

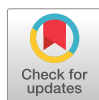


# Impact of fan therapy during exercise on breathlessness and recovery time in patients with COPD: a pilot randomised controlled crossover trial

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Fan therapy was acceptable and provided symptomatic relief to patients with COPD during exercise; these positive preliminary findings suggest that fan therapy merits further investigation in larger and more methodologically rigorous studies <https://bit.ly/3xR2GDW>

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## Abstract

**Background** Patients with COPD reduce physical activity to avoid the onset of breathlessness. Fan therapy can reduce breathlessness at rest, but the efficacy of fan therapy during exercise remains unknown in this population. The aim of the present study was to investigate 1) the effect of fan therapy on exercise-induced breathlessness and post-exercise recovery time in patients with COPD and 2) the acceptability of fan therapy during exercise; and 3) to assess the reproducibility of any observed improvements in outcome measures.

**Methods** A pilot single-centre, randomised, controlled, crossover open (nonmasked) trial ([clinicaltrials.gov NCT03137524](https://clinicaltrials.gov/NCT03137524)) of fan therapy *versus* no fan therapy during 6-min walk test (6MWT) in patients with COPD and a modified Medical Research Council (mMRC) dyspnoea score  $\geq 2$ . Breathlessness intensity was quantified before and on termination of the 6MWT, using the numerical rating scale (NRS) (0–10). Post-exertional recovery time was measured, defined as the time taken to return to baseline NRS breathlessness score. Oxygen saturation and heart rate were measured pre- and post-6MWT.

**Results** 14 patients with COPD completed the trial per protocol (four male, 10 female; median (interquartile range (IQR)) age 66.50 (60.75 to 73.50) years); mMRC dyspnoea 3 (2 to 3)). Fan therapy resulted in lower exercise-induced breathlessness ( $\Delta$ NRS;  $\Delta$  modified Borg scale) (within-individual differences in medians (WIDiM)  $-1.00$ , IQR  $-2.00$  to  $-0.50$ ;  $p < 0.01$ ; WIDiM  $-0.25$ , IQR  $-2.00$  to  $0.00$ ;  $p = 0.02$ ), greater distance walked (metres) during the 6MWT (WIDiM  $21.25$ , IQR  $12.75$  to  $31.88$ ;  $p < 0.01$ ), and improved post-exertional breathlessness (NRS) recovery time (WIDiM  $-10.00$ , IQR  $-78.75$  to  $50.00$ ;  $p < 0.01$ ). Fan therapy was deemed to be acceptable by 92% of participants.

**Conclusion** Fan therapy was acceptable and provided symptomatic relief to patients with COPD during exercise. These data will inform larger pilot studies and efficacy studies of fan therapy during exercise.

## Introduction

COPD is defined as “a common and treatable disease characterised by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gas” [1]. COPD is progressive, associated with frequent exacerbation of symptoms including increased breathlessness, leading to increased disability and reduced quality of life [1].

COPD is the fourth leading cause of death worldwide [2]. Over a million individuals in the United Kingdom (UK) have COPD, resulting in  $>25000$  deaths each year due to COPD [3]. COPD mortality in the UK is third in Europe [3].



The burden of chronic breathlessness is significant for patients with COPD, negatively impacting upon health-related quality of life and physical function, as patients frequently avoid activities that evoke breathlessness. This fear-avoidance results in disuse atrophy, which perpetuates a cycle of increasing breathlessness and disability [4, 5].

Exercise interventions such as pulmonary rehabilitation for patients with COPD improve breathlessness and physical function and reduce exacerbation frequency and hospital admission [6]. However, pulmonary rehabilitation is a brief intervention and maintaining these benefits requires patients to continue to exercise independently. Breathlessness is the main limiting factor to exercise in COPD [7]; therefore, any interventions to help patients to self-manage their exercise-induced breathlessness are sought.

Evidence suggests that cool facial airflow from either medical air (room air delivered under pressure *via* a concentrator or canister) or a fan can reduce breathlessness at rest [8, 9]. The burden of chronic breathlessness is significant for patients with COPD, and their families [10, 11]. Holistic breathlessness support services have been shown to improve breathlessness mastery and reduce distress due to breathlessness, where fan therapy is an integral part of these self-management interventions [12, 13]. Moreover, qualitative data from patients with chronic breathlessness describe improvements in their ability to control their breathlessness at rest (self-mastery) with the use of fan therapy [12]. The efficacy and acceptability of fan therapy during exercise remains unknown in patients with COPD.

The aim of this study was 1) to investigate the effect of fan therapy on exercise-induced breathlessness and post-exercise recovery time in patients with COPD; 2) to investigate the acceptability of fan therapy during exercise; and 3) to assess the reproducibility of any observed improvements in outcome measures.

We hypothesised that fan therapy would reduce exercise-induced breathlessness and improve post-exercise recovery time in patients with COPD. (Null hypothesis: there would be no difference in exercise-induced breathlessness, physiological variables, *e.g.* heart rate, oxygen saturation or recovery time when assessed in the fan therapy and no fan therapy conditions for a 6-min walk test (6MWT).)

## Methods

### Design

A pilot single-centre randomised controlled crossover, open (nonmasked) trial (NCT03137524) of fan therapy *versus* no fan therapy during 6MWT in patients with COPD and modified Medical Research Council (mMRC) dyspnoea score  $\geq 2$ . There was a 30-min washout period between 6MWTs (figure 1).

### Participants

Inclusion criteria: adults with a diagnosis of COPD by a respiratory physician (characterised by forced expiratory volume in 1 s ( $FEV_1$ )/forced vital capacity ratio  $\leq 70\%$ ), with exertional breathlessness (mMRC dyspnoea score  $\geq 2$ ) and a stable smoking status were eligible.

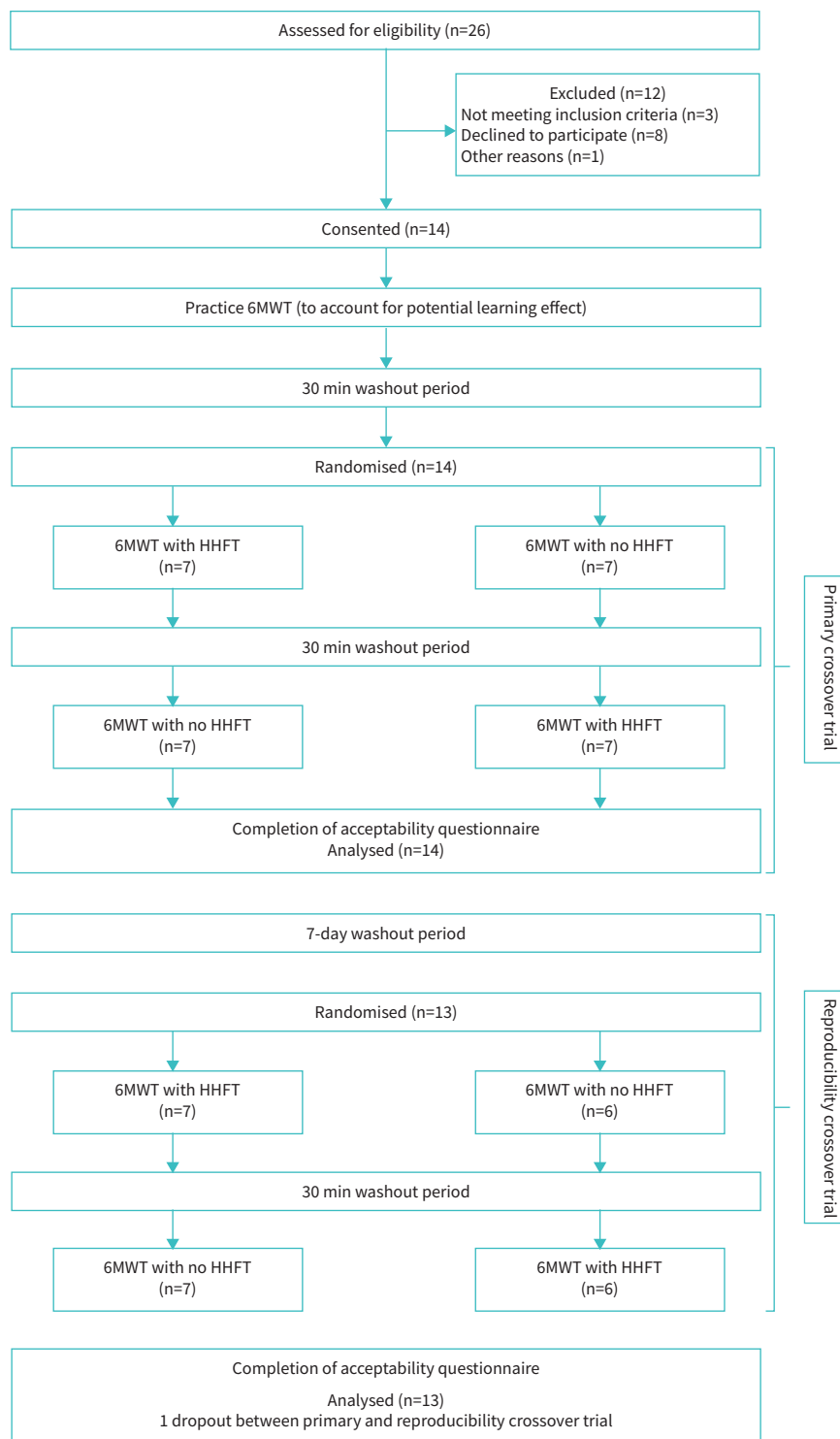
Exclusion criteria: significant cardiovascular or peripheral disease that could influence exercise tolerance, recent change in medication or exacerbation of COPD symptoms requiring admission during the preceding 4 weeks; unable to hold a handheld fan; unable to speak English; or not capable of providing informed consent.

### Recruitment

Patients were recruited from specialist COPD outpatient clinics and Pulmonary Rehabilitation at King's College Hospital NHS Foundation Trust (KCH) (Denmark Hill site, London, UK). Participants fulfilling eligibility criteria were recruited by convenience sampling. Potential participants were identified by members of the clinical teams, who gained consent for their contact details to be passed on to the researcher. Thereafter, participants were sent by post an invitation to participate and an information letter from the researcher, given  $\geq 1$  week to read thoroughly, then re-contacted by the researcher to discuss any concerns. Interest in the study led to an assessment date being organised, at which consent forms were signed.

### Randomisation and masking

Block randomisation was implemented using an online tool ([www.sealedenvelope.com/simple-randomiser/v1/](http://www.sealedenvelope.com/simple-randomiser/v1/)) to allocate participants to their initial experimental conditions (*i.e.* walking with a hand-held fan *versus* walking without a fan) and ensure the conditions were numerically balanced. Simple four-block randomisation was applied. On completion of the initial walking test and outcome assessments,



**FIGURE 1** Study design and flow of patient through the study protocol: a pilot single-centre randomised controlled crossover open (nonmasked) trial of hand-held fan therapy (HHFT) versus no HHFT during 6-min walk test (6MWT) in patients with COPD and modified Medical Research Council dyspnoea score  $\geq 2$ .

participants were given 30 min to recover physiologically and then they repeated the walking test in the alternative experimental condition. Due to the nature of the intervention (fan therapy), it was not possible to blind the researcher or patients to the allocations.

### *Sample size*

No formal sample size calculation was performed, due to the lack of data regarding the potential impact fan therapy may have on exercise-induced breathlessness in COPD. Therefore, this pilot study aimed to recruit 14–16 participants. The pilot data will inform subsequent efficacy studies of fan therapy during exercise.

### *Ethical approval*

Ethical and local research and development approval (KCH17–062) was obtained prior to commencing this research (LREC protocol number: REC 17/NE/0063). The study was registered on [www.clinicaltrials.gov](http://www.clinicaltrials.gov) (NCT03137524). All participants provided written informed consent.

### *Intervention: fan therapy*

The handheld fans used were commercially available and battery-operated, with three soft propeller blades and an on/off switch usable by participants (Marks and Spencer's Pocket-Sized Travel Fan, cost per fan GBP 6.00). Patients were provided with standardised instructions as how to use the handheld fan: to hold the fan to their face throughout both the walking test and during the recovery period until they reported that breathlessness returned to baseline.

### *Primary outcome measure*

Breathlessness change: the magnitude of exercise-induced breathlessness during a 6MWT, defined as the change ( $\Delta$ ) in breathlessness scores from rest (immediately pre-exercise) to immediately post-exercise, quantified using the numerical rating scale (NRS). The NRS breathlessness is a validated, self-reported, unidimensional scale to rate chronic breathlessness intensity. It is simple to use across a variety of everyday activities, and adjustable to specific time points [14]. NRS anchors were 0=not breathless at all, 10=worst possible breathlessness.

### *Secondary outcome measures*

#### *Breathlessness intensity*

Self-reported level or intensity of breathlessness as indicated on the NRS.

#### *Perceived breathing difficulty/effort*

Perceived breathing difficulty/effort was quantified using the modified Borg breathlessness (mBorg) scale at rest and at end exercise. The mBorg is quantifies perceived breathing difficulty/effort on a 0–10 scale, with descriptors, *e.g.* 0=none at all, 5=severe, 10=maximal. It was developed for use during exertion [15]. It has a minimal clinically important difference (MCID) of 1 point, with larger changes more likely at the higher end of the scale due to larger numerical intervals between descriptive markers [16]. Reliability and validity of mBorg breathlessness measurement during 6MWT is accepted (intraclass correlation coefficient from 0.59 to 0.92; mean difference of <1 point) [17].

#### *Distance walked (m) during the 6MWT*

The 6MWT is a self-paced walking test. It measures walking capacity by measuring total distance covered around a flat 30-m course in 6 min. Standardised instructions are given throughout the test. It is a robust test of functional exercise capacity [17].

#### *Post-exertional recovery time (s)*

Post-exertional recovery time was measured, defined as the time taken to return to baseline NRS breathlessness score, peripheral oxygen saturation ( $S_{pO_2}$ ) and heart rate. Participants were asked to report when their NRS breathlessness score had returned to base levels.  $S_{pO_2}$  and heart rate were measured using a pulse oximetry (Onyx 9500 Fingertip Pulse Oximeter; Nonin Medical, Plymouth, MN, USA).  $S_{pO_2}$  and heart rate were measured at rest, during and post-6MWT.

#### *Acceptability of using the handheld fan*

Acceptability was assessed *via* a Likert scale questionnaire (range 1–5) based on the theoretical framework of acceptability (TFA) [18]. Participants were asked to respond to specific questions reflecting the overall acceptability of fan therapy and five subconstructs from the TFA (affective attitude, burden, perceived effectiveness, intervention coherence and self-efficacy).

### *Experimental protocol*

The study was conducted at the clinical research facility at KCH. Baseline demographic data included age, sex, spirometry, smoking history, body mass index, mMRC dyspnoea score, COPD Assessment Test (CAT).

Participants performed three 6MWTs: one for practice, to account for potential learning effect, followed by two as per protocol (figure 1). The 6MWT was performed in accordance with technical procedures described by the American Thoracic Society [19]. Participants were given a 30-min period between the practice 6MWT and commencing the crossover trial experimental protocol (figure 1). Outcome measures recorded pre and post all 6MWTs included NRS breathlessness, mBorg, heart rate and  $S_{pO_2}$ . The distance walked and number of rest periods/stops the patient required was recorded for all 6MWTs completed. Recovery time for NRS and heart rate to return to baseline post-6MWT was timed (in seconds) immediately from the end of the 6MWT. Recovery was recorded in standardised seated position. The self-reported acceptability questionnaire was completed at the end of the crossover trial (figure 1).

### Reproducibility

To assess the reproducibility/consistency of any observed improvements in outcome measures, patients were invited to complete the experimental protocol again, a week later (trial 2). To reduce the chance of any imbalances between allocation sequence groups (AB *versus* BA) following the initial randomisation in trial 1 being carried forward to trial 2, participants were re-randomised to allocation sequences for trial 2.

### Data analysis and reporting

Inferential statistical analysis of outcomes was completed, with a significance level of  $p < 0.05$  using the statistical package SPSS v26 (IBM, Armonk, NY, USA). Normality of the data was determined by skewness and Shapiro–Wilk test. The data was non-normally distributed, hence central tendencies are described using medians and interquartile ranges (IQRs) calculated in Microsoft Excel (version 2016). Within-individual differences in the medians (WIDiMs) and IQRs (fan *versus* no fan) were calculated by first subtracting a participant's score in the no fan condition from their score in the fan condition, and then calculating the median (IQR) of these within-individual differences. WIDiMs retain the repeated nature of the crossover design at the level of the individual and are used to assess treatment effects [20], in our case using nonparametric tests (Wilcoxon matched-pairs signed-rank tests, with two-sided exact significance). In addition, in tables 2 and 3, group-level medians are reported. For example, for participants allocated to the sequence fan-then-no-fan ( $n=7$ ), we report the group-level medians for each outcome in the fan condition and in the no-fan condition. These group-level medians do not retain the repeated nature of the crossover design at the level of the individual, so they cannot legitimately be used to estimate treatment effects; however, they are helpful in understanding the likelihood of carryover effects and period (order) effects, as well as the amount of missing data [20]. WIDiMs and group-level medians are not directly related, as they are generated from independent calculations.

## Results

### Recruitment and engagement

Recruitment took place over 10 weeks (May to July 2017). 26 patients were screened; three (12%) were ineligible. Of the 23 eligible patients, eight (35%) declined to participate and 14 (61%) agreed to participate and were randomised. 14 participants (100%) completed the trial per protocol (table 1). 13

**TABLE 1** Patient characteristics of the 14 patients who completed the randomised controlled crossover trial of fan therapy *versus* no fan therapy during 6-min walk test

Age (years)	66.50 (60.75–73.50)
BMI ( $\text{kg}\cdot\text{m}^{-2}$ )	25.85 (20.60–30.25)
Male/female	4/10
<b>Smoking status</b>	
Current smoker	6
Ex-smoker	8
Smoking (pack-years)	48.00 (25.75–82.60)
mMRC dyspnoea score	3.00 (2.00–3.00)
FEV <sub>1</sub> (L)	1.30 (0.94–1.59)
FEV <sub>1</sub> (%)	63.00 (38.75–74.0)
FVC (L)	2.30 (1.90–2.75)
FVC (%)	82.00 (71.00–93.25)
FEV <sub>1</sub> /FVC ratio	56.75 (47.43–63.50)
CAT score	21.00 (12.25–29.75)

Data are presented as median (interquartile range) or n. BMI: body mass index; mMRC: modified Medical Research Council; FEV<sub>1</sub>: forced expiratory volume in 1 s; FVC: forced vital capacity; CAT: COPD Assessment Test.

**TABLE 2** Results observed in the primary randomised controlled crossover trial of fan therapy *versus* no fan therapy during 6-min walk test (6MWT) in patients with COPD

	Allocation sequence AB (fan/no fan)				Allocation sequence BA (no fan/fan)				Overall treatment effect	
	Group-level median (IQR)		WIDiM (IQR)		Group-level median (IQR)		WIDiM (IQR)		WIDiM (IQR)	
	Period 1 fan	Period 2 no fan	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>	Period 1 no fan	Period 2 fan	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>
Patients (n)	7	7	7		6	6	6		13	
<b>Subjective measures of breathlessness</b>										
NRS <sup>†</sup>	5.00 (3.75 to 6.25)	7.00 (6.25 to 8.25)	-2.00 (-2.00 to -1.00)	0.02	4.00 (2.50 to 5.75)	3.00 (2.00 to 4.75)	-0.50 (-1.25 to 0.00)	0.25	-1.00 (-2.00 to -0.50)	<0.01
ΔNRS <sup>§</sup>	3.00 (1.25 to 4.25)	5.00 (3.00 to 6.75)	-1.50 (-2.00 to -1.00)	0.02	3.50 (2.25 to 4.75)	3.00 (1.75 to 3.25)	-0.50 (-1.25 to 0.00)	0.25	-1.00 (-2.00 to -0.50)	<0.01
NRS recovery time <sup>†</sup>	110.00 (15.00 to 135.00)	210.00 (160.00 to 295.00)	-90.00 (-205.00 to -32.50)	0.03	150.00 (75.00 to 195.00)	210.00 (165.00 to 227.50)	60.00 (10.00 to 65.00)	0.09	-10.00 (-78.75 to 50.00)	<0.01
mBorg <sup>†</sup>	3.00 (0.75 to 3.50)	4.00 (4.00 to 5.00)	-1.00 (-2.50 to 0.25)	0.06	3.00 (2.00 to 4.50)	3.00 (1.00 to 3.50)	0.00 (-1.00 to 0.00)	0.50	-0.25 (-2.00 to 0.00)	0.02
ΔmBorg <sup>§</sup>	2.00 (0.25 to 3.00)	3.50 (3.50 to 4.00)	-1.00 (-2.50 to -0.25)	0.06	3.00 (1.75 to 3.50)	2.00 (0.75 to 3.00)	0.00 (-1.00 to 0.00)	0.50	-0.25 (-2.00 to 0.00)	0.02
<b>Objective measures of physiology</b>										
HR <sup>†</sup>	84.00 (74.00 to 89.50)	82.00 (79.00 to 96.00)	-4.00 (-12.00 to 4.00)	0.38	96.00 (94.00 to 106.50)	92.00 (85.50 to 97.50)	-3.00 (-5.50 to -2.00)	0.14	-3.50 (-7.50 to 1.00)	0.11
ΔHR <sup>§</sup>	11.00 (5.50 to 14.00)	12.00 (8.50 to 19.00)	-3.00 (-5.50 to -1.00)	0.20	15.00 (4.00 to 18.00)	2.00 (0.50 to 14.00)	-3.00 (-5.50 to -1.00)	0.47	-3.00 (-5.75 to -0.25)	0.13
S <sub>pO<sub>2</sub></sub> <sup>†</sup>	96.00 (94.50 to 98.50)	97.00 (96.50 to 98.00)	0.00 (-1.00 to 1.00)	1.00	96.00 (95.00 to 96.50)	97.00 (95.00 to 97.00)	0.00 (-1.00 to 1.00)	0.94	0.00 (-1.00 to 1.00)	0.70
Δ S <sub>pO<sub>2</sub></sub> <sup>§</sup>	0.00 (-1.00 to 1.50)	0.00 (-1.00 to 1.00)	0.00 (-0.50 to 1.00)	1.00	0.00 (-1.50 to 0.50)	0.00 (-1.50 to 1.00)	0.00 (-1.00 to 1.00)	1.00	0.00 (-0.75 to 1.00)	1.00
<b>Objective measures of functional response</b>										
6MWT distance <sup>f</sup> (m)	404.00 (336.25 to 465.00)	400.00 (312.50 to 420.00)	25.00 (17.50 to 30.00)	0.02	330.00 (223.75 to 517.50)	383.00 (247.50 to 561.25)	15.00 (11.00 to 42.75)	0.02	21.25 (12.75 to 31.88)	<0.01
6MWT stops <sup>f</sup> (n)	0.00 (0.00 to 0.00)	0.00 (0.00 to 1.00)	0.00 (-0.50 to 0.00)	1.00	0.00 (0.00 to 2.00)	0.00 (0.00 to 1.50)	0.00 (0.00 to 0.00)	1.000	0.00 (0.00 to 0.00)	0.63

Only within-individual differences in the medians (WIDiMs) are used for estimating treatment effects; group-level medians are helpful in assessing carryover and order effects (see methods section). IQR: interquartile range; NRS: numerical rating scale; Δ: change; mBorg: modified Borg scale for breathlessness; HR: heart rate; S<sub>pO<sub>2</sub></sub>: oxygen saturation measured by pulse oximetry. <sup>#</sup>: calculated so that positive values indicate higher scores for the fan condition and negative values indicate higher scores for the no-fan condition; <sup>¶</sup>: exact significant, two-tailed; <sup>†</sup>: assessed post-exercise; <sup>§</sup>: change from pre- to post-exercise; <sup>f</sup>: assessed during the exercise period.

**TABLE 3** Results observed in the repeated randomised controlled crossover trial of fan therapy *versus* no fan therapy during 6-min walk test (6MWT) in patients with COPD

	Allocation sequence AB (fan/no fan)				Allocation sequence BA (no fan/fan)				Overall treatment effect	
	Group-level median (IQR)		WIDiM (IQR)		Group-level median (IQR)		WIDiM (IQR)		WIDiM (IQR)	
	Period 1 fan	Period 2 no fan	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>	Period 1 no fan	Period 2 fan	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>	WIDiM <sup>#</sup>	Wilcoxon signed rank test <sup>¶</sup>
Patients (n)	7	7	7		7	7	7		13	
<b>Subjective measures of breathlessness</b>										
NRS <sup>+</sup>	5.00 (3.50 to 5.50)	5.50 (4.25 to 7.00)	-1.00 (-1.00 to -0.75)	0.03	3.80 (0.75 to 6.00)	1.80 (0.38 to 5.00)	-0.25 (-0.88 to 0.00)	0.25	-1.00 (-1.00 to 0.00)	<0.01
ΔNRS <sup>§</sup>	3.50 (2.25 to 3.75)	4.00 (2.75 to 4.75)	-1.00 (-1.00 to -0.75)	0.03	1.80 (0.75 to 2.75)	1.80 (0.38 to 2.00)	-0.25 (-0.88 to 0.00)	0.25	-1.00 (-1.00 to 0.00)	<0.01
NRS recovery time <sup>+</sup>	120.00 (75.00 to 180.00)	185.00 (152.50 to 277.50)	-110.00 (-127.00 to -62.50)	0.02	175.00 (43.75 to 227.50)	105.00 (25.75 to 185.00)	-17.00 (-102.50 to -11.00)	0.06	-65.00 (-130.00 to -20.00)	<0.01
mBorg <sup>+</sup>	3.00 (2.00 to 4.00)	4.00 (3.00 to 4.50)	-1.00 (-2.00 to -0.50)	0.06	2.50 (0.88 to 5.25)	1.50 (0.25 to 5.00)	-0.25 (-0.88 to 0.00)	0.250	-1.00 (-2.00 to 0.00)	<0.01
ΔmBorg <sup>§</sup>	3.00 (1.00 to 3.00)	3.00 (2.50 to 3.50)	-1.00 (-2.00 to -0.50)	0.06	2.50 (0.88 to 3.00)	1.50 (0.25 to 2.00)	-0.25 (-0.88 to 0.00)	0.25	-1.00 (-2.00 to 0.00)	<0.08
<b>Objective measures of physiology</b>										
HR <sup>+</sup>	89.00 (84.50 to 99.50)	87.00 (85.00 to 99.50)	0.00 (-4.50 to 1.50)	0.69	89.50 (86.75 to 91.50)	84.50 (81.75 to 90.25)	-1.50 (-6.50 to 2.75)	0.69	0.00 (-6.00 to 2.00)	0.49
ΔHR <sup>§</sup>	10.00 (5.00 to 15.00)	10.00 (10.00 to 12.00)	0.00 (-6.00 to 4.00)	0.88	6.00 (2.50 to 12.50)	5.50 (2.75 to 12.75)	1.00 (-2.00 to 2.50)	0.85	1.00 (-3.00 to 3.00)	0.96
S <sub>pO<sub>2</sub></sub> <sup>+</sup>	94.00 (92.50 to 95.50)	94.00 (93.00 to 97.00)	0.00 (-3.00 to 0.00)	0.25	98.00 (96.50 to 98.00)	96.50 (96.00 to 97.75)	0.00 (-0.75 to 0.00)	0.75	0.00 (-2.00 to 0.00)	0.16
Δ S <sub>pO<sub>2</sub></sub> <sup>§</sup>	0.00 (-3.50 to 1.00)	-1.00 (-1.50 to 0.50)	-1.00 (-2.50 to 1.50)	0.52	0.50 (-1.50 to 2.50)	-0.50 (-1.00 to 0.00)	-1.00 (-1.75 to 0.50)	0.53	-1.00 (-2.00 to 1.00)	0.29
<b>Objective measures of functional response</b>										
6MWT distance <sup>f</sup> (m)	282.50 (233.75 to 470.25)	265.00 (209.75 to 430.00)	28.00 (20.00 to 38.75)	0.06	432.50 (399.38 to 516.25)	531.30 (421.25 to 560.63)	22.50 (11.25 to 71.25)	0.06	28.00 (17.50 to 45.00)	<0.01
6MWT stops <sup>f</sup> (n)	0.00 (0.00 to 2.00)	1.00 (0.00 to 1.50)	0.00 (0.00 to 0.00)	1.00	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)	0.00 (0.00 to 0.00)	1.00	0.00 (0.00 to 0.00)	0.75

Only within-individual differences in the medians (WIDiMs) are used for estimating treatment effects; group-level medians are helpful in assessing carryover and order effects (see methods section). IQR: interquartile range; NRS: numerical rating scale; Δ: change; mBorg: modified Borg scale for breathlessness; HR: heart rate; S<sub>pO<sub>2</sub></sub>: oxygen saturation measured by pulse oximetry. <sup>#</sup>: calculated so that positive values indicate higher scores for the fan condition and negative values indicate higher scores for the no-fan condition; <sup>¶</sup>: exact significant, two-tailed; <sup>+</sup>: assessed post-exercise; <sup>§</sup>: change from pre- to post-exercise; <sup>f</sup>: assessed during the exercise period.

(92%) out of the 14 patients completed the reproducibility study. One patient declined to participate in the reproducibility study due to unforeseeable personal circumstances.

### Patient characteristics

14 patients with COPD completed the trial per protocol (four male, 10 female; median (IQR) age 66.50 (60.75 to 73.50) years and mMRC dyspnoea 3 (2 to 3)), summarised in table 1.

### Outcomes

Prior to exercise there were no differences between the experimental conditions for resting NRS breathlessness, mBorg, heart rate or  $S_{pO_2}$ . Following exercise, change scores for the primary outcome ( $\Delta$ NRS) showed that low-level physical activity under the fan condition resulted in lower exercise-induced breathlessness, *i.e.* smaller increases in breathlessness compared to the no-fan condition (WIDiM  $-1.00$ , IQR  $-2.00$  to  $-0.50$ ;  $p<0.01$ ). For the secondary outcomes, the fan condition resulted in smaller increases in perceived breathing difficulty/effort ( $\Delta$ mBorg) (WIDiM  $-0.25$ , IQR  $-2.00$  to  $0.00$ ;  $p=0.02$ ), greater distance walked during the 6MWT (WIDiM  $21.25$  m, IQR  $12.75$  to  $31.88$  m;  $p<0.01$ ), and a shorter post-exertional breathlessness recovery time (seconds) (WIDiM  $-10.00$  s, IQR  $-78.75$  to  $50.00$  s;  $p<0.01$ ) (table 2). However, there were no overall treatment effects for heart rate,  $S_{pO_2}$  or the number of stops taken during the 6MWT.

The reproducibility crossover trial (trial 2) demonstrated consistent findings of benefits for the fan condition: smaller increases in breathlessness ( $\Delta$ NRS) (WIDiM  $-1.00$ , IQR  $-1.00$  to  $0.00$ ;  $p<0.01$ ), smaller increases in perceived breathing difficulty/effort ( $\Delta$ mBorg) (WIDiM  $-1.00$ , IQR  $-2.00$  to  $0.00$ ;  $p<0.01$ ), greater distance walked during the 6MWT (WIDiM  $28.00$  m, IQR  $17.50$  to  $45.00$  m,  $p<0.01$ ) and a shorter post-exertional breathlessness recovery time (seconds) (WIDiM  $-65.00$  s, IQR  $-130.00$  to  $-20.00$  s;  $p<0.01$ ) (table 3). Again, there were no overall treatment effects for heart rate,  $S_{pO_2}$  or the number of stops taken during the 6MWT.

Fan therapy was acceptable to 92% of participants (table 4), with a median (IQR) acceptability score of 4 (4 to 5) out of 5. 53% reported no additional burden of fan therapy during the 6MWT. Patients reported they liked the handheld fan (median 4, IQR 3 to 5) and that it was of minimal burden (median 1, IQR 1 to 3). Patients were confident to use the handheld fan (median 5, IQR 4 to 5) and understood how it was supposed to help them (median 4, IQR 3 to 5).

In keeping with the observed improvements in breathlessness scores and exercise performance, patients perceived the handheld fan to be effective during exercise (median 4, IQR 3 to 4) and to help to resolve breathlessness post-exertion (median 4, IQR 3 to 4). Moreover, these patients who had not used a fan

TABLE 4 Patient-reported acceptability of hand-held fan (HHF) therapy during exercise

	Question	Median (IQR)	Range (min-max)
Overall acceptability	How acceptable was it to use the HHF during the exercise test? (1=completely unacceptable, 5=completely acceptable)	4 (4-5)	3-5
Affective attitude	How much did you like using the HHF during the walking test? (1=strongly dislike, 5=strongly like)	4 (3-5)	3-5
Burden	How much additional effort was required to use the HHF during the walking test? (1=no additional effort, 5=a huge additional effort)	1 (1-3)	1-4
Self-efficacy	How confident were you about using the HHF as instructed during the walking test? (1=very unconfident, 5=very confident)	5 (4-5)	1-5
Intervention coherence	Do you understand how the HHF therapy was supposed to work? (1=definitely do not understand, 5=completely understand)	4 (3-5)	2-5
Perceived effectiveness	How effective was the HHF in reducing breathlessness when walking? (1=very ineffective, 5=very effective)	4 (3-4)	3-5
	How effective was the HHF therapy in helping you to recover your breathing after you finished walking? (1=very ineffective, 5=very effective)	4 (3-4)	3-5
	Would you use a HHF to help with breathlessness in your everyday life? (1=I definitely would not use it, 5=I definitely would use it)	5 (4-5)	2-5

IQR: interquartile range.



before reported that they would use a handheld fan during everyday life (median 5, IQR 4 to 5), which reinforces the acceptability of this intervention. One person commented that using (holding) the fan negatively affected their walking style. Free-text comments were limited, but supported the use of the handheld fan:

*“very useful during exercising” (male, FEV<sub>1</sub> 0.59 L)*

*“I think it worked... it helped my breathing” (female, FEV<sub>1</sub> 1.40 L)*

*“it acts as a distraction from my breathing, which I find useful” (female, FEV<sub>1</sub> 1.55 L)*

## Discussion

This study aimed to investigate the effect of fan therapy on exercise-induced breathlessness and post-exercise recovery time in patients with COPD, and the acceptability of using fan therapy during exercise in controlled circumstances. Findings across two pilot crossover trials with the same participants suggest that using a hand-held fan during low-level exercise has no impact on physiological measures (heart rate, S<sub>pO<sub>2</sub></sub>), but reduces subjective feelings of exercise-induced breathlessness, increases walking distance and speeds post-exertional recovery time. Fan therapy was deemed to be acceptable by 92% of participants.

This is the first article to report an improvement in recovery time post-exertion due to fan therapy in patients with COPD. The reduction in exercise-induced breathlessness was similar to that described by MARCHETTI *et al.* [21], who reported significance between median (range) mBorg at maximal exercise of 6.50 (0 to 10) with fan directed to leg *versus* 5.00 (0 to 10) with fan directed to face (p=0.03). Our data extend these findings and show that using a handheld fan during exercise was perceived to be acceptable to participants and provided symptomatic relief to patients with COPD during exercise. These data will inform larger efficacy studies of fan therapy during exercise.

## Relevance of findings

The UK MRC produced a series of guidelines from 2000 onwards to help researchers develop and evaluate of complex health interventions. These MRC guidelines explicitly recommend that developers assess the acceptability of prototype interventions at an early stage and throughout the development process [22–24]. There is now a growing consensus that developers need to optimise interventions to ensure acceptability to those delivering and receiving them [25]. Evidence shows that the acceptability of interventions impacts on their implementation, uptake, adherence and effectiveness [24, 26–28]. The TFA [18] identifies underlying constructs presumed to contribute to evaluations of intervention acceptability and offers suggestions on how to assess acceptability. The current study used the TFA to guide the assessment of the retrospective acceptability of fan therapy to intervention recipients. The findings provide preliminary support for the acceptability of the fan therapy to patients with COPD, suggesting not only that fan therapy was acceptable overall, but that the intervention required low effort, was liked and participants understood how the fan was supposed to help them during exertion. Participants were confident as how to use the fan as directed. Participants perceived the fan to be effective at reducing breathlessness, helping them return to normal breathing post-exertion, and that it would be useful during everyday tasks (table 4). This is in line with the observation by BAUSEWEIN *et al.* [29] that at 2 months post-completion, 50% of participants continued to use the fan. Findings relating to acceptability were positive for all TFA constructs assessed, suggesting that there is no need adapt the intervention prior to further evaluation. However, acceptability can change with exposure to an intervention; therefore, future studies should assess the acceptability of fan therapy for people with COPD and other respiratory conditions at multiple time points during longer exposures. Furthermore, studies should use the full range of TFA constructs (we did not assess the perceived opportunity costs or ethics of fan therapy) and assess acceptability of fan therapy to intervention deliverers.

In keeping with our observations, JOHNSON *et al.* [30] used magnetoencephalography to scan the brains of participants (n=8) with chronic lung disease (50% diagnosed with COPD) during post-exertional recovery following exercise with or without airflow. Time recovery was median 270 s (range 60 to 360 s) with airflow *versus* 330 s (range 210–390 s), which is longer than in our cohort, indicating that our sample recovered quicker, although our sample did not achieve such a high breathlessness intensity. Preliminary imaging suggested that facial airflow might result in different areas of lobar activity being identified, potentially altering central processing and perception of neural respiratory drive and breathlessness. The insular cortex, anterior cingulate cortex and amygdala contribute towards this [31].

Brain imaging in healthy participants suggest that affective experiences (*e.g.* distress, anxiety, fear) and the sensory experiences (*e.g.* pain, difficulty breathing) of breathlessness are processed by different neural pathways [32].

Physiological studies in healthy volunteers propose that cool air stimulates facial receptors connected to the trigeminal nerve, altering input to sensory processing areas of the brain [33], while oral mucosal stimulation can affect afferent information [34], thereby altering and reducing the perception and intensity of breathlessness. MORÉLOT-PANZINI [35] describes this as “fooling the brain” into the perception that the respiratory system is more efficient than it is. These physiological observations are supported by qualitative accounts of patients’ coping strategies used to manage acute breathlessness *e.g.* opening windows, letting cold air into the room [36].

LANSING *et al.* [37] proposed a multidimensional model of dyspnoea based on the pain literature, where unpleasant sensations of breathlessness lead to withdrawal from physical activity, while an emotional component then leads to lifestyle changes to avoid dyspnoea. Avoiding dyspnoea triggers, such as physical activity, results in deconditioning, which lowers the threshold for dyspnoea and causes further decline.

Patients with COPD frequently feel helpless or not in control of their breathlessness, which is distressing for both the patient and their significant others [36, 38]. This can lead to them avoiding activities that make them breathless. An intervention that could reduce the extent of exertion-induced breathlessness and improve the recovery time could be important in breaking the cycle of avoidance behaviours commonly seen in patients with COPD and potentially lead to improvements in health-related quality of life.

Significant differences in favour of fan therapy were observed for two measures of breathlessness (NRS and mBorg) and distance on the 6MWT (tables 2 and 3). Based on the overall treatment effect, NRS scores were 1 unit lower in the fan condition (trial 1 and trial 2); mBorg scores were between 0.25 units (trial 1) and 1 unit (trial 2) lower in the fan condition; and distance walked was between 21 m (trial 1) and 28 m (trial 2) greater in the fan condition. Of these outcomes, only the NRS demonstrated consistent benefits (across both trials) for the fan condition which reached the respective MCID (1 unit for NRS) [39].

Benefits of the fan condition as assessed by mBorg breathlessness and distance on the 6MWT failed to consistently meet the MCIDs of 1 unit and 30 m [17, 19, 39]. Nevertheless, the findings for NRS suggest that the use of a fan during low-level physical activity may lead to clinically meaningful improvements in breathlessness and functional response. However, these improvements need to be contextualised as they were observed in a controlled situation on a flat indoor surface and were transitory. Taken at face value, the findings suggest there could be a role for fan therapy in helping individuals with COPD to cope with physical exertion (*e.g.* walking upstairs) or participation in patient exercise/rehabilitation programmes.

All outcomes were assessed over a very short period of time, and we cannot comment on the longer-term potential benefits of fan therapy. Future studies need to validate these acute findings and look at the acceptability and feasibility of sustained use of fan therapy and potential long-term benefits. Different roles for fan therapy should also be explored. For example, fans can be used for temporary symptomatic relief during day-to-day activities or in a more therapeutic way as an adjunct to exercise interventions and/or breathlessness self-management interventions; both approaches may be useful. Studies should explore benefits across a wider range of patient-reported outcomes such as breathlessness mastery, health-related quality of life and illness perception, as these are potentially modifiable factors.

We report some positive preliminary findings, along with some null results that suggest fan therapy merits further investigation in larger and more methodologically rigorous studies. The current study raises important practical considerations such as how will people use handheld fans in their day-to-day life (is it just an aid while they try to improve their respiratory fitness on a treadmill, or would they find it useful while walking to the park/shop/friend’s house?). There is also a question of whether people will use a fan on an ongoing basis, either as a rehabilitation aid or as a practical day-to-day aid for going to shops, *etc.* Does the use of a fan translate into quality-of-life benefits? The low cost and scalability of fan therapy could increase the potential impact, although the real-world practicalities of fan therapy should be examined.

### **Strengths and limitations**

A strength of the study was the use of a practice walk with the 6MWT. There is known learning effect with the 6MWT, with the second test usually performing better [17].

Internal validity was enhanced by a randomised crossover study design, which is suitable in chronic disease for evaluating the temporary effect of an intervention [40].

This study achieved a 53.8% recruitment rate from screening, similar to previous breathlessness literature [41]. This suggests that the generalisability of the current findings may be limited to only those people willing to engage with the intervention. Future studies could usefully embed an assessment of the reasons for refusal to participate, as has been done in other challenging clinical areas, *e.g.* occupational therapy intervention for individuals with dementia [42].

We must acknowledge the potential fatigue impact of undertaking three 6MWTs in a day. We ensured that there was sufficient time between walk tests and that patients remained at their symptomatic baseline prior to each test. However, we did not account for the potential effect of fatigue on the observed outcomes, a point that warrants consideration when planning subsequent trials.

Washout periods aim to reduce the potential of carryover effects of the intervention being studied. There is no consensus on the optimal duration of washout periods. Pharmacological studies often calculate their washout period based on five or more times the half-life of the drug under investigation [43]. For nonpharmacological interventions, deciding the optimal duration of the washout period is challenging. GALBRAITH *et al.* [44] reported that a 10-min washout after use of hand-held fan therapy at rest was insufficient. In this study, we choose a 30-min washout period as we believe that this would provide sufficient time for patients to physiologically recover from the 6MWT and for the acute potential effects of the fan therapy to have diminished. It must be acknowledged that a longer washout period of an hour may be more appropriate in subsequent studies, especially if including patients with advanced disease (mMRC >3). Moreover, it is important to factor in the overall time burden of the study design on participants, an important factor when estimating recruitment rates.

Commercially purchased, pocket-sized travel fans were used [41]; however, a limitation of this and most other fan therapy literature is that the that airflow generated by each fan used (either static or hand-held) appears to be generally unknown. MARCHETTI *et al.* [21] reported that the peak airflow generated by their static fan was 840 ft·min<sup>-1</sup>. Airflow studies describe a range of flow rates. What remains to be ascertained is whether there is a minimal or optimum flow rate that should be used in these studies to allow for greater comparison and transparency of results.

### Conclusion

Fan therapy using a low-cost, readily available hand-held fan was acceptable and provided symptomatic relief to patients with COPD during a short period of low-level exercise (walking). Our positive preliminary findings suggest that fan therapy merits further investigation in larger and more methodologically rigorous studies. The current study raises important practical considerations such as (how) would people use handheld fans in their day-to-day life

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