sciences; **BMI:** Body Mass Index; **MCID:** Minimal Clinically Important Difference.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the institutional ethics committee (GCSMC/EC/Research project/APPROVE/2022/352) and all participants provided written informed consent prior to enrolment.

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