Facial airflow enhances the benefits of exercise training in people with chronic lung disease: A randomized controlled trial

Rachelle Aucoin[1,2]*, Dan Nguyen[3], Bryan Ross[2,3,4], Jean Bourbeau[2,3,4], Hayley Lewthwaite[5], Magnus Ekström[6], Andreas von Leupoldt[7], Dennis Jensen[1,2]

[1]Clinical Exercise & Respiratory Physiology Laboratory, Department of Kinesiology and Physical Education, McGill University, Montréal, Quebéc, Canada.
[2]Translational Research in Respiratory Diseases Program and Respiratory Epidemiology and Clinical Research Unit, Research Institute of the McGill University Health Centre, Montréal, Québec, Canada.
[3]Division of Clinical and Translational Research, Department of Medicine, McGill University Health Center, Montréal, Québec, Canada.
[4]Montreal Chest Institute, McGill University Health Centre, McGill University, Montréal, Québec, Canada.
[5]College of Engineering, Science and Environment, School of Environment & Life Sciences, The University of Newcastle, Ourimbah, Australia.
[6]Department of Respiratory Medicine, Allergology and Palliative Medicine, Institution for Clinical Sciences, Lund University, Sweden.
[7]Research Group Health Psychology, University of Leuven, Leuven, Belgium.

***Corresponding author at:**

475 Pine Avenue West, Montreal, Québec, H2W 1S4.

Phone: +1 (514) 396-2454

Email: rachelle.aucoin@mail.mcgill.ca (R. Aucoin)

Abstract

Introduction: Breathlessness limits exercise training (ExT) intensity in people with chronic lung disease (CLD). Stimulation of the trigeminal nerve via fan-to-face (F2F) therapy (facial airflow) can reduce exertional breathlessness and improve exercise endurance in CLD. This randomized controlled trial tested the hypothesis that adding F2F therapy to an ExT program could enhance the benefits of ExT on exercise endurance time (EET) and exertional breathlessness in adults with CLD by allowing them to train at higher intensities.

Methods: Twenty-three participants with chronic obstructive pulmonary disease (n=19) or interstitial lung disease (n=4) were randomized to 5 weeks of thrice weekly supervised ExT with (F2F; n=12) or without (No Fan [NF]; n=11) facial airflow. Primary outcomes were baseline to post-ExT change in EET and iso-time breathlessness intensity ratings assessed using constant work-rate cardiopulmonary treadmill exercise testing.

Results: Cumulative ExT volume over the 5-week ExT program was similar in the F2F and NF groups, whereas breathlessness intensity ratings were consistently lower across all ExT sessions in the F2F group. Both the F2F and NF groups showed significant increases in EET (mean±SD 7.2±9.1 mins, 95% CI[3.0, 13.6] *vs.* 8.6±8.5 mins, 95% CI[6.3, 9.0], respectively) and decreases in iso-time breathlessness intensity ratings (-2.1±1.5 mins, 95% CI[0.6, 3.2] *vs.* -1.5±1.1 mins, 95% CI[0.8, 4.0], respectively) from baseline to post-ExT, with similar magnitudes of change observed between groups.

Conclusion: F2F therapy (facial airflow) is a simple, feasible, low-cost, low-resource non-pharmacological approach to reduce exertional breathlessness during an ExT program in people with CLD.

Introduction

Breathlessness is a disabling symptom in people with chronic obstructive pulmonary disease (COPD) and interstitial lung disease (ILD), particularly during physical activity [1, 2]. The symptom is associated with poor health status, exercise intolerance, and premature death [3, 4]. Despite differences in pulmonary pathophysiology between COPD and ILD, emerging evidence suggests a common mechanism of exertional breathlessness: the conscious awareness of heightened inspiratory neural drive required to sustain ventilation in the setting of critical inspiratory constraints [5]. Although pharmacotherapies like inhaled bronchodilators and anti-fibrotic drugs can improve health outcomes, many people with COPD and ILD continue to experience significant breathlessness [1]. While both low- and high-intensity exercise training (ExT) are effective at improving exercise capacity, exertional breathlessness and health status in these populations, higher intensity ExT is better; however, severe breathlessness often limits ExT to lower rather than higher intensities [6]. This underscores the need for breathlessness-specific interventions to help optimize the benefits of an ExT program on clinical and patient-reported outcomes in people with chronic lung disease, especially those with the most severe, disabling breathlessness in daily life [7].

The transient receptor potential melastatin-8 (TRPM8) ion channel, present on the trigeminal nerve in the face, is a promising target for reducing breathlessness: at rest, during exercise and recovery from exercise in people with chronic lung disease; and in people receiving mechanical ventilation [8-13]. Selective TRPM8 agonists, such as L-menthol and cool facial airflow from fan-to-face (F2F) therapy, have been shown to acutely reduce breathlessness (both at and on exertion) and improve exercise endurance in COPD without significant changes in objective physiological variables, including ventilation, breathing pattern, heart rate (HR) and blood oxygen saturation

(SpO_2) [9-11, 14, 15]. This suggests a central mechanism of action, possibly by stimulating TRPM8 channels and potentially influencing brain regions involved in breathlessness perception (e.g., amygdala, insular cortex), with possible reductions in inspiratory neural drive [16, 17]. These findings suggest that adding F2F therapy to an ExT program could enhance its benefits by enabling people with chronic lung disease to train at higher intensities without greater exertional breathlessness.

This randomized controlled trial (RCT) aimed to evaluate whether F2F therapy can optimize the benefits of a 5-week supervised ExT program on exercise endurance time (EET) and exertional breathlessness in adults with COPD or ILD. We hypothesized that during an ExT program, F2F therapy (compared to no fan [NF]) would increase the ability of people with chronic lung disease to train at higher intensities for longer durations, leading to greater ExT-induced improvements in EET and exertional breathlessness.

Methods

Study Design

This single center trial randomized people with chronic lung disease to a 5-week supervised ExT program with F2F (intervention) or NF (control) in a 1:1 ratio (ClinicalTrials.gov: NCT05646407). Participants completed two baseline (Visits 1 and 2) and two post-ExT (Visits 3 and 4) assessment visits (**Figure 1**). Ethics approval was obtained from the Research Institute of the McGill University Health Centre (#2023-9286; see ***Supplemental Material*** for more details).

Assessments

Visit 1 included baseline evaluation of patient-reported breathlessness [18, 19] and health status [20, 21]; post-bronchodilator (400 mcg Salbutamol) pulmonary function testing; and a symptom-limited incremental (INCR) CPET on a motorised treadmill (Trackmaster 428 CP Medical Treadmill, Full Vision, Inc., Newton, KC) to determine peak power output (PPO) and peak rate of O_2 consumption ($V'O_{2peak}$). Visit 2 included a dual energy x-ray absorptiometry (DEXA) body composition scan with measurements referenced to normal predicted values [22]; and a symptom-limited constant work-rate (CWR) CPET on a motorised treadmill at 75% of the PPO achieved at visit 1. Except for pulmonary function testing, the assessments performed at visits 3 and 4 were identical to those at visits 1 and 2, respectively. All assessments are detailed in the ***Supplemental Material.***

Cardiopulmonary Exercise Testing (CPET)

All baseline and post-ExT CPETs were conducted under NF conditions. The INCR CPET included a pre-exercise rest period of ≥6 minutes (seated on a chair on the treadmill) after which the power output was increased by 10 W every 2 minutes, starting at 10 W, until symptom-limitation, based on a protocol adapted from *Jones* [23] that accounts for treadmill incline, speed, gravitational acceleration, and participant body mass. The CWR CPET also included a pre-exercise rest period of ≥6 minutes before a step increase to 75% of each participant's PPO. To reach this target power output, the treadmill incline was set at 60% of the peak incline achieved during the INCR CPET at visit 1, with speed adjusted for body mass.

Symptom evaluation during CPETs

The modified Borg Category-Ratio 0-10 (mBorg-CR10) scale [24] was used to assess participants' breathlessness intensity, breathlessness unpleasantness, leg discomfort and perceived exertion (RPE) at rest, within the last 30-seconds of every 2-min interval during INCR and CWR CPETs, and at end-exercise. The endpoints of the mBorg-CR10 scale were anchored prior to each CPET such that 0 represented '*no breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion*' and 10 represented '*the most severe breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion you have ever experienced or can imagine experiencing*'. Researchers used standardized scripts to assess exertional symptoms and to help participants distinguish between breathlessness intensity and unpleasantness. See ***Supplemental Material*** for more details.

Supervised 5-week Exercise Training (ExT) Program

Both NF and F2F groups followed the same assessment procedures outlined for the supervised 5-week supervised ExT program, which consisted of three aerobic ExT sessions/week for a total of 15 sessions (**Figure 1**). Participants were given an additional week to make up for missed attendance within the 5-week program. Each ExT session was individualized based on the participant's results from the symptom-limited INCR CPET completed at visit 1 and progressed so that they were exercising at a target intensity corresponding to a breathlessness intensity rating between 3-5 mBorg-CR10 scale units [24]. See ***Supplemental Material*** for more details.

Fan-to-Face (F2F)

A Honeywell HT-908 TurboForce Room Air Circulator (60 W, 120 V, 3 x 12" blades, Honeywell International Inc., NC, USA) was mounted to a pole with a C-clamp so that the position of the

standing fan could be adjusted to direct facial airflow to the second (forehead) and third (cheek) branches of the trigeminal nerve [16, 17]. At the first ExT session, participants chose their preferred fan speed for optimal comfort, which was measured at the face with a digital anemometer (Model FB61321, Fisher Scientific, Friendswood, TX, USA) and kept consistent throughout the program. To minimize bias, researchers avoided referencing breathlessness when asking participants to identify their preferred fan speed.

Primary Outcome Variables

The primary outcome was the change (Δ) in EET from baseline to post-ExT, where EET was defined as the duration of exercise (loaded pedaling) during the CWR CPET. The co-primary outcome was the Δ in breathlessness intensity ratings at iso-time during CWR CPET, where iso-time was defined as the highest equivalent submaximal time completed by a given participant during CWR CPETs done at both baseline and post-ExT. See ***Supplemental Material*** for information on secondary outcome variables.

Sample Size

Using a repeated measures within factor analysis of variance (ANOVA) formula with $\alpha = 0.05$, $\beta = 0.80$, a presumed correlation among repeated measures of 0.50 and an expected effect size of 0.31 [25], we estimated that at least 22 participants (i.e., 11 per group) were needed to detect a minimally clinically important difference (MCID) of ±101 seconds in EET [26] or ±1 mBorg-CR10 unit in breathlessness intensity at iso-time [25] during the symptom-limited CWR CPET from baseline to post-ExT.

Statistical Analysis

Participants completing at least 80% of the ExT program (≥12/15 sessions) without major protocol deviations were included in the final analysis. Primary outcomes were analyzed using a repeated measures analysis of co-variance, with time (baseline vs. post-ExT) as the within-subjects factor, allocation group (F2F vs. NF) as the between-subjects factor, and the ratio of forced expiratory volume in 1-sec to forced vital capacity (FEV_1/FVC) and residual volume (RV) as covariates to control for statistically significant between-group differences in baseline characteristics. Secondary outcomes were assessed using repeated measures ANOVA or unpaired t-tests for continuous data. Post hoc analyses were conducted where appropriate, and 95% confidence intervals (CIs) were calculated for between-group differences. Significance was considered at $p<0.05$.

Results

Baseline Participant Characteristics

Of the 36 participants assessed for eligibility, 30 were randomized to the F2F group (n=16) or NF group (n=14) (**Figure 2**). In the F2F group, one participant with ILD and two with COPD did not complete the study due to disease exacerbation or study withdrawal, while three participants with COPD in the NF group withdrew due to disease exacerbation or study withdrawal. Thus, a total of 12 participants in the F2F group (COPD, n=12) and 11 participants in the NF group (COPD, n=7; ILD, n=4) completed the study and were included in the analysis. Participants in both groups had impaired lung function and severe exercise intolerance mostly due to intolerable breathlessness (**Table 1**). The F2F group had a lower FEV_1/FVC and higher RV than the NF group. Otherwise, baseline participant characteristics were not significantly different between groups.

Exercise Training Program Outcomes

In the F2F group, the facial airflow applied during ExT sessions was 3.73 ± 1.51 m/s, with six, four and two participants self-selecting fan setting I (~2.5 m/s), II (~4.2 m/s) and III (~6.5 m/s), respectively.

The proportion of participants in the F2F group completing 13, 14 and 15 ExT sessions was 83%, 67% and 58%, respectively. The corresponding proportions for the NF group were 91%, 64% and 64%. Cumulative ExT volume over the 5-week ExT program was similar between groups: F2F, 10,589±7,251 *vs.* NF, 11,298±9,391 W x min (p=0.78). Average ExT session volume, duration, SpO_2 and breathlessness unpleasantness ratings were not different across the 15 ExT sessions between groups, whereas power output, HR, RPE, intensity ratings of breathlessness and leg discomfort, and facial skin surface temperature (T_{face}) were significantly lower in the F2F compared to NF group (**Figure 3**). Participant responses to an end-of-study questionnaire concerning their perceived benefit of the fan and the ExT program can be found in the ***Supplemental Material.***

Primary and Co-Primary Outcomes

Both the F2F and NF groups showed significant increases in EET and decreases in iso-time breathlessness intensity ratings during CWR CPET from baseline to post-ExT, with similar magnitudes of change observed between groups (**Table 2, Figure 4**). The proportion of participants in the F2F who showed: an increase in EET from baseline to post-ExT by the absolute and relative MCID of 101 seconds and 34% was 50% and 81%, respectively; and a decrease in

iso-time breathlessness intensity ratings by the MCID of 1 mBorg-CR10 unit was 83% (**Figure 4**). The corresponding proportions in the NF group were 72%, 58%, and 72% (**Figure 4**).

Physiological and Perceptual Responses to Cardiopulmonary Exercise Testing

Both the F2F and NF groups showed significant increases in exercise duration and PPO during the INCR CPET from baseline to post-ExT, with similar magnitudes of change observed between groups (***Supplemental Material Table 1***).

Both the F2F and NF groups showed significant decreases from baseline to post-ExT in breathlessness unpleasantness and leg discomfort ratings at iso-time during CWR CPET, with similar magnitudes of change observed between groups (**Table 2**). See ***Supplemental Material Table 2*** for peak CWR CPET data.

Symptom Burden and Health Status

Both the F2F and NF groups showed significant improvements in breathlessness burden (increased baseline dyspnea index (BDI)/transition dyspnea index (TDI) rating), health status (decreased COPD assessment test (CAT) total score), and symptoms of anxiety and depression (Hospital Anxiety and Depression Scale (HADS) score) from baseline to post-ExT, with similar magnitudes of change observed between groups (***Supplemental Material Figure 1***). The proportion of participants in the F2F group improving by the level of the MCIDs for their BDI/TDI rating (±1 unit), CAT total score (±2 units), and HADS total score (±2 units) from baseline to post-ExT was 75%, 62%, and 66%, respectively. The corresponding proportions in the NF group were 50%, 85%, and 50%.

Exploratory Post-Hoc Analysis

Four participants with ILD were randomized to the NF group, whereas only participants with COPD were randomized to the F2F group. To reduce potential bias from this imbalance, we compared the effects of the 5-week ExT program among people with COPD only in the F2F (n=12) and NF groups (n=7). Baseline participant characteristics were similar between groups (***Supplemental Material Table 3***) and both the F2F and NF groups showed significant increases in EET and decreases in iso-time breathlessness intensity ratings from baseline to post-ExT (***Supplemental Material Figure 3***). The magnitude of these changes was slightly but not significantly greater in the F2F vs. NF group (both p=0.74). Cumulative ExT volume over the 5-week ExT program was significantly greater in the F2F vs. NF group (10,589±7,251 vs. 6,999±3,481 W x min, p<0.001). Despite significantly greater ExT session volume, duration and power output in the F2F vs. NF group, the F2F group showed significantly lower HR, intensity ratings of breathlessness and leg discomfort, RPE, and T_{face} across the 15 ExT sessions (***Supplemental Material Figure 4)***.

Discussion

This RCT is the first to test the hypothesis that F2F therapy enhances the benefits of a supervised ExT program in people with chronic lung disease by allowing them to train at higher ExT volumes without greater exertional breathlessness. The main findings indicate that cumulative ExT volume over the 5-week ExT program was similar in the F2F and NF group, despite the F2F group reporting consistently lower exertional symptoms (breathlessness intensity, RPE, leg discomfort) across the 15 ExT sessions. While the 5-week supervised ExT program led to statistically significant and clinically meaningful improvements in EET, exertional (iso-time) breathlessness,

symptom burden and health status in both F2F and NF groups, the magnitude of these improvements were not different between groups. However, a sub-group analysis of participants with COPD only demonstrated that a greater ExT volume was accumulated over the 5-week ExT program in the F2F vs. NF group, with slightly greater improvements in EET and iso-time breathlessness intensity ratings from baseline to post-ExT in the F2F group.

Strengths and Limitations

Participants in both F2F and NF groups completed ExT sessions at individualized intensities with progressive overload, following established exercise prescription principles [27]. This approach aimed to evaluate the effects of F2F therapy beyond the established benefits of ExT in people with chronic lung disease, with breathlessness intensity targets set at 3-5 mBorg-CR10 units for each ExT session. While using breathlessness intensity ratings to guide prescription, monitoring and progression of ExT intensity is common in chronic lung disease management [27], this method has limitations for symptomatic adults with more severe disease who struggle to achieve and/or maintain these intensity targets [27, 28]. In these people, adding F2F therapy to an ExT program may decrease exertional symptoms, thereby enhancing the enjoyment or tolerability of a given exercise session, without necessarily increasing ExT intensity, duration or volume, as noted in our main analysis.

Although blinding was not possible, participants exercised alone with researcher supervision, and the study hypothesis was partially concealed to minimize bias. While a sham control group was not included in this study, including such a group into future trials could allow for better concealment of the study hypothesis, while also potentially untangling the effectiveness of facial

airflow versus airflow applied to other areas of the body (e.g., calf). The absence of significant between-group differences in primary and secondary outcomes argues against the likelihood of substantial bias contributing to our results.

The modest sample size and relatively short duration of the 5-week ExT program may have limited the ability to detect potentially meaningful between group differences in the magnitude of change in clinical and patient-reported outcomes following the ExT program. This highlights the need for larger, longer RCTs with more balanced enrollment of people with COPD and ILD across F2F and NF groups to confirm and extend our findings.

Facial Airflow as an Adjunct to Exercise Training in Chronic Lung Disease

F2F therapy (facial airflow) is a simple, feasible, acceptable, low-cost, low-risk and low-resource non-pharmacological intervention for use by healthcare providers (e.g., clinicians, physiotherapists, respiratory therapists) in their patients with chronic lung disease [9, 10, 16, 17]. When added to an ExT program – including pulmonary rehabilitation – F2F therapy may enhance exercise tolerability and enjoyment in people with chronic lung disease by reducing exertional breathlessness [9, 10, 16, 17], thereby potentially improving exercise adherence. This perspective aligns with previous recommendations highlighting the potential of F2F therapy for breathlessness relief [29, 30]. While our main analysis did not show significantly greater improvements in clinical or patient-reported outcomes when F2F therapy was added to a 5-week supervised ExT program (possibly due to our modest sample size, relatively short 5-week ExT program and/or baseline group differences), participants in the F2F vs. NF group consistently reported fewer exertional symptoms over the 15 ExT sessions despite accumulating a similar ExT volume. To minimize bias

from baseline group differences caused by the imbalance of people with ILD randomized to the NF group, we conducted a judicious exploratory sub-group analysis of people with COPD only. In this analysis, the F2F group accumulated a significantly greater ExT volume over the course of the 5-week ExT program (secondary to greater ExT session duration and power output) and reported lower exertional breathlessness intensity, RPE and leg discomfort across the ExT sessions compared to the NF group. T_{face} was consistently lower (by ~2°C) during each ExT session in the F2F vs. NF group throughout the 5-week ExT program. This cooling effect, which has been shown to reduce RPE and overall exercise-related discomfort [43, 44], may partly explain the lower reports of exertional symptoms observed across the ExT sessions in our F2F group. Future research should work to identify phenotypic traits of people with chronic lung disease that would most likely benefit from F2F therapy during acute exercise and/or rehabilitative exercise training. The optimal facial airflow speed identified in our study (3.56 m/s) differed from prior reports, being lower than the 4.27 m/s used by *Marchetti et al.* [9], but higher than the 2.85 m/s recommended by *Luckett et al.* [31] and *Burrell et al.* [32], and the ≥1.7 m/s suggested by *Brew et al.* [33], perhaps driven by the use of a standing fan in our study as opposed to a smaller handheld fan [32, 33]. These finding point to a potential "Goldilocks airflow" range for optimal comfort and symptom relief, which may also vary depending on context, such as during acute exercise vs. post-exercise recovery. Future research should include low facial airflow speeds (e.g., <1.7 m/s [33]) as active controls alongside higher, participant-preferred speeds to better characterize the relationship between comfort and symptom relief during both exercise and recovery. Consistent with the results of several other studies [9, 10], no adverse events were experienced by participants in either F2F or NF groups, and participant responses to end-of-study questionnaires revealed that people in the F2F group perceived a direct benefit from facial airflow, including better breathing control,

reduced fear, and greater focus on the exercise itself. In contrast, participants in the NF group primarily emphasized their motivation and pride in completing the ExT program.

In conclusion, the collective results of this RCT suggest that adding F2F therapy to a supervised ExT program may allow people with chronic lung disease to train at their prescribed or even higher than prescribed ExT volumes with lower exertional symptoms and subjective perceptions of respiratory discomfort. Larger, longer duration ExT trials in both supervised and unsupervised settings are needed to confirm our results and evaluate the potential of F2F therapy to deliver sustained benefits on exercise tolerance and symptom burden to people living with chronic lung disease in real-world contexts such as pulmonary rehabilitation. Incorporating health economic analyses into future trials will also be important to assess the financial feasibility of large-scale F2F therapy implementation.

Acknowledgements

The authors thank Justin Riffou, Erica Delucilla, Anna Blinova, and Aleksander Illic for their help with data collection; Dr. Camilla Illidi for her help with statistical analysis; and the pulmonary rehabilitation multi-disciplinary groups at the McGill University Health Centre and Jewish General Hospital for their help with recruitment. Importantly, the authors thank the COPD and ILD patients who participated in this study. Without their commitment and support, this study would not have been possible.

368

369 **Table 1.** Baseline characteristics of participants.

	F2F group (n=12)		NF group (n=11)	
Variables	**Value**	**% Predicted**	**Value**	**% Predicted**
Female, n (%)	5 (41)	-	6 (54)	-
Age, years	67.6 ± 5.2	-	71.2 ± 9.3	-
Smoking history, pack-years	60.0 ± 43.2	-	37.0 ± 20.6	-
Body mass, kg	77.5 ± 33.6	-	73.4 ± 24.2	-
Body mass index, kg/m^2	28.4 ± 10.9	-	28.4 ± 10.6	-
Clinical Diagnosis, n (%)				
COPD				
GOLD stage 1	1 (8)	-	1 (9)	-
GOLD stage 2	2 (16)	-	2 (18)	-
GOLD stage 3	6 (50)	-	3 (27)	-
GOLD stage 4	3 (25)	-	1 (9)	-
ILD				
Idiopathic Pulmonary Fibrosis	0 (0)	-	2 (50)	-
Sarcoidosis	0 (0)	-	1 (25)	-
Undefined	0 (0)	-	1 (25)	-
Medication Summary, n (%)				
SABA	7 (58)	-	7 (63)	-
SAMA	1 (8)	-	0 (0)	-
SABA + SAMA	1 (8)	-	0 (0)	-
LABA	4 (33)	-	0 (0)	-

LAMA	2 (16)	-	4 (36)	-
LABA + LAMA	6 (50)	-	5 (54)	-
ICS	2 (16)	-	3 (27)	-
LABA + ICS	3 (25)	-	7 (63)	-
LABA + LAMA + ICS	3 (25)	-	0 (0)	-
Anti-Fibrotic	0 (0)	-	1 (9)	-
Domiciliary Oxygen	1 (8)	-	1 (9)	-
Breathlessness and health status				
mMRC dyspnea score, 0-4	2.5 ± 1.4	-	1.7 ± 0.9	-
mMRC ≥ 2, n (%)	9 (75)	-	5 (45)	-
CAT total score, 0-40[#]	21.6 ± 11.1	-	15.9 ± 7.7	-
CAT ≥ 10, n (%)[#]	7 (58)	-	6 (54)	-
Baseline Dyspnea Index, 0-12	4.4 ± 1.9	-	6.3 ± 2.5	-
HADS Anxiety score, 0-21	8.0 ± 4.2	-	5.6 ± 3.4	-
HADS Depression score, 0-21	6.2 ± 4.7	-	4.1 ± 1.7	-
Post-bronchodilator lung function				
FEV_1/FVC	41.2 ± 14.9	-	58.0 ± 18.1*	-
FEV_1, L	1.1 ± 0.5	46 ± 22	1.5 ± 0.8	66 ± 26
Total Lung Capacity, L	6.3 ± 1.1	113 ± 19	5.3 ± 1.4	99 ± 18
Inspiratory Capacity, L	2.0 ± 0.6	75 ± 15	2.6 ± 0.8	81 ± 24
Residual Volume, L	3.5 ± 0.9	176 ± 56	2.6 ± 0.8*	139 ± 49
Functional Residual Capacity, L	4.3 ± 1.1	139 ± 38	3.4 ± 1.1	107 ± 40
D_LCO, mL/min/mmHg	14.2 ± 5.1	66 ± 24	12.7 ± 5.1	63 ± 24
R5, kPa/L/s	6.7 ± 3.1	210 ± 111	5.0 ± 3.5	153 ± 151

X5, kPa/L/s	-4.4 ± 6.4	351 ± 499	-3.2 ± 4.4	246 ± 458
R5-R20, kPa/L/s	3.9 ± 1.2	263 ± 266	3.7 ± 1.9	149 ± 149
DEXA-derived measures				
Fat Mass, kg	33.5 ± 13.0	-	34.6 ± 15.8	-
Fat Mass, % total body mass	44 ± 15	-	53 ± 13	-
Fat-Free Mass, kg	46.9 ± 13.6	-	42.2 ± 9.6	-
Fat-Free Mass, % total body mass	63 ± 11	-	59 ± 10	-
Fat-Free Mass Index, kg/m^2	17.2 ± 0.4	76 ± 13	16.2 ± 0.3	81 ± 11
Peak incremental cardiopulmonary treadmill exercise test data				
V'O_2, mL/kg/min	13.6 ± 5.1	68 ± 69	14.3 ± 7.4	101 ± 99
Power output, Watts	41.6 ± 20.4	62 ± 16	47.3 ± 31.6	64 ± 15
Reason(s) for stopping exercise, n (%)				
Breathlessness	6 (50)	-	7 (63)	-
Leg Discomfort	3 (25)	-	3 (27)	-
Breathlessness + Leg Discomfort	1 (8)	-	0 (0)	-
Other**	2 (16)	-	1 (9)	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 between the fan-to-face (F2F) and no fan (NF) groups, # = 8 participants in the F2F group and 9 participants in the NF group completed the CAT, ** = other reasons for stopping exercise included general overall fatigue and CPET mask discomfort.

Abbreviations: BMI = body mass index; COPD = chronic obstructive pulmonary disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease; ILD = interstitial lung disease; SABA = short-acting beta-agonist; SAMA = short-acting muscarinic antagonist; LABA = long acting beta-agonist; LAMA = long-acting muscarinic antagonist; ICS = inhaled corticosteroid; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; mMRC = modified Medical Research Council dyspnea scale; CAT = COPD assessment test; HADS = Hospital Anxiety and Depression Scale; D_LCO = diffusion capacity of the lung for carbon monoxide; R5 = resistance at 5 hertz; R20 = resistance at 20 hertz; X5 = reactance at 5 hertz; V'O_2 = rate oxygen consumption

Table 2. Physiological and perceptual responses from baseline to post-exercise training (ExT) at iso-time during constant work-rate cardiopulmonary treadmill exercise testing in the fan-to-face (F2F) and no fan (NF) groups.

	F2F Group (n=12)				NF Group (n=11)					
Variables	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Difference in change between groups**	**95% CI**
Exercise time, minutes	5.2 ± 3.2	-	-	-	5.4 ± 4.2	-	-	-	-	-
Power output, Watts	28.5 ± 15.3	-	-	-	34.8 ± 24.2	-	-	-	-	-
$V'O_2$, mL/kg/min	13.6 ± 4.6	12.1 ± 3.7	-1.5*	0.6, 2.4	14.5 ± 7.4	13.3 ± 6.0	-1.2	0.01, 2.5	0.3	-1.5, 1.9
RER	0.92 ± 0.1	0.87 ± 0.1	-0.05	0.01, 0.09	0.99 ± 0.1	0.93 ± 0.1	-0.06	0.01, 0.1	0.01	-0.08, 0.06
Heart rate, beats/min	97.0 ± 15.0	91.5 ± 17.2	-5.5	0.0, 19.8	107.5 ± 26.8	104.5 ± 13.5	-3.0	-6.3, 13.1	2.2	-9.5, 21.9
SpO_2, %	86.9 ± 6.5	88.2 ± 4.9	1.3	-5.6, 1.7	91.4 ± 3.5	91.4 ± 4.7	0	-1.4, 1.6	1.3	-2.0, 5.2
$V'_E/V'CO_2$	38.1 ± 9.4	37.7 ± 6.9	-0.4	-1.2, 2.1	39.0 ± 9.8	38.8 ± 8.9	0.2	-1.4, 1.5	0.2	-2.5, 2.6
V'_E, L/min	33.8 ± 11.6	29.2 ± 9.6	-4.6	-7.5, 11.1	38.3 ± 19.6	32.1 ± 12.4	-6.2	-12.1, 12.1	1.6	-17.2, 17.5
V_T, L	1.1 ± 0.2	1.1 ± 0.2	0	-0.3, 0.1	1.2 ± 0.6	1.1 ± 0.6	-0.1	-0.6, 0.3	0.1	-0.5, 0.5
V_T%IC	67.5 ± 17.3	63.2 ± 9.1	-4.3	-5.3, 14.2	70.2 ± 10.1	62.0 ± 7.5	-8.2*	1.2, 15.2	3.9	-13.4, 6.6
*f*R, breaths/min	31.2 ± 6.2	26.4 ± 6.8	-4.8	-1.9, 9.1	33.8 ± 7.3	31.0 ± 6.7	-2.8	-3.2, 9.3	2.0	-8.7, 10.1
*Δ*IC, L	-0.6 ± 0.5	-0.5 ± 0.3	-0.1	0.2, 0.3	-0.4 ± 0.4	-0.4 ± 0.5	0	-0.4, 0.5	0.1	-0.5, 0.6
IRV, L	0.6 ± 0.4	0.7 ± 0.3	0.1	-0.5, 0.2	0.5 ± 0.2	0.6 ± 0.2	0.1	-0.4, 0.04	0.0	-0.4, 0.5
RPE, mBorg-CR10 units	3.7 ± 3.1	1.4 ± 1.7	-2.3	-0.8, 2.9	3.8 ± 1.0	1.9 ± 1.6	-1.9*	0.7, 3.7	0.4	-4.1, 1.6
Breathlessness intensity, mBorg-CR10 units	3.6 ± 2.6	1.1± 1.4	-2.5*	0.6, 3.2	3.7 ± 1.3	1.8 ± 1.5	-1.9*	0.8, 4.0	0.6	-2.5, 2.0
Breathlessness unpleasantness, mBorg-CR10 units	3.8 ± 2.5	1.2 ± 1.4	-2.6*	0.7, 3.6	3.7 ± 1.3	1.3 ± 1.3	-2.4*	1.3, 4.2	0.2	-2.9, 1.8
Leg Discomfort, mBorg-CR10 units	3.4 ± 2.6	1.0 ± 1.7	-2.4*	0.3, 3.3	3.0 ± 1.9	1.3 ± 1.3	-1.7	0.3, 4.0	0.7	-3.0, 3.7
Reasons for stopping exercise, n (%)										

Breathlessness	8 (66)	4 (33)	-	-	7 (63)	5 (45)	-	-	-	-
Leg Discomfort	2 (16)	1 (8)	-	-	3 (27)	1 (8)	-	-	-	-
Breathlessness + Leg Discomfort	1 (8)	1 (8)	-	-	1 (8)	1 (8)	-	-	-	-
Other, n	1 (8)	6 (50)	-	-	0 (0)	4 (36)	-	-	-	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 from baseline to post-ExT within group.
Abbreviations: $V'O_2$ = rate of oxygen consumption; RER = respiratory exchange ratio; SpO_2 = blood oxygen saturation; $V'_E/V'CO_2$ = ventilatory equivalent for carbon dioxide; V'_E = minute ventilation; V_T = tidal volume; f_R = breathing frequency; Δ = change from baseline; IC = inspiratory capacity; IRV = inspiratory reserve volume; RPE = rating of perceived exertion; mBorg-CR10 = modified Borg Category-Ratio 0-10 scale

REFERENCES

1. Sundh, J. and M. Ekström, *Persistent disabling breathlessness in chronic obstructive pulmonary disease.* International journal of chronic obstructive pulmonary disease, 2016. **11**: p. 2805-2812.
2. Parshall, M.B., et al., *An official American Thoracic Society statement: update on the mechanisms, assessment, and management of dyspnea.* Am J Respir Crit Care Med, 2012. **185**(4): p. 435-52.
3. Johnson, M.J., et al., *Breathlessness despite optimal pathophysiological treatment: on the relevance of being chronic.* Eur Respir J, 2017. **50**(3).
4. Currow, D.C., et al., *The need to research refractory breathlessness.* Eur Respir J, 2016. **47**(1): p. 342-3.
5. Jensen, D., M.R. Schaeffer, and J.A. Guenette, *Pathophysiological mechanisms of exertional breathlessness in chronic obstructive pulmonary disease and interstitial lung disease.* Curr Opin Support Palliat Care, 2018. **12**(3): p. 237-245.
6. Maltais, F., et al., *Intensity of training and physiologic adaptation in patients with chronic obstructive pulmonary disease.* Am J Respir Crit Care Med, 1997. **155**(2): p. 555-61.
7. O'Donnell, D.E., et al., *Dyspnea in COPD: New Mechanistic Insights and Management Implications.* Adv Ther, 2020. **37**(1): p. 41-60.
8. Fisher, J.T., *TRPM8 and dyspnea: from the frigid and fascinating past to the cool future?* Curr Opin Pharmacol, 2011. **11**(3): p. 218-23.
9. Marchetti, N., et al., *Air Current Applied to the Face Improves Exercise Performance in Patients with COPD.* Lung, 2015. **193**(5): p. 725-31.
10. Long, A., M. Cartwright, and C.C. Reilly, *Impact of fan therapy during exercise on breathlessness and recovery time in patients with COPD: a pilot randomised controlled crossover trial.* ERJ Open Research, 2021. **7**(4): p. 00211-2021.
11. Swan, F., et al., *Airflow relieves chronic breathlessness in people with advanced disease: An exploratory systematic review and meta-analyses.* Palliative Medicine, 2019. **33**(6): p. 618-633.
12. Schwartzstein, R.M., et al., *Cold facial stimulation reduces breathlessness induced in normal subjects.* Am Rev Respir Dis, 1987. **136**(1): p. 58-61.
13. Bureau, C., et al., *Sensory interventions to relieve dyspnoea in critically ill mechanically ventilated patients.* Eur Respir J, 2024. **63**(1).
14. Qian, Y., et al., *Fan Therapy for the Treatment of Dyspnea in Adults: A Systematic Review.* Journal of Pain and Symptom Management, 2019. **58**(3): p. 481-486.
15. Kako, J., et al., *Immediate Effect of Fan Therapy in Terminal Cancer With Dyspnea at Rest: A Meta-Analysis.* Am J Hosp Palliat Care, 2020. **37**(4): p. 294-299.
16. Aucoin, R., et al., *Impact of trigeminal and/or olfactory nerve stimulation on measures of inspiratory neural drive: Implications for breathlessness.* Respiratory Physiology & Neurobiology, 2023. **311**: p. 104035.
17. Aucoin, R., et al., *Impact of trigeminal nerve and/or olfactory nerve stimulation on activity of human brain regions involved in the perception of breathlessness.* Respiratory Physiology & Neurobiology, 2023: p. 104036.

18. Bestall, J.C., et al., *Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease.* Thorax, 1999. **54**(7): p. 581-6.
19. Mahler, D.A., et al., *The measurement of dyspnea. Contents, interobserver agreement, and physiologic correlates of two new clinical indexes.* Chest, 1984. **85**(6): p. 751-8.
20. Jones, P.W., et al., *Development and first validation of the COPD Assessment Test.* Eur Respir J, 2009. **34**(3): p. 648-54.
21. Zigmond, A.S. and R.P. Snaith, *The hospital anxiety and depression scale.* Acta Psychiatr Scand, 1983. **67**(6): p. 361-70.
22. Jenkins, A.R., H. Lewthwaite, and D. Jensen, *Development and validation of reference equations for dual-energy X-ray absorptiometry-derived measures of fat-free mass in adults aged 45-85 years: results from the Canadian Longitudinal Study on Aging.* Appl Physiol Nutr Metab, 2024. **49**(10): p. 1317-1327.
23. Jones, N.L., *Clinical exercise testing*. 1997, Philadelphia: W.B. Saunders.
24. Borg, G.A., *Psychophysical bases of perceived exertion.* Med Sci Sports Exerc, 1982. **14**(5): p. 377-81.
25. Ries, A.L., *Minimally clinically important difference for the UCSD Shortness of Breath Questionnaire, Borg Scale, and Visual Analog Scale.* Copd, 2005. **2**(1): p. 105-10.
26. Puente-Maestu, L., et al., *Clinical relevance of constant power exercise duration changes in COPD.* Eur Respir J, 2009. **34**(2): p. 340-5.
27. Gloeckl, R., et al., *Prescribing and adjusting exercise training in chronic respiratory diseases – Expert-based practical recommendations.* Pulmonology, 2023. **29**(4): p. 306-314.
28. Horowitz, M.B., B. Littenberg, and D.A. Mahler, *Dyspnea Ratings for Prescribing Exercise Intensity in Patients With COPD.* Chest, 1996. **109**(5): p. 1169-1175.
29. Luckett, T., et al., *ERS guideline recommendation on airflow for breathlessness: the pitfalls of applying GRADE evidence ratings to complex non-pharmacological interventions.* European Respiratory Journal, 2025. **65**(2): p. 2402244.
30. Holland, A.E., et al., *Reply: A recommendation for increased airflow to relieve breathlessness: evidence in context is a strength of the GRADE approach.* Eur Respir J, 2025. **65**(2).
31. Luckett, T., M. Roberts, and F. Swan, *Fan therapy for breathlessness - how do you do it and why?* Curr Opin Support Palliat Care, 2025.
32. Burrell, T., et al., *Cool facial airflow hastens exertion recovery in chronic breathlessness: randomised crossover trial of different fan airflow speeds.* BMJ Support Palliat Care, 2025.
33. Brew, A., et al., *Airflow rates and breathlessness recovery from submaximal exercise in healthy adults: prospective, randomised, cross-over study.* BMJ Support Palliat Care, 2024. **14**(4): p. 442-448.

Table 1. Baseline characteristics of participants.

	F2F group (n=12)		NF group (n=11)	
Variables	**Value**	**% Predicted**	**Value**	**% Predicted**
Female, n (%)	5 (41)	-	6 (54)	-
Age, years	67.6 ± 5.2	-	71.2 ± 9.3	-
Smoking history, pack-years	60.0 ± 43.2	-	37.0 ± 20.6	-
Body mass, kg	77.5 ± 33.6	-	73.4 ± 24.2	-
Body mass index, kg/m^2	28.4 ± 10.9	-	28.4 ± 10.6	-
Clinical Diagnosis, n (%)				
COPD				
GOLD stage 1	1 (8)	-	1 (9)	-
GOLD stage 2	2 (16)	-	2 (18)	-
GOLD stage 3	6 (50)	-	3 (27)	-
GOLD stage 4	3 (25)	-	1 (9)	-
ILD				
Idiopathic Pulmonary Fibrosis	0 (0)	-	2 (50)	-
Sarcoidosis	0 (0)	-	1 (25)	-
Undefined	0 (0)	-	1 (25)	-
Medication Summary, n (%)				
SABA	7 (58)	-	7 (63)	-
SAMA	1 (8)	-	0 (0)	-
SABA + SAMA	1 (8)	-	0 (0)	-
LABA	4 (33)	-	0 (0)	-
LAMA	2 (16)	-	4 (36)	-
LABA + LAMA	6 (50)	-	5 (54)	-
ICS	2 (16)	-	3 (27)	-

LABA + ICS	3 (25)	-	7 (63)	-
LABA + LAMA + ICS	3 (25)	-	0 (0)	-
Anti-Fibrotic	0 (0)	-	1 (9)	-
Domiciliary Oxygen	1 (8)	-	1 (9)	-
Breathlessness and health status				
mMRC dyspnea score, 0-4	2.5 ± 1.4	-	1.7 ± 0.9	-
mMRC ≥ 2, n (%)	9 (75)	-	5 (45)	-
CAT total score, 0-40[#]	21.6 ± 11.1	-	15.9 ± 7.7	-
CAT ≥ 10, n (%)[#]	7 (58)	-	6 (54)	-
Baseline Dyspnea Index, 0-12	4.4 ± 1.9	-	6.3 ± 2.5	-
HADS Anxiety score, 0-21	8.0 ± 4.2	-	5.6 ± 3.4	-
HADS Depression score, 0-21	6.2 ± 4.7	-	4.1 ± 1.7	-
Post-bronchodilator lung function				
FEV_1/FVC	41.2 ± 14.9	-	58.0 ± 18.1*	-
FEV_1, L	1.1 ± 0.5	46 ± 22	1.5 ± 0.8	66 ± 26
Total Lung Capacity, L	6.3 ± 1.1	113 ± 19	5.3 ± 1.4	99 ± 18
Inspiratory Capacity, L	2.0 ± 0.6	75 ± 15	2.6 ± 0.8	81 ± 24
Residual Volume, L	3.5 ± 0.9	176 ± 56	2.6 ± 0.8*	139 ± 49
Functional Residual Capacity, L	4.3 ± 1.1	139 ± 38	3.4 ± 1.1	107 ± 40
D_LCO, mL/min/mmHg	14.2 ± 5.1	66 ± 24	12.7 ± 5.1	63 ± 24
R5, kPa/L/s	6.7 ± 3.1	210 ± 111	5.0 ± 3.5	153 ± 151
X5, kPa/L/s	-4.4 ± 6.4	351 ± 499	-3.2 ± 4.4	246 ± 458
R5-R20, kPa/L/s	3.9 ± 1.2	263 ± 266	3.7 ± 1.9	149 ± 149
DEXA-derived measures				
Fat Mass, kg	33.5 ± 13.0	-	34.6 ± 15.8	-
Fat Mass, % total body mass	44 ± 15	-	53 ± 13	-

Fat-Free Mass, kg	46.9 ± 13.6	-	42.2 ± 9.6	-
Fat-Free Mass, % total body mass	63 ± 11	-	59 ± 10	-
Fat-Free Mass Index, kg/m^2	17.2 ± 0.4	76 ± 13	16.2 ± 0.3	81 ± 11
Peak incremental cardiopulmonary treadmill exercise test data				
V'O_2, mL/kg/min	13.6 ± 5.1	68 ± 69	14.3 ± 7.4	101 ± 99
Power output, Watts	41.6 ± 20.4	62 ± 16	47.3 ± 31.6	64 ± 15
Reason(s) for stopping exercise, n (%)				
Breathlessness	6 (50)	-	7 (63)	-
Leg Discomfort	3 (25)	-	3 (27)	-
Breathlessness + Leg Discomfort	1 (8)	-	0 (0)	-
Other**	2 (16)	-	1 (9)	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 between the fan-to-face (F2F) and no fan (NF) groups, # = 8 participants in the F2F group and 9 participants in the NF group completed the CAT, ** = other reasons for stopping exercise included general overall fatigue and CPET mask discomfort.

Abbreviations: BMI = body mass index; COPD = chronic obstructive pulmonary disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease; ILD = interstitial lung disease; SABA = short-acting beta-agonist; SAMA = short-acting muscarinic antagonist; LABA = long acting beta-agonist; LAMA = long-acting muscarinic antagonist; ICS = inhaled corticosteroid; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; mMRC = modified Medical Research Council dyspnea scale; CAT = COPD assessment test; HADS = Hospital Anxiety and Depression Scale; D_LCO = diffusion capacity of the lung for carbon monoxide; R5 = resistance at 5 hertz; R20 = resistance at 20 hertz; X5 = reactance at 5 hertz; V'O_2 = rate oxygen consumption

Table 2. Physiological and perceptual responses from baseline to post-exercise training (ExT) at iso-time during constant work-rate cardiopulmonary treadmill exercise testing in the fan-to-face (F2F) and no fan (NF) groups.

	F2F Group (n=12)				NF Group (n=11)					
Variables	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Difference in change between groups**	**95% CI**
Exercise time, minutes	5.2 ± 3.2	-	-	-	5.4 ± 4.2	-	-	-	-	-
Power output, Watts	28.5 ± 15.3	-	-	-	34.8 ± 24.2	-	-	-	-	-
$V'O_2$, mL/kg/min	13.6 ± 4.6	12.1 ± 3.7	-1.5*	0.6, 2.4	14.5 ± 7.4	13.3 ± 6.0	-1.2	0.01, 2.5	0.3	-1.5, 1.9
RER	0.92 ± 0.1	0.87 ± 0.1	-0.05	0.01, 0.09	0.99 ± 0.1	0.93 ± 0.1	-0.06	0.01, 0.1	0.01	-0.08, 0.06
Heart rate, beats/min	97.0 ± 15.0	91.5 ± 17.2	-5.5	0.0, 19.8	107.5 ± 26.8	104.5 ± 13.5	-3.0	-6.3, 13.1	2.2	-9.5, 21.9
SpO_2 %	86.9 ± 6.5	88.2 ± 4.9	1.3	-5.6, 1.7	91.4 ± 3.5	91.4 ± 4.7	0	-1.4, 1.6	1.3	-2.0, 5.2
$V'_E/V'CO_2$	38.1 ± 9.4	37.7 ± 6.9	-0.4	-1.2, 2.1	39.0 ± 9.8	38.8 ± 8.9	0.2	-1.4, 1.5	0.2	-2.5, 2.6
V'_E, L/min	33.8 ± 11.6	29.2 ± 9.6	-4.6	-7.5, 11.1	38.3 ± 19.6	32.1 ± 12.4	-6.2	-12.1, 12.1	1.6	-17.2, 17.5
V_T, L	1.1 ± 0.2	1.1 ± 0.2	0	-0.3, 0.1	1.2 ± 0.6	1.1 ± 0.6	-0.1	-0.6, 0.3	0.1	-0.5, 0.5
V_T%IC	67.5 ± 17.3	63.2 ± 9.1	-4.3	-5.3, 14.2	70.2 ± 10.1	62.0 ± 7.5	-8.2*	1.2, 15.2	3.9	-13.4, 6.6
*f*R, breaths/min	31.2 ± 6.2	26.4 ± 6.8	-4.8	-1.9, 9.1	33.8 ± 7.3	31.0 ± 6.7	-2.8	-3.2, 9.3	2.0	-8.7, 10.1
⊿IC, L	-0.6 ± 0.5	-0.5 ± 0.3	-0.1	0.2, 0.3	-0.4 ± 0.4	-0.4 ± 0.5	0	-0.4, 0.5	0.1	-0.5, 0.6
IRV, L	0.6 ± 0.4	0.7 ± 0.3	0.1	-0.5, 0.2	0.5 ± 0.2	0.6 ± 0.2	0.1	-0.4, 0.04	0.0	-0.4, 0.5
RPE, mBorg-CR10 units	3.7 ± 3.1	1.4 ± 1.7	-2.3	-0.8, 2.9	3.8 ± 1.0	1.9 ± 1.6	-1.9*	0.7, 3.7	0.4	-4.1, 1.6
Breathlessness intensity, mBorg-CR10 units	3.6 ± 2.6	1.1± 1.4	-2.5*	0.6, 3.2	3.7 ± 1.3	1.8 ± 1.5	-1.9*	0.8, 4.0	0.6	-2.5, 2.0
Breathlessness unpleasantness, mBorg-CR10 units	3.8 ± 2.5	1.2 ± 1.4	-2.6*	0.7, 3.6	3.7 ± 1.3	1.3 ± 1.3	-2.4*	1.3, 4.2	0.2	-2.9, 1.8
Leg Discomfort, mBorg-CR10 units	3.4 ± 2.6	1.0 ± 1.7	-2.4*	0.3, 3.3	3.0 ± 1.9	1.3 ± 1.3	-1.7	0.3, 4.0	0.7	-3.0, 3.7
Reasons for stopping exercise, n (%)										
Breathlessness	8 (66)	4 (33)	-	-	7 (63)	5 (45)	-	-	-	-
Leg Discomfort	2 (16)	1 (8)	-	-	3 (27)	1 (8)	-	-	-	-

Breathlessness + Leg Discomfort	1 (8)	1 (8)	-	-	1 (8)	1 (8)	-	-	-	-
Other, n	1 (8)	6 (50)	-	-	0 (0)	4 (36)	-	-	-	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 from baseline to post-ExT within group.
Abbreviations: $V'O_2$ = rate of oxygen consumption; RER = respiratory exchange ratio; SpO_2 = blood oxygen saturation; $V'_E/V'CO_2$ = ventilatory equivalent for carbon dioxide; V'_E = minute ventilation; V_T = tidal volume; f_R = breathing frequency; Δ = change from baseline; IC = inspiratory capacity; IRV = inspiratory reserve volume; RPE = rating of perceived exertion; mBorg-CR10 = modified Borg Category-Ratio 0-10 scale

Table 1. Baseline characteristics of participants.

	F2F group (n=12)		NF group (n=11)	
Variables	**Value**	**% Predicted**	**Value**	**% Predicted**
Female, n (%)	5 (41)	-	6 (54)	-
Age, years	67.6 ± 5.2	-	71.2 ± 9.3	-
Smoking history, pack-years	60.0 ± 43.2	-	37.0 ± 20.6	-
Body mass, kg	77.5 ± 33.6	-	73.4 ± 24.2	-
Body mass index, kg/m^2	28.4 ± 10.9	-	28.4 ± 10.6	-
Clinical Diagnosis, n (%)				
COPD				
GOLD stage 1	1 (8)	-	1 (9)	-
GOLD stage 2	2 (16)	-	2 (18)	-
GOLD stage 3	6 (50)	-	3 (27)	-
GOLD stage 4	3 (25)	-	1 (9)	-
ILD				
Idiopathic Pulmonary Fibrosis	0 (0)	-	2 (50)	-
Sarcoidosis	0 (0)	-	1 (25)	-
Undefined	0 (0)	-	1 (25)	-
Medication Summary, n (%)				
SABA	7 (58)	-	7 (63)	-
SAMA	1 (8)	-	0 (0)	-
SABA + SAMA	1 (8)	-	0 (0)	-
LABA	4 (33)	-	0 (0)	-
LAMA	2 (16)	-	4 (36)	-
LABA + LAMA	6 (50)	-	5 (54)	-
ICS	2 (16)	-	3 (27)	-

LABA + ICS	3 (25)	-	7 (63)	-
LABA + LAMA + ICS	3 (25)	-	0 (0)	-
Anti-Fibrotic	0 (0)	-	1 (9)	-
Domiciliary Oxygen	1 (8)	-	1 (9)	-
Breathlessness and health status				
mMRC dyspnea score, 0-4	2.5 ± 1.4	-	1.7 ± 0.9	-
mMRC ≥ 2, n (%)	9 (75)	-	5 (45)	-
CAT total score, 0-40[#]	21.6 ± 11.1	-	15.9 ± 7.7	-
CAT ≥ 10, n (%)[#]	7 (58)	-	6 (54)	-
Baseline Dyspnea Index, 0-12	4.4 ± 1.9	-	6.3 ± 2.5	-
HADS Anxiety score, 0-21	8.0 ± 4.2	-	5.6 ± 3.4	-
HADS Depression score, 0-21	6.2 ± 4.7	-	4.1 ± 1.7	-
Post-bronchodilator lung function				
FEV_1/FVC	41.2 ± 14.9	-	58.0 ± 18.1*	-
FEV_1, L	1.1 ± 0.5	46 ± 22	1.5 ± 0.8	66 ± 26
Total Lung Capacity, L	6.3 ± 1.1	113 ± 19	5.3 ± 1.4	99 ± 18
Inspiratory Capacity, L	2.0 ± 0.6	75 ± 15	2.6 ± 0.8	81 ± 24
Residual Volume, L	3.5 ± 0.9	176 ± 56	2.6 ± 0.8*	139 ± 49
Functional Residual Capacity, L	4.3 ± 1.1	139 ± 38	3.4 ± 1.1	107 ± 40
D_LCO, mL/min/mmHg	14.2 ± 5.1	66 ± 24	12.7 ± 5.1	63 ± 24
R5, kPa/L/s	6.7 ± 3.1	210 ± 111	5.0 ± 3.5	153 ± 151
X5, kPa/L/s	-4.4 ± 6.4	351 ± 499	-3.2 ± 4.4	246 ± 458
R5-R20, kPa/L/s	3.9 ± 1.2	263 ± 266	3.7 ± 1.9	149 ± 149
DEXA-derived measures				
Fat Mass, kg	33.5 ± 13.0	-	34.6 ± 15.8	-
Fat Mass, % total body mass	44 ± 15	-	53 ± 13	-

Fat-Free Mass, kg	46.9 ± 13.6	-	42.2 ± 9.6	-
Fat-Free Mass, % total body mass	63 ± 11	-	59 ± 10	-
Fat-Free Mass Index, kg/m^2	17.2 ± 0.4	76 ± 13	16.2 ± 0.3	81 ± 11
Peak incremental cardiopulmonary treadmill exercise test data				
V'O_2, mL/kg/min	13.6 ± 5.1	68 ± 69	14.3 ± 7.4	101 ± 99
Power output, Watts	41.6 ± 20.4	62 ± 16	47.3 ± 31.6	64 ± 15
Reason(s) for stopping exercise, n (%)				
Breathlessness	6 (50)	-	7 (63)	-
Leg Discomfort	3 (25)	-	3 (27)	-
Breathlessness + Leg Discomfort	1 (8)	-	0 (0)	-
Other**	2 (16)	-	1 (9)	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 between the fan-to-face (F2F) and no fan (NF) groups, # = 8 participants in the F2F group and 9 participants in the NF group completed the CAT, ** = other reasons for stopping exercise included general overall fatigue and CPET mask discomfort.

Abbreviations: BMI = body mass index; COPD = chronic obstructive pulmonary disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease; ILD = interstitial lung disease; SABA = short-acting beta-agonist; SAMA = short-acting muscarinic antagonist; LABA = long acting beta-agonist; LAMA = long-acting muscarinic antagonist; ICS = inhaled corticosteroid; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; mMRC = modified Medical Research Council dyspnea scale; CAT = COPD assessment test; HADS = Hospital Anxiety and Depression Scale; D_LCO = diffusion capacity of the lung for carbon monoxide; R5 = resistance at 5 hertz; R20 = resistance at 20 hertz; X5 = reactance at 5 hertz; V'O_2 = rate oxygen consumption

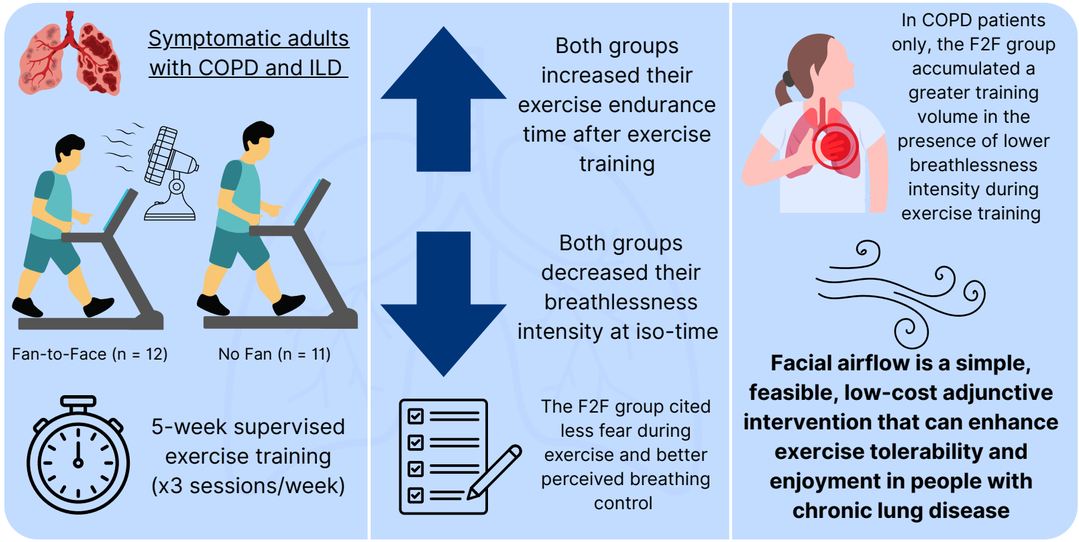
Table 2. Physiological and perceptual responses from baseline to post-exercise training (ExT) at iso-time during constant work-rate cardiopulmonary treadmill exercise testing in the fan-to-face (F2F) and no fan (NF) groups.

	F2F Group (n=12)				NF Group (n=11)					
Variables	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Baseline**	**Post-Ext**	**Difference**	**95% CI**	**Difference in change between groups**	**95% CI**
Exercise time, minutes	5.2 ± 3.2	-	-	-	5.4 ± 4.2	-	-	-	-	-
Power output, Watts	28.5 ± 15.3	-	-	-	34.8 ± 24.2	-	-	-	-	-
$V'O_2$, mL/kg/min	13.6 ± 4.6	12.1 ± 3.7	-1.5*	0.6, 2.4	14.5 ± 7.4	13.3 ± 6.0	-1.2	0.01, 2.5	0.3	-1.5, 1.9
RER	0.92 ± 0.1	0.87 ± 0.1	-0.05	0.01, 0.09	0.99 ± 0.1	0.93 ± 0.1	-0.06	0.01, 0.1	0.01	-0.08, 0.06
Heart rate, beats/min	97.0 ± 15.0	91.5 ± 17.2	-5.5	0.0, 19.8	107.5 ± 26.8	104.5 ± 13.5	-3.0	-6.3, 13.1	2.2	-9.5, 21.9
SpO_2 %	86.9 ± 6.5	88.2 ± 4.9	1.3	-5.6, 1.7	91.4 ± 3.5	91.4 ± 4.7	0	-1.4, 1.6	1.3	-2.0, 5.2
$V'_E/V'CO_2$	38.1 ± 9.4	37.7 ± 6.9	-0.4	-1.2, 2.1	39.0 ± 9.8	38.8 ± 8.9	0.2	-1.4, 1.5	0.2	-2.5, 2.6
V'_E, L/min	33.8 ± 11.6	29.2 ± 9.6	-4.6	-7.5, 11.1	38.3 ± 19.6	32.1 ± 12.4	-6.2	-12.1, 12.1	1.6	-17.2, 17.5
V_T, L	1.1 ± 0.2	1.1 ± 0.2	0	-0.3, 0.1	1.2 ± 0.6	1.1 ± 0.6	-0.1	-0.6, 0.3	0.1	-0.5, 0.5
V_T%IC	67.5 ± 17.3	63.2 ± 9.1	-4.3	-5.3, 14.2	70.2 ± 10.1	62.0 ± 7.5	-8.2*	1.2, 15.2	3.9	-13.4, 6.6
*f*R, breaths/min	31.2 ± 6.2	26.4 ± 6.8	-4.8	-1.9, 9.1	33.8 ± 7.3	31.0 ± 6.7	-2.8	-3.2, 9.3	2.0	-8.7, 10.1
⊿IC, L	-0.6 ± 0.5	-0.5 ± 0.3	-0.1	0.2, 0.3	-0.4 ± 0.4	-0.4 ± 0.5	0	-0.4, 0.5	0.1	-0.5, 0.6
IRV, L	0.6 ± 0.4	0.7 ± 0.3	0.1	-0.5, 0.2	0.5 ± 0.2	0.6 ± 0.2	0.1	-0.4, 0.04	0.0	-0.4, 0.5
RPE, mBorg-CR10 units	3.7 ± 3.1	1.4 ± 1.7	-2.3	-0.8, 2.9	3.8 ± 1.0	1.9 ± 1.6	-1.9*	0.7, 3.7	0.4	-4.1, 1.6
Breathlessness intensity, mBorg-CR10 units	3.6 ± 2.6	1.1± 1.4	-2.5*	0.6, 3.2	3.7 ± 1.3	1.8 ± 1.5	-1.9*	0.8, 4.0	0.6	-2.5, 2.0
Breathlessness unpleasantness, mBorg-CR10 units	3.8 ± 2.5	1.2 ± 1.4	-2.6*	0.7, 3.6	3.7 ± 1.3	1.3 ± 1.3	-2.4*	1.3, 4.2	0.2	-2.9, 1.8
Leg Discomfort, mBorg-CR10 units	3.4 ± 2.6	1.0 ± 1.7	-2.4*	0.3, 3.3	3.0 ± 1.9	1.3 ± 1.3	-1.7	0.3, 4.0	0.7	-3.0, 3.7
Reasons for stopping exercise, n (%)										
Breathlessness	8 (66)	4 (33)	-	-	7 (63)	5 (45)	-	-	-	-
Leg Discomfort	2 (16)	1 (8)	-	-	3 (27)	1 (8)	-	-	-	-

Breathlessness + Leg Discomfort	1 (8)	1 (8)	-	-	1 (8)	1 (8)	-	-	-	-
Other, n	1 (8)	6 (50)	-	-	0 (0)	4 (36)	-	-	-	-

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 from baseline to post-ExT within group.

Abbreviations: $V'O_2$ = rate of oxygen consumption; RER = respiratory exchange ratio; SpO_2 = blood oxygen saturation; $V'_E/V'CO_2$ = ventilatory equivalent for carbon dioxide; V'_E = minute ventilation; V_T = tidal volume; f_R = breathing frequency; Δ = change from baseline; IC = inspiratory capacity; IRV = inspiratory reserve volume; RPE = rating of perceived exertion; mBorg-CR10 = modified Borg Category-Ratio 0-10 scale


Symptomatic adults with COPD and ILD
Fan-to-Face (n = 12)
No Fan (n = 11)
5-week supervised exercise training (x3 sessions/week)
Both groups increased their exercise endurance time after exercise training
Both groups decreased their breathlessness intensity at iso-time
The F2F group cited less fear during exercise and better perceived breathing control
In COPD patients only, the F2F group accumulated a greater training volume in the presence of lower breathlessness intensity during exercise training
Facial airflow is a simple, feasible, low-cost adjunctive intervention that can enhance exercise tolerability and enjoyment in people with chronic lung disease

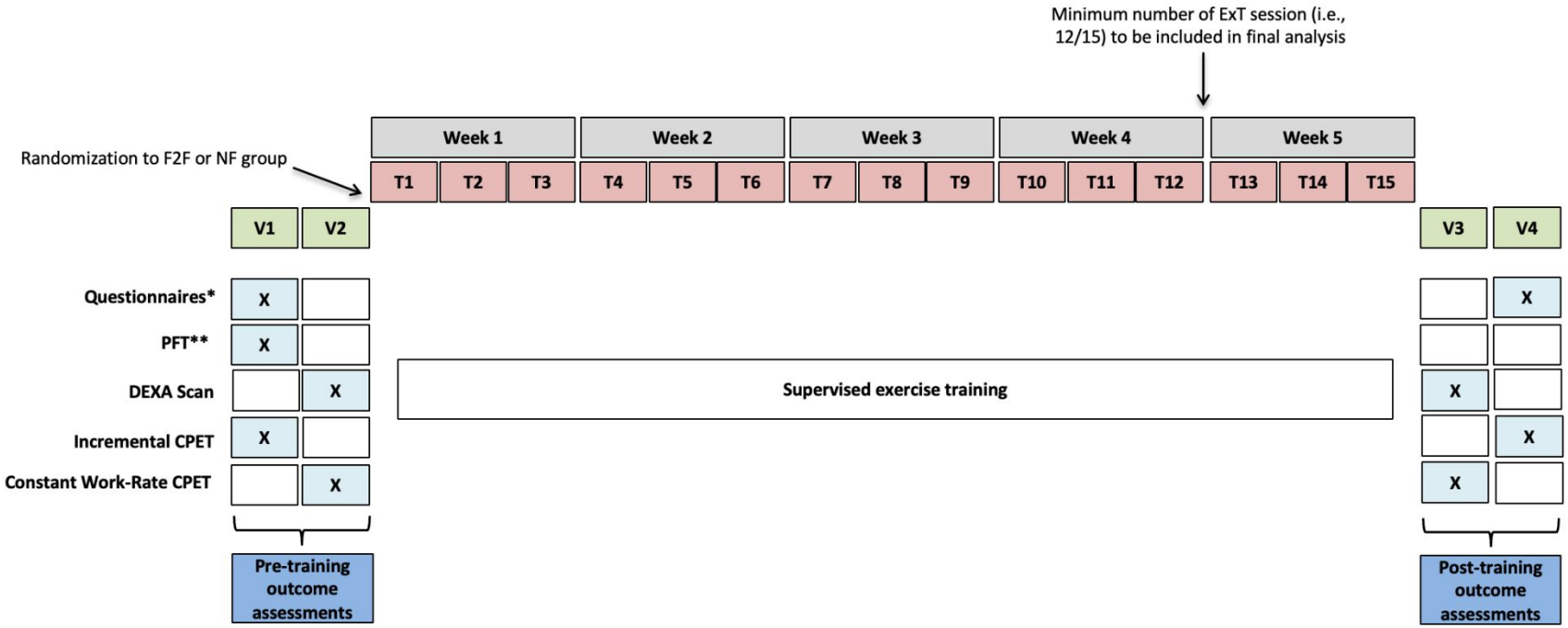


Figure 1. Experimental study design, showing two baseline exercise training (ExT) outcome assessment visits (Visit 1 [V1] and Visit 2 [V2]), the 5-week supervised ExT program, and two post-ExT outcome assessment visits (Visit 3 [V3] and Visit 4 [V4]). Prior to beginning the 5-week supervised ExT program, following completion of V2, participants with chronic obstructive pulmonary disease (COPD) or interstitial lung disease (ILD) were randomized to a fan-to-face (F2F) group or a no fan (NF) control group in a 1:1 ratio.
Note: * = questionnaires included the modified Medical Research Council dyspnea scale, the COPD Assessment Test, the Baseline Dyspnea Index/Transition Dyspnea Index, and the Hospital Anxiety and Depression Scale. ** = pulmonary function testing included post-bronchodilator (400 mcg Salbutamol) spirometry, constant-volume body plethysmography, diffusion capacity of the lung for carbon monoxide, and impulse oscillometry.
Abbreviations: F2F = fan-to-face; NF = no fan; PFT = pulmonary function testing; DEXA = dual energy x-ray absorptiometry; CPET = cardiopulmonary exercise testing; T# = Training session (T1-T15); ExT = exercise training.

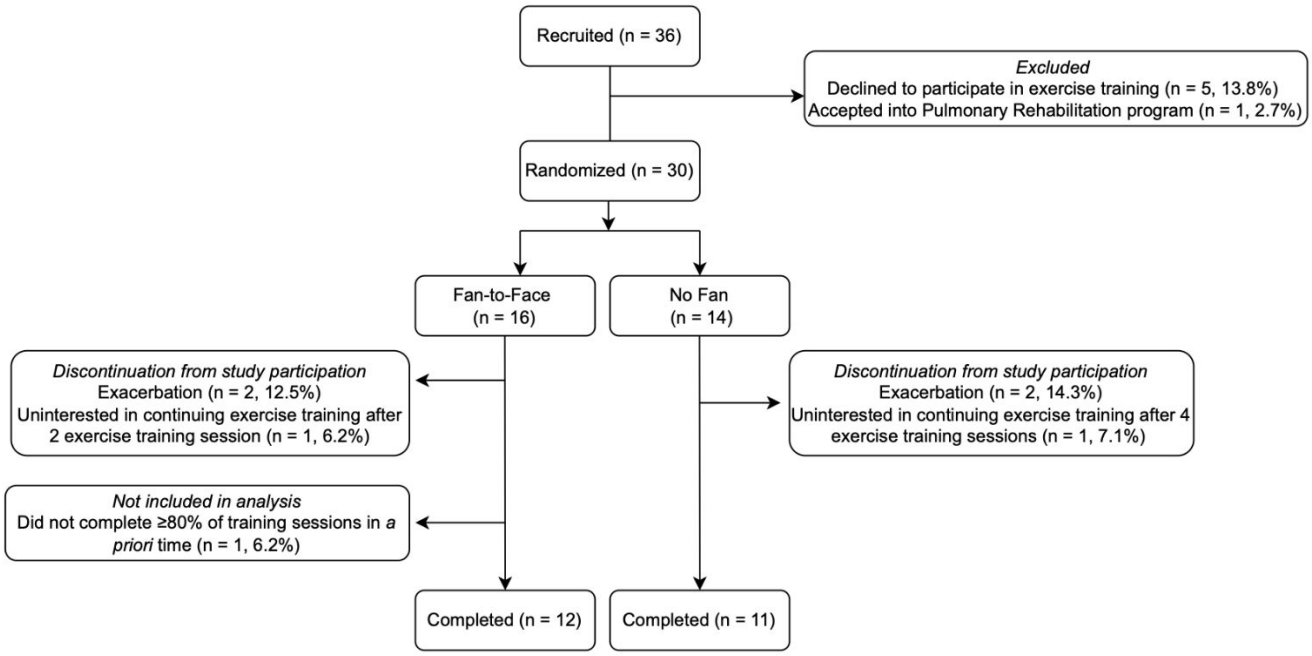


Figure 2. Flow diagram of participant recruitment, enrollment, and completion.

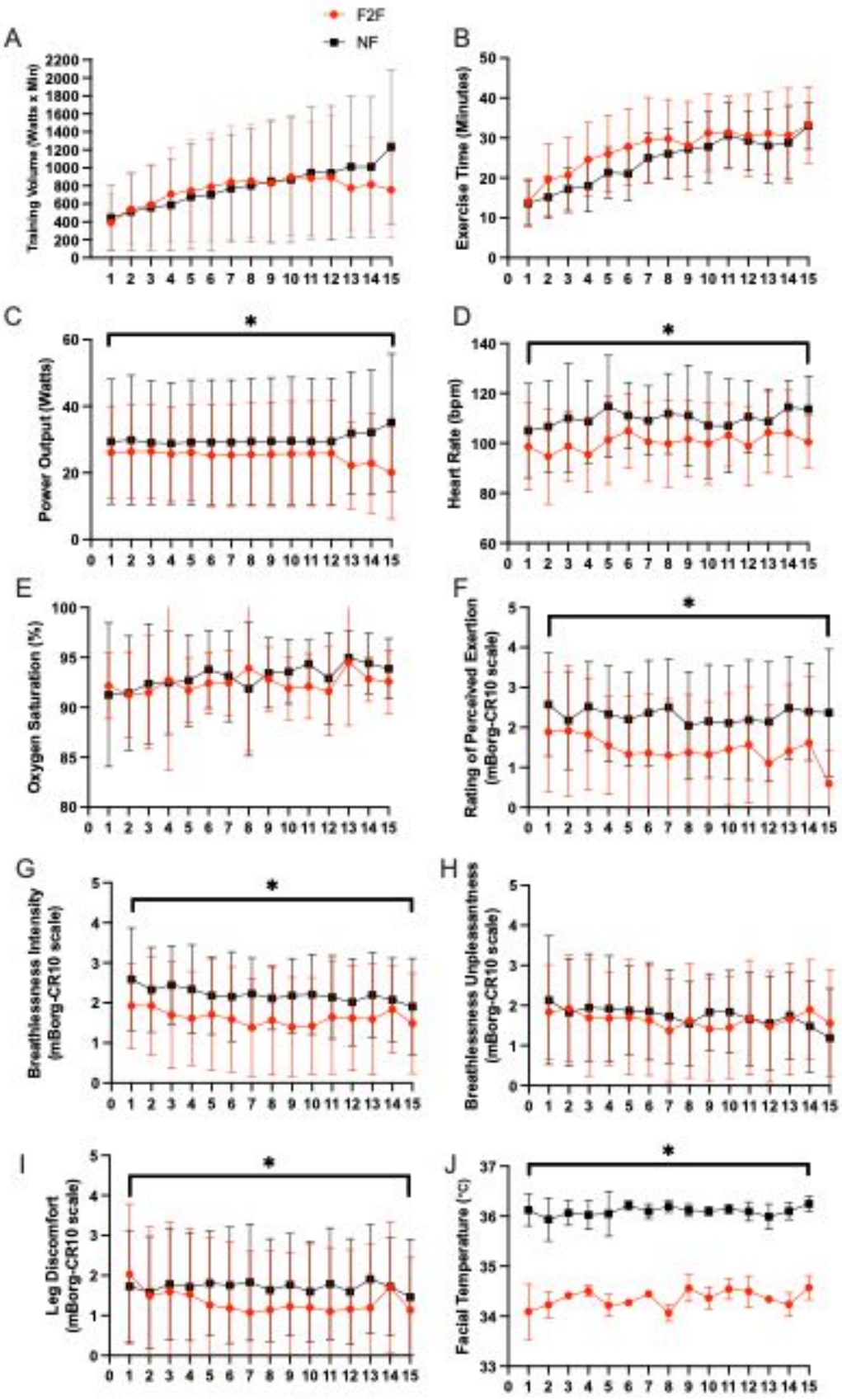

F2F
NF
A
Training Volume (Watts x Min)
B
Exercise Time (Minutes)
C
Power Output (Watts)
D
Heart Rate (bpm)
E
Oxygen Saturation (%)
F
Rating of Perceived Exertion (mBorg-CR10 scale)
G
Breathlessness Intensity (mBorg-CR10 scale)
H
Breathlessness Unpleasantness (mBorg-CR10 scale)
I
Leg Discomfort (mBorg-CR10 scale)
J
Facial Temperature (°C)
*

Figure 3. Exercise training (ExT) program variables during a 5-week supervised ExT program in people with chronic lung disease in the fan-to-face (F2F) and no fan (NF) groups: A) ExT session volume; B) ExT session time; C) ExT session power output; D) ExT session heart rate); E) ExT session blood oxygen saturation; F) ExT session rating of perceived exertion; G) ExT session breathlessness intensity; H) Ext session breathlessness unpleasantness; I) ExT session leg discomfort; and J) ExT session facial skin surface temperature.
Note: Values are mean ± standard deviation. *$p<0.05$ between the F2F and NF groups across the 5-week ExT program.
Abbreviations: mBorg-CR10 scale = modified Borg Category-Ratio 0-10 scale.

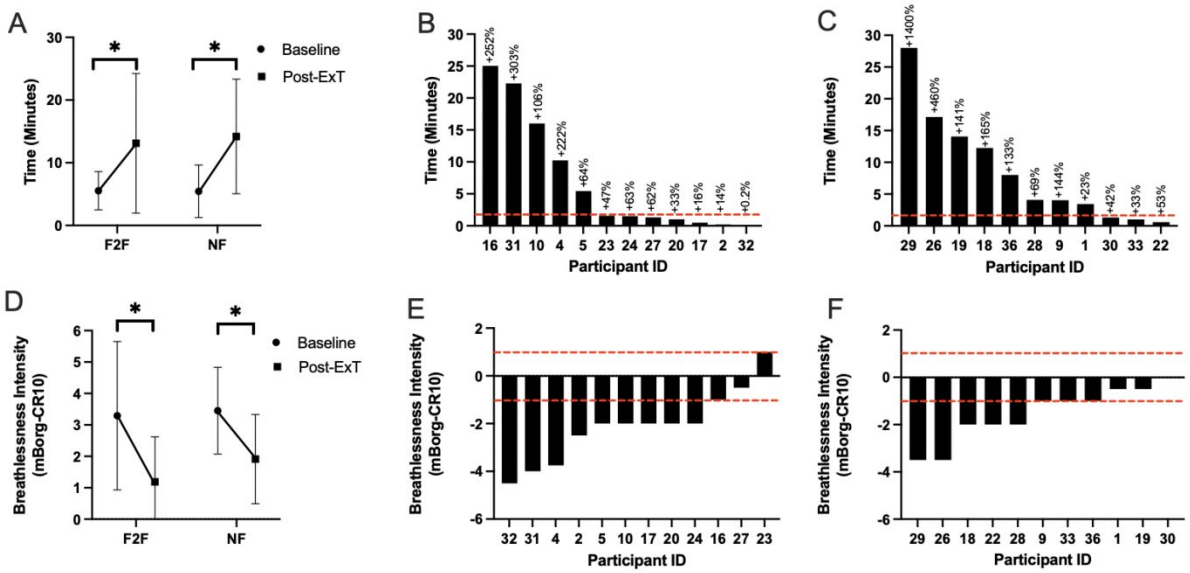


Figure 4. Changes in primary and co-primary outcome variables following a 5-week supervised exercise training (ExT) program in people with chronic lung disease: A) mean ± standard deviation (SD) exercise endurance time (EET) from baseline to post-ExT in the fan-to-face (F2F) and no fan (NF) groups; B) individual participant changes in EET in the F2F group (with relative [%] change labels) from baseline to post-ExT; C) individual participant changes in EET in the NF group (with relative [%] change labels) from baseline to post-ExT; D) mean ± SD breathlessness intensity ratings at iso-time during the symptom-limited constant work-rate cardiopulmonary treadmill exercise test at baseline and post-ExT in the F2F and NF groups; E) individual participant changes in iso-time breathlessness intensity ratings in the F2F group; and F) individual participant changes in iso-time breathlessness intensity ratings in the NF group.

Note: *p<0.05 from baseline to post-ExT within group. The red dashed horizontal lines in panels B-C and panels E-F represent the minimally clinical important difference (MCID) of ±101 seconds for EET (Puente-Maestu et al., *Eur Respir J*, 2009. 34(2):340-5) and of ±1 modified Borg Category-Ratio 0-10 (mBorg-CR10) scale units for breathlessness intensity ratings (Ries, *COPD*, 2005. 2(1):105-10), respectively.

Does facial airflow improve exercise training in people with chronic lung disease? A randomized controlled trial

Rachelle Aucoin[1,2]*, Dan Nguyen[3], Bryan Ross[2,3,4], Jean Bourbeau[2,3,4], Hayley Lewthwaite[5], Magnus Ekström[6], Andreas von Leupoldt[7], Dennis Jensen[1,2]

[1]Clinical Exercise & Respiratory Physiology Laboratory, Department of Kinesiology and Physical Education, McGill University, Montréal, Quebéc, Canada.
[2]Translational Research in Respiratory Diseases Program and Respiratory Epidemiology and Clinical Research Unit, Research Institute of the McGill University Health Centre, Montréal, Québec, Canada.
[3]Division of Clinical and Translational Research, Department of Medicine, McGill University Health Center, Montréal, Québec, Canada.
[4]Montreal Chest Institute, McGill University Health Centre, McGill University, Montréal, Québec, Canada.
[5]College of Engineering, Science and Environment, School of Environment & Life Sciences, The University of Newcastle, Ourimbah, Australia.
[6]Department of Respiratory Medicine, Allergology and Palliative Medicine, Institution for Clinical Sciences, Lund University, Sweden.
[7]Research Group Health Psychology, University of Leuven, Leuven, Belgium.

Methods

Study Design

The study took place at the McConnell Center for Innovative Medicine of the McGill University Health Centre between April 2023 and December 2024. Participants were recruited from the chronic obstructive pulmonary disease (COPD) and interstitial lung disease (ILD) outpatient clinics of the Montreal Chest Institute (MCI) and Jewish General Hospital (JGH) in Montreal, QC, Canada, as well as from a list of people with COPD or ILD who (i) previously completed an outpatient pulmonary rehabilitation program at the MCI or JGH and/or (ii) consented to be contacted for consideration of participation in clinical research.

Participants

Participants were men or women aged ≥40 years with physician-diagnosed COPD (Global Initiative for Obstructive Lung Disease [GOLD] stages 1-4 [1], with a post-bronchodilator forced expiratory volume in 1 second/forced vital capacity [FEV_1/FVC] ratio of <0.70) or ILD who were cleared by a physician to perform cardiopulmonary exercise testing (CPET) and had a body mass index of >18.5 kg/m^2 and <40 kg/m^2. Participants were excluded if they had:

(i) changed their respiratory medication dosage and/or frequency of administration within the last two weeks;

(ii) self-reported disease exacerbation or hospitalization within the last six weeks;

(iii) important contraindication(s) to exercise (e.g., significant musculoskeletal or neurological disease) or pulmonary function testing (e.g., eye, chest or stomach surgery, or any history of coughing up significant amounts of blood in the previous 3 months);

(iv) participated in a pulmonary rehabilitation program within the last 6 months.

Assessments

Participants were encouraged to remain on their normal pharmacological treatment regimen during study participation, and to avoid (i) consuming alcohol and performing strenuous exercise within 24 hours of all scheduled study visits, (ii) consuming heavy meals and caffeine within 4 hours of all scheduled study visits, and (iii) cigarette smoking within 1 hour of all scheduled study visits. After providing written and informed consent, participants completed two baseline assessment visits (**Figure 1**). Visit 1 included: evaluation of participant-reported breathlessness (modified Medical Research Council Dyspnea Scale [mMRC] [2] and Baseline Dyspnea Index/Transition Dyspnea Index [BDI/TDI] [3]), health status (COPD Assessment Test [CAT] [4]), and anxiety/depression (Hospital Anxiety and Depression Scale [HADS [5]); post-bronchodilator (400 mcg Salbutamol) spirometry, constant-volume body plethysmography, diffusion capacity of the lung for carbon monoxide (D_LCO), and impulse oscillometry (iOS) performed according to recommended techniques [6-9] using automatic equipment (Vmax 229d with Vs62j body plethysmography, SensorMedics, Yorba Linda, CA; Jaeger Impulse Oscillometry System, Vyaire Medical, Chicago, IL) with measurements expressed as a percentage of normal predicted values [10-12]; and a symptom-limited incremental (INCR) CPET on a motorised treadmill (Trackmaster 428 CP Medical Treadmill, Full Vision, Inc., Newton, KC) to determine peak power output (PPO) and the peak rate of O_2 consumption ($V'O_{2peak}$) with measurements expressed as a percentage of normal predicted values [13, 14]. Visit 2 included: a dual energy x-ray absorptiometry (DEXA) body composition scan to determine whole body fat mass and fat-free mass with measures expressed as a percentage of normal

predicted values [15]; and a symptom-limited constant work-rate (CWR) CPET on a motorised treadmill at 75% of the PPO achieved at visit 1. Visit 3 included: post-ExT evaluation of the patient-reported breathlessness (mMRC, TDI), health status (CAT), and anxiety/depression (HADS) and assessed for change using established minimal clinically important differences (MCID) [3, 16-18]; and a symptom-limited INCR treadmill CPET to determine ExT-induced changes in PPO and $V'O_{2peak}$. Visit 4 included a DEXA body composition scan and a symptom-limited CWR treadmill CPET at 75% of the PPO achieved at visit 1 to determine ExT-induced changes in exercise endurance time (EET) and exertional breathlessness at iso-time.

At the end of visit 4, all participants completed an end-of-study questionnaire to assess their perceived benefit of the 5-week ExT program on their overall exercise capacity and health status, whereas participants randomized to the F2F group completed an additional end-of-study questionnaire on how F2F affected their exertional breathlessness during ExT.

End-of-Study Questionnaires for All Participants

We will be asking you several questions regarding your perceived experience with the 5-weeks of exercise training. There are no wrong answers, we simply want to know how you felt about the exercise program.

1. What was your perceived benefit (overall) of the 5-week exercise program?

	Check the one that best applies
Very substantial perceived benefit	
Some perceived benefit	

Uncertain about benefit	
No perceived benefit	

Why did you choose this criterion (please explain)?

2. What was your perceived benefit of the exercise program on your daily breathlessness?

	Check the one that best applies
Very substantial perceived benefit	
Some perceived benefit	
Uncertain about benefit	
No perceived benefit	

Why did you choose this criterion (please explain)?

3. Any other comments, concerns, or feedback regarding the exercise program?

End-of-Study Questionnaires for Participants in the Fan-to-Face Group

We will be asking you several questions regarding your perceived experience using the fan during the 5-weeks of exercise training. There are no wrong answers, we simply want to know how you felt about the fan.

1. What was your perceived benefit (overall) of the fan?

	Check the one that best applies

Very substantial perceived benefit	
Some perceived benefit	
Uncertain about benefit	
No perceived benefit	

Why did you choose this criterion (please explain)?

2. What was your perceived benefit of the fan on your breathlessness during exercise?

	Check the one that best applies
Very substantial perceived benefit	
Some perceived benefit	
Uncertain about benefit	
No perceived benefit	

Why did you choose this criterion (please explain)?

3. Would you use a fan in the future while exercising (e.g., at the pulmonary rehabilitation program)?

	Check the one that best applies
Yes	
No	

Why did you choose this criterion (please explain)?

4. Any other comments, concerns, or feedback regarding the use of the fan?

Cardiopulmonary Exercise Testing (CPET)

Participants using domiciliary oxygen performed all CPETs and ExT sessions with their prescribed supplemental oxygen (F2F, n = 1 with COPD at 4 L/min; NF, n = 1 with ILD at 15 L/min).

Gas exchange and breathing pattern parameters were collected breath-by-breath using a computerized CPET system (Vmax Encore™29C, Sensormedics, Yorba Linda, CA, USA). Dynamic operating lung volumes were collected via serial inspiratory capacity (IC) maneuvers performed at rest, within the last 15-seconds of every 2-min interval during INCR and CWR CPETs, and at end-exercise [19]. Heart rate (HR) and blood oxygen saturation (SpO_2) were continuously monitored by finger pulse oximetry (Rad-57® Handheld Pulse CO-Oximeter® with Masimo Rainbow® SET® Technology, Masimo Corporation, Irvine, CA, USA). The modified Borg Category-Ratio 0-10 (mBorg-CR10) scale [20], specifically the version by Burdon et al. [21] with 'slight' and 'severe' verbal descriptors and no verbal descriptors at numerical categories 6 and 8, was used to assess participants' breathlessness intensity, breathlessness unpleasantness, leg discomfort and perceived exertion (RPE) at rest, within the last 30-seconds of every 2-min interval during INCR and CWR CPETs, and at end-exercise. The endpoints of the mBorg-CR10 scale were anchored prior to each CPET such that 0 represented '*no breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion*' and 10 represented '*the*

most severe breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion you have ever experienced or can imagine experiencing'. Researchers used standardized scripts to assess exertional symptoms and to help participants distinguish between breathlessness intensity and unpleasantness (***see below***). The mBorg-CR10 scale was chosen as it represents a standardized tool to quantify breathlessness intensity associated with exercise in chronic cardiopulmonary populations [22, 23] and has an established MCID of +/- 1 unit [24]. Previous research has also shown that breathlessness intensity and unpleasantness can be separately rated during exercise using the mBorg-CR10 scale in healthy young people [25] and in people with COPD [26]. The mBorg-CR10 scale has also demonstrated high test-retest repeatability of iso-time breathlessness intensity ratings during CWR CPET in a large cohort of adults with COPD [27]. At end-exercise, participants identified their reason(s) for stopping exercise by answering the following question: '*Did you stop because of your breathlessness, leg discomfort, a combination of breathlessness and leg discomfort, or something else?*'.

Peak power output (PPO) was defined as the highest power output the participant was able to sustain for ≥30-sec, and $V'O_{2peak}$ was taken as the $V'O_2$ averaged over the last 30-sec of exercise. EET was defined as the duration of exercise (loaded pedaling) during the CWR CPET, whereas iso-time was defined as the highest equivalent submaximal time completed by a given participant during CWR CPETs done both at baseline and post-ExT. Physiological variables measured breath-by-breath during CPET were averaged over the first 30-sec of every 2-min interval of exercise and over the last 30-sec of exercise (peak). These variables were then linked with contemporaneous measures of HR, SpO_2, IC and IC-derived variables, breathlessness intensity, breathlessness unpleasantness, leg discomfort and RPE.

Incremental and constant-work rate cardiopulmonary exercise test (CPET) protocols on the treadmill:

The INCR CPET protocol consisted of a pre-exercise rest period of ≥6 minutes (while sitting on a chair placed on the treadmill), followed by 10 W/2-min increases in power output (starting at 10 W) to the point of symptom-limitation. The treadmill protocol was individualized for each participant based on their body mass using the following equation from *Jones* [28]:

$$\text{Power output (watts)} = m \times g \times v \times \sin(\alpha)$$

where the power output is in watts (W), m is the body mass of the participant in kilograms, g is the gravitational acceleration (9.81 m/s^2), v is the velocity of the treadmill in meters per second, and α is the angle of inclination (grade) of the treadmill in radians. The grade of the treadmill started at 5% and was increased by 1% every 2-min until a 12% grade was reached. The increments in treadmill speed required to achieve the 10 W/2-min increase in power output was determined using the formula.

The CWR CPET protocol consisted of a pre-exercise rest period of ≥6 minutes (while sitting on a chair placed on the treadmill), followed by a step increase in power output to 75% PPO with participants exercising to the point of symptom-limitation. To determine the 75% PPO for the CWR CPET for each participant, the incline of the treadmill was set at 60% of the peak incline achieved during the INCR CPET at visit 1, and treadmill speed was adjusted to achieve the desired power output based on each participants' body mass.

Except to help maintain their balance, participants were encouraged to perform all CPETs without holding onto the treadmill handrails.

Standardized scripts for the modified Borg Category-Ratio 0-10 (mBorg-CR10) scale

The following script was used for each participant during INCR and CWR CPETs, as well as the supervised ExT program/sessions.

'At rest, every two minutes during exercise, and in exercise recovery, we are going to ask you to rate your perceived exertion, your overall sensation of breathlessness intensity, your breathlessness unpleasantness, and your leg discomfort. We will ask the following questions:

Rating of perceived exertion: *'What is your rating of perceived exertion at the moment?'* This refers to how much overall perceived exertion you experience in relation to the exercise.

Breathlessness intensity: '*How intense is your sensation of breathing overall*?' This refers to how much breathlessness you experience.

Breathlessness unpleasantness: '*How unpleasant or distressed does your breathing make you feel*?' This refers to how bad the breathlessness is. That is, how distressed or uncomfortable the breathlessness makes you feel.

Leg discomfort: '*How intense is your sensation of left discomfort?*' This refers to the overall sensation of fatigue in your leg muscles. It is important to focus on what is going on in your leg muscles rather than your joints. So if you are experiencing joint discomfort such as in your knees, ankles, and/or hips, please avoid rating these sensations and focus more on how fatigued your leg muscles are feeling.

We will ask you to point to a number on this modified Borg Category-Ratio 0-10 scale. 0 represents '*no breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion*' and 10 represents '*the most severe breathlessness intensity, breathlessness unpleasantness, leg discomfort or perceived exertion you have ever experienced or can imagine experiencing*'.

Using a music analogy, we provided participants an explanation on how to distinguish between breathlessness intensity and breathlessness unpleasantness:

'Breathlessness intensity (how strong the sensation feels) is like the loudness of a sound, while breathlessness unpleasantness (how uncomfortable or bad it feels) is like how agreeable or disagreeable the sound is, even at low volumes.

Breathlessness Intensity**:** Think of this as the physical sensation of breathing. In the music analogy, this is analogous to the loudness or volume of a sound. A loud sound can be intense, even if you like or dislike it.

Breathlessness Unpleasantness**:** This refers to how uncomfortable or distressing the sensation of breathlessness is. In the music analogy, this is how pleasant or unpleasant the sound is, regardless of its volume. You might dislike a sound even if it's not loud.

Supervised 5-week Exercise Training (ExT) Program

The 5-week supervised ExT program consisted of three aerobic ExT sessions/week for a total of 15 sessions. Participants were given up to an additional week (7 days) to make up for missed attendance within the 5-week program. Each ExT session was individualized based on the participant's results from the symptom-limited INCR CPET completed at visit 1 and progressed to ensure that they were exercising at an intensity corresponding to a target breathlessness intensity rating between 3-5 mBorg-CR10 scale units. Specifically, participants were asked to walk continuously on the treadmill at the programmed intensity for at least 5-10 minutes during the first ExT session, where treadmill incline and speed were both first programmed between 65-75% of their respective peak values achieved during the INCR CPET at visit 1, and then adjusted within that range so that participants' breathlessness intensity ratings were within the desired 3-5 mBorg-CR10 range. Following the first ExT session, exercise duration was increased in 1–5 min intervals every session up to a maximum of 40 mins, while the prescribed treadmill incline remained consistent throughout the entire 5-week ExT program. If participants reached the maximum time of 40 mins prior to the end of the 5-week ExT program, exercise intensity was increased by increasing treadmill speed by 5-15% of baseline speed. Except to help maintain their balance, participants were encouraged to perform each ExT session without holding onto the treadmill handrails. In the last 30-sec of every 2-minute interval of each ExT session, participants rated their perceived exertion (RPE), breathlessness intensity, breathlessness unpleasantness, and leg discomfort using the

mBorg-CR10 scale; HR and SpO_2 were recorded using a finger pulse oximeter (Rad-57® Handheld Pulse CO-Oximeter® with Masimo Rainbow® SET® Technology, Masimo Corporation, Irvine, CA, USA); and forehead and cheek skin surface temperature were measured using a medical grade infrared contactless digital thermometer (Model PC828, Shenzhen Pacom Medical Instruments Co. Ltd., Shenzhen, Guandong, China). Facial skin surface temperature (T_{face}) was calculated as the average of forehead and cheek skin surface temperatures and used for analysis. For every ExT session, physiological (HR, SpO_2, T_{face}) and perceptual variables (RPE, breathlessness intensity, breathlessness unpleasantness, leg discomfort) recorded within the last 30-sec of each 2-min interval of exercise were averaged and used for analysis. For every ExT session, training volume (W x min) was calculated as the product of power output and exercise duration. Cumulative ExT volume was calculated for each participant as the sum of all individual ExT session volumes over the 5-week ExT program.

Secondary Outcomes

Secondary outcomes included the change (Δ) from baseline to post-ExT in:

- ExT program variables, including volume, duration, power output, HR, SpO_2 and symptom ratings;
- physiological and symptom responses at iso-time during CWR CPETs, and at the peak of both INCR CPETs and CWR CPETs;
- breathlessness burden (mMRC, BDI/TDI), health status (CAT), and symptoms of anxiety and depression (HADS);
- body composition;
- end-of-study assessments of the participant's perceived benefits of the ExT program, including the fan for people in the F2F group.

Results

Supplemental Material Table 1. Physiological and perceptual responses from baseline to post-exercise training (ExT) at the symptom-limited peak of incremental cardiopulmonary treadmill exercise testing in the fan-to-face (F2F) and no fan (NF) groups.

	F2F Group (n=12)				NF Group (n=11)					
Variables	**Baseline**	**Post-ExT**	**Difference**	**95% CI**	**Baseline**	**Post-ExT**	**Difference**	**95% CI**	**Difference in change between groups**	**95% CI**
Exercise time, minutes	8.0 ± 4.0	11.1 ± 5.6	3.1*	1.9, 4.1	9.3 ± 6.3	12.7 ± 7.0	3.4*	0.8, 6.2	0.3	-2.6, 3.3
Power output, Watts	41.6 ± 20.4	56.6 ± 28.1	15.0*	9.1, 20.8	47.3 ± 31.6	65.4 ± 33.8	18.1*	5.0, 32.0	3.1	-11.8, 18.1
Power output, %predicted	62.8 ± 16.8	78.2 ± 15.5	15.4	8.9, 19.8	64.7 ± 15.4	79.7 ± 17.8	15.0	5.3, 30.1	5.6	-10.5, 17.6
$V'O_{2peak,}$ mL/kg/min	13.6 ± 5.1	13.6 ± 7.2	0	-1.4, 1.8	14.3 ± 7.4	15.5 ± 7.3	1.2	-2.6, 0.2	1.2	-1.3, 3.8
$V'O_{2peak}$, %predicted	76.0 ± 67.4	76.0 ± 68.5	0	-1.2, 1.5	101.2 ± 99.3	102.3 ± 95.8	1.1	-2.0, 0.2	1.1	-1.2, 3.5
RER	0.93 ± 0.07	0.91 ± 0.06	-0.02	-0.02, 0.06	0.97 ± 0.12	1.0 ± 0.08	0.03	-0.08, 0.03	0.05	-0.04, 0.1
Heart rate, beats/min	90.9 ± 18.2	107.6 ± 12.7	16.7*	-29.4, -4.0	114.7 ± 27.5	120.2 ± 21.5	5.5	-10.9, 8.3	11.2	-32.3, 9.9
Heart rate, % predicted	59.6 ± 11.1	76.6 ± 16.2	17.0*	-28.5, -4.5	71.7 ± 16.2	80.6 ± 13.1	8.9	-11.5, 9.1	8.1	-30.5, 10.0
$SpO_{2,}$ % (Δ from baseline)	88.0 ± 5.8 (4.0)	88.9 ± 5.7 (4.5)	0.8	-3.0, 0.9	89.6 ± 7.6 (3.8)	86.6 ± 9.8 (4.1)	-0.3	-3.5, 10.0	1.1	-11.1, 3.3
$V'_E/V'CO_2$	38.4 ± 8.6	39.8 ± 14.8	1.4	-5.6, 1.9	38.6 ± 7.7	39.3 ± 11.6	0.7	-4.8, 3.1	0.7	-7.1, 5.4
$V'_{E,}$ L/min	34.3 ± 11.9	33.7 ± 15.7	-0.6	-3.1, 4.7	37.3 ± 19.6	40.9 ± 18.9	3.6	-8.3, 0.9	4.2	-2.8, 11.1
V_T, L	1.1 ± 0.2	1.1 ± 0.3	0	-0.1, 1.0	1.1 ± 0.5	1.1 ± 0.5	0	-0.1, 0.1	0	-0.2, 0.1
V_T%IC	69.5 ± 10.8	70.2 ± 11.4	0.7	-7.3, 5.8	64.5 ± 5.9	68.7 ± 13.4	4.2	-13.0, 4.7	3.5	-5.6, 13.0
*f*R, breaths/min	31.6 ± 7.2	31.2 ± 10.2	-0.4	-2.6, 4.4	34.5 ± 7.3	38.9 ± 9.8	4.4	-8.4, -0.1	4.8	-1.6, 11.1
*Δ*IC, L	-0.7 ± 0.4	-0.7 ± 0.4	0	-0.1, 0.1	-0.3 ± 0.5	-0.5 ± 0.5	0.2	-0.04, 0.4	0.2	-0.1, 0.4
IRV, L	0.5 ± 0.3	0.5 ± 0.3	0	-0.1, 0.1	0.6 ± 0.2	0.5 ± 0.2	-0.1	-0.01, 0.3	0.1	-0.3, 0.07
RPE, mBorg-CR10 units	4.1 ± 2.4	3.3 ± 1.9	-0.8	-2.8, 4.5	4.1 ± 1.8	3.4 ± 1.5	-0.7	-0.3, 1.7	0.4	-2.7, 3.0
Breathlessness intensity,	4.6 ± 2.4	3.2 ± 1.8	-1.3	-0.05, 2.9	4.0 ± 1.9	3.1 ± 1.4	-0.9*	0.3, 1.3	0.4	-0.9, 2.0

mBorg-CR10 units										
Breathlessness unpleasantness, mBorg-CR10 units	4.6 ± 2.4	3.2 ± 1.7	-1.3	-0.1, 3.0	3.7 ± 1.7	2.6 ± 1.9	-1.1*	0.06, 2.3	0.2	-1.6, 2.0
Leg Discomfort, mBorg-CR10 units	4.1 ± 2.6	1.9 ± 2.1	-2.2*	0.8, 3.4	3.4 ± 2.4	2.6 ± 1.8	-1.2	-0.03, 1.6	1	-0.2, 2.8
Reasons for stopping exercise, n (%)										
Breathlessness	6 (50)	7 (58)	-	-	7 (63)	8 (72)	-	-	-	-
Leg Discomfort	3 (25)	2 (16)	-	-	3 (27)	2 (18)	-	-	-	-
Breathlessness + Leg Discomfort	1 (8)	0 (0)	-	-	0 (0)	1 (9)	-	-	-	-
Other, n	2 (16)	3 (25)	-	-	1 (9)	0 (0)	-	-	-	-

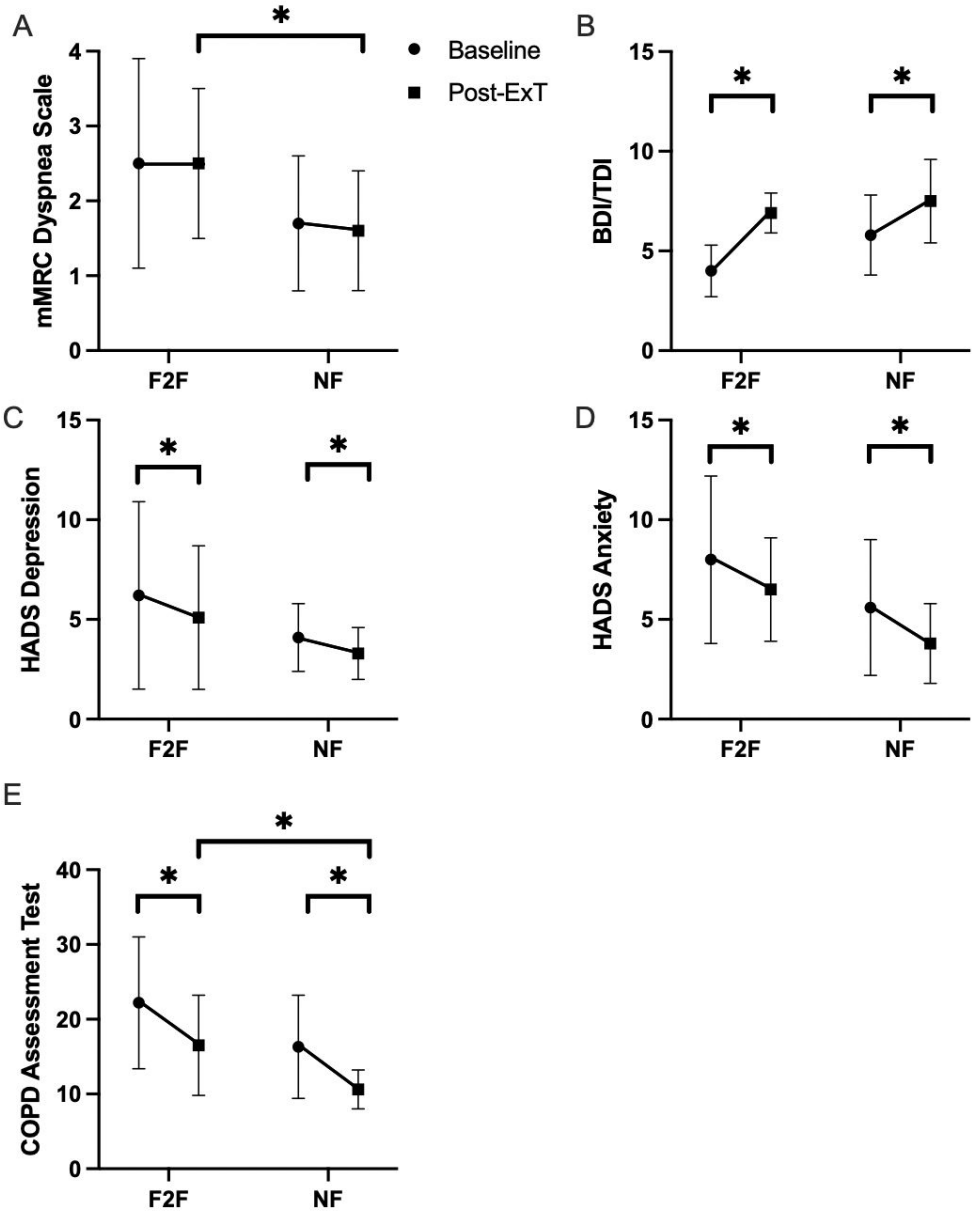
Note: Data are presented as mean ± standard deviation, unless otherwise stated. *$p<0.05$ from baseline to post- ExT within group.
Abbreviations: $V'O_2$ = rate of oxygen consumption; RER = respiratory exchange ratio; SpO_2 = blood oxygen saturation; $V'_E/V'CO_2$ = ventilatory equivalent for carbon dioxide; V'_E = minute ventilation; V_T = tidal volume; f_R = breathing frequency; Δ = change from baseline; IC = inspiratory capacity; IRV = inspiratory reserve volume; RPE = rating of perceived exertion; mBorg-CR10 = modified Borg Category-Ratio 0-10 scale.

Supplemental Material Table 2. Physiological and perceptual responses from baseline to post-exercise training (ExT) at the symptom-limited peak of a constant work-rate cardiopulmonary treadmill exercise test in the fan-to-face (F2F) and no fan (NF) groups.

	F2F Group (n=12)				NF Group (n=11)					
Variables	**Baseline**	**Post-ExT**	**Difference**	**95% CI**	**Pre-ExT**	**Baseline**	**Difference**	**95% CI**	**Difference in change between groups**	**95% CI**
Exercise time, minutes	5.9 ± 3.1	13.1 ± 11.1	7.2*	3.0, 13.6	5.7 ± 4.3	14.3 ± 9.2	8.6*	3.7, 11.3	1.4	-6.3, 9.0
Power output, Watts	28.5 ± 15.2	-	-	-	34.8 ± 24.2	-	-	-	-	-
$V'O_{2peak,}$ mL/kg/min	13.5 ± 4.6	13.1 ± 4.1	-0.4	-0.3, 1.5	14.5 ± 7.4	13.9 ± 6.2	-0.6	-0.3, 1.8	-0.2	-1.6, 1.3
RER	0.92 ± 0.1	0.91 ± 0.1	-0.01	-0.0, 0.06	0.99 ± 0.1	0.96 ± 0.1	-0.03	-0.03, 0.09	-0.02	-0.07, 0.06
Heart rate, beats/min	96.6 ± 15.2	97.6 ± 19.2	1	-11.4, 10.9	107.5 ± 26.8	105.3 ± 19.3	-2.2	-12.7, 18.3	-3.2	-22.0, 15.6
SpO_2, %	86.9 ± 6.5	87.6 ± 5.7	0.7	-2.7, 1.1	91.4 ± 3.5	90.4 ± 4.8	-1	-2.7, 0.01	-1.7	-2.6, 2.5
$V'_E/V'CO_2$	38.1 ± 9.4	38.0 ± 6.6	-0.1	-8.3, 7.7	39.2 ± 9.8	39.2 ± 8.9	0	-10.7, 6.0	0.1	-11.8, 14.8
V'_E, L/min	33.8 ± 11.6	32.3 ± 9.7	-1.5	-0.9, 4.4	38.3 ± 19.6	35.1 ± 11.1	3.2	-1.9, 10.9	4.7	-8.3, 4.9
V_T, L	1.0 ± 0.2	1.1 ± 0.2	0.1	-0.1, 0.06	1.1 ± 0.6	1.0 ± 0.5	-0.1	-0.02, 0.2	-0.2	-0.3, 0.04
V_T%IC	65.9 ± 16.8	65.3 ± 10.8	-0.6	-10.3, 11.5	71.3 ± 10.1	65.3 ± 11.8	-6	-2.1, 14.1	5.4	-16.2, 6.6
*f*R, breaths/min	31.3 ± 6.1	30.1 ± 6.1	-1.2	-0.7, 4.2	34.0 ± 7.3	36.3 ± 6.0	2.3	-5.1, 2.2	3.5	-1.3, 8.4
*Δ*IC, L	-0.7 ± 0.5	-0.6 ± 0.4	-0.1	-0.1, 0.5	-0.4 ± 0.4	-0.3 ± 0.4	-0.1	-0.3, 0.4	0	-0.4, 0.6
IRV, L	0.6 ± 0.4	0.5 ± 0.3	-0.2	-0.3, 0.4	0.5 ± 0.2	0.6 ± 0.4	0.1	-0.3, 0.4	0.3	-0.4, 0.6
RPE, mBorg-CR10 units	3.7 ± 3.1	2.2 ± 1.8	-1.5	-1.9, 5.4	3.8 ± 1.0	3.4 ± 1.6	-0.4	-1.4, 5.4	1.1	-2.5, 4.9
Breathlessness intensity, mBorg-CR10 units	3.3 ± 2.4	2.1± 1.6	-1.5	-0.2, 3.6	3.4 ± 1.4	3.0 ± 1.6	-0.7	-0.7, 1.7	0.8	-1.3, 3.6
Breathlessness unpleasantness, mBorg-CR10 units	3.8 ± 2.5	2.2 ± 1.5	-1.6	0.1, 3.9	3.6 ± 1.3	2.4 ± 1.7	-1.2	-0.6, 2.3	0.4	-1.6, 3.5
Leg Discomfort, mBorg-CR10 units	3.4 ± 2.6	1.5 ± 1.9	-1.9*	0.4, 4.2	3.0 ± 1.9	2.3 ± 2.0	-0.7	-1.0, 1.8	1.2	-0.8, 4.4
Reasons for stopping exercise, n (%)										

Breathlessness	8 (66.6%)	4 (33.3%)	-		7 (63.6%)	5 (45.5%)	-		-	
Leg Discomfort	2 (16.6%)	1 (8.3%)	-		3 (27.2%)	1 (8.1%)	-		-	
Breathlessness + Leg Discomfort	1 (8.3%)	1 (8.3%)	-		1 (8.1%)	1 (8.1%)	-		-	
Other, n	1 (8.3%)	6 (50%)	-		0 (0%)	4 (36.3%)	-		-	

Note: Data are presented as mean ± standard deviation, unless otherwise stated. *$p<0.05$ from baseline to post-ExT within group.
Abbreviations: $V'O_2$ = rate of oxygen consumption; RER = respiratory exchange ratio; SpO_2 = blood oxygen saturation; $V'_E/V'CO_2$ = ventilatory equivalent for carbon dioxide; V'_E = minute ventilation; V_T = tidal volume; f_R = breathing frequency; Δ = change from baseline; IC = inspiratory capacity; IRV = inspiratory reserve volume; RPE = rating of perceived exertion; mBorg-CR10 = modified Borg Category-Ratio 0-10 scale.


A
mMRC Dyspnea Scale
Baseline
Post-ExT
F2F
NF
B
BDI/TDI
C
HADS Depression
D
HADS Anxiety
E
COPD Assessment Test

241

Supplemental Material Figure 1. Changes in breathlessness burden, health status, and symptoms of anxiety and depression from baseline to post-exercise training (ExT) in the fan-to-face (F2F) and no fan (NF) groups: A) modified Medical Research Council dyspnea scale; B) Baseline Dyspnea Index/Transition Dyspnea Index; C) HADS Anxiety; D) HADS Depression; E) COPD Assessment Test
Note: *p<0.05 from baseline to post-ExT within group or between groups post-ExT.
Abbreviations: mMRC = modified Medical Research Council; HADS = Hospital Anxiety and Depression Scale; BDI/TDI = Baseline Dyspnea Index/Transition Dyspnea Index; COPD = chronic obstructive pulmonary disease.

Participant Responses to End-of-Study Questionnaire(s)

Following completion of the 5-week ExT program, 9 of 12 (75%) participants in the F2F group reported either a very substantial or some perceived benefit of the fan on their breathlessness during exercise. 9/12 (75%) of participants reported that they would use a fan in the future while exercising. Participants offered the following comments on their perceived benefit of the fan:

'I noticed that I needed less concentration to get more air in, I realised I have a higher tolerance [for exercise] and [the fan] removed my fear when receiving lots of wind on my face (participant [P]27)'

'I found my breathing stayed under control with the cool air and I was able to control by breathing by not becoming too hot (P10)'

'The air makes me catch my breath better (P32)'

'It feels like it [the fan] is pushing air into my mouth...like a CPAP [continuous positive airway pressure] machine (P17)'

'It gives the impression of having more air and the stimulation and distraction helps me not to focus on my breathing only (P20)'

Participants in both the F2F and the NF groups were asked to comment on their perceived benefit of the ExT program overall and on their daily breathlessness. Of the 6 participants in F2F and NF group who received this end-of study questionnaire, all responded to every question in the questionnaire. Comments from people in the F2F group included:

'I found it very beneficial as it allowed me to push myself in a secure and controlled environment with encouragement. I was gradually able to do more and push myself, proving to myself that I was capable of dealing better with my COPD and have confidence (P24)'

'I now know how to breath under control (P32)'

'*[The study is] important for me because exercise improves my situation, and I have a better tolerance now (P27)'*

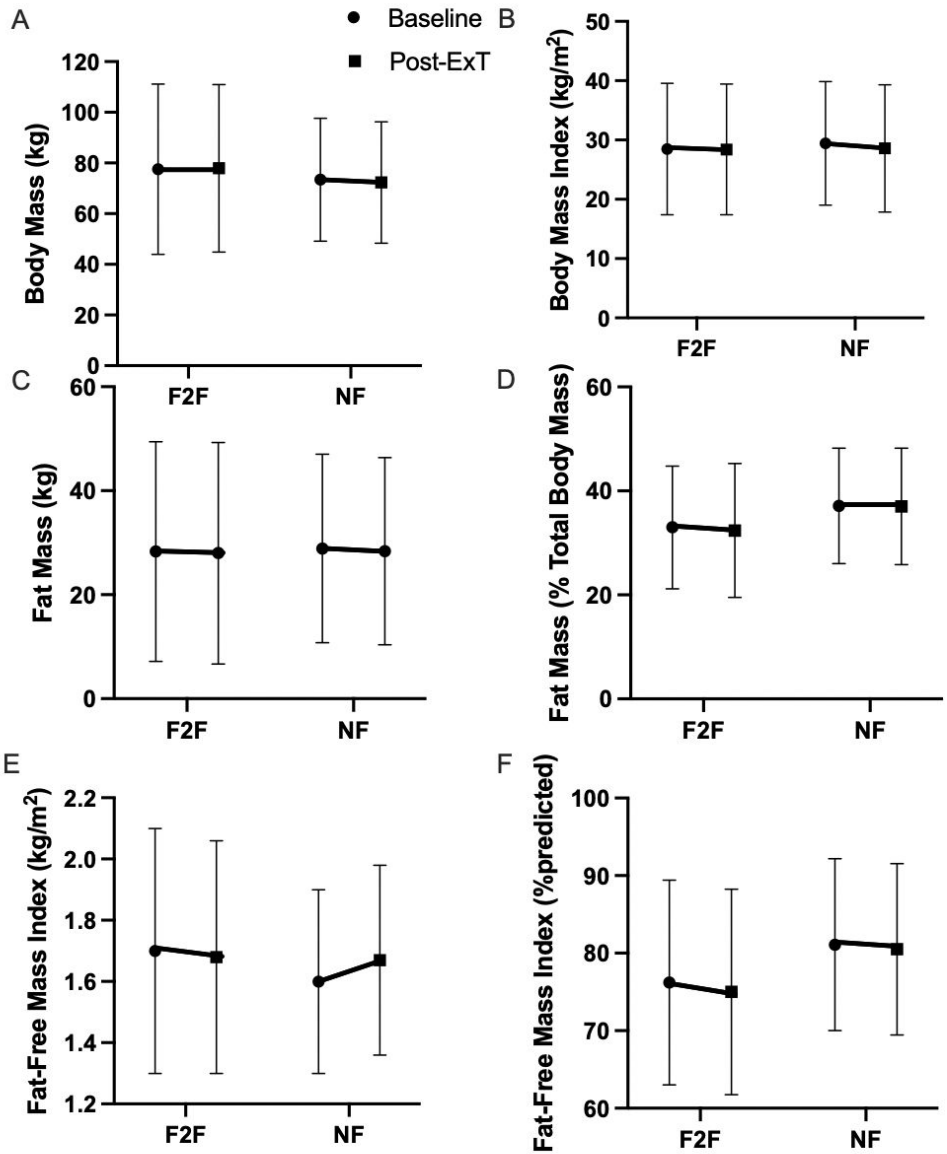
Comments from people in the NF group included:

'Training motivated me to move more than usual. During the exercise on the treadmill, I was less breathless than usual at the speed I was training at (P19)'

'My daily activities are a lot easier than before. I feel a strong sense of pride now. I would say I am a bit less breathless, but I can definitely tolerate more easily my level of breathlessness (P26)'

Body composition

The 5-week ExT program had no significant effect on body mass, body mass index, fat mass, or fat-free mass in either the F2F or NF groups, with no difference in the magnitudes of change between groups (***Supplemental Material Figure 2***).


A
Baseline
Post-ExT
Body Mass (kg)
120
100
80
60
40
20
0
F2F
NF
B
Body Mass Index (kg/m²)
50
40
30
20
10
0
F2F
NF
C
Fat Mass (kg)
60
40
20
0
F2F
NF
D
Fat Mass (% Total Body Mass)
60
40
20
0
F2F
NF
E
Fat-Free Mass Index (kg/m²)
2.2
2.0
1.8
1.6
1.4
1.2
F2F
NF
F
Fat-Free Mass Index (%predicted)
100
90
80
70
60
F2F
NF

285

Supplemental Material Figure 2. Changes in body composition outcome variables from baseline to post-exercise training (ExT) in the fan-to-face (F2F) and no fan (NF) groups: A) body mass; B) body mass index; C) fat mass; D) fat mass (% total body mass); E) fat-free mass index; F) fat-free mass index (% predicted).

Supplemental Material Table 3. Baseline participant demographics of people with chronic obstructive pulmonary disease (COPD) only in the fan-to-face (F2F) and no fan (NF) groups.

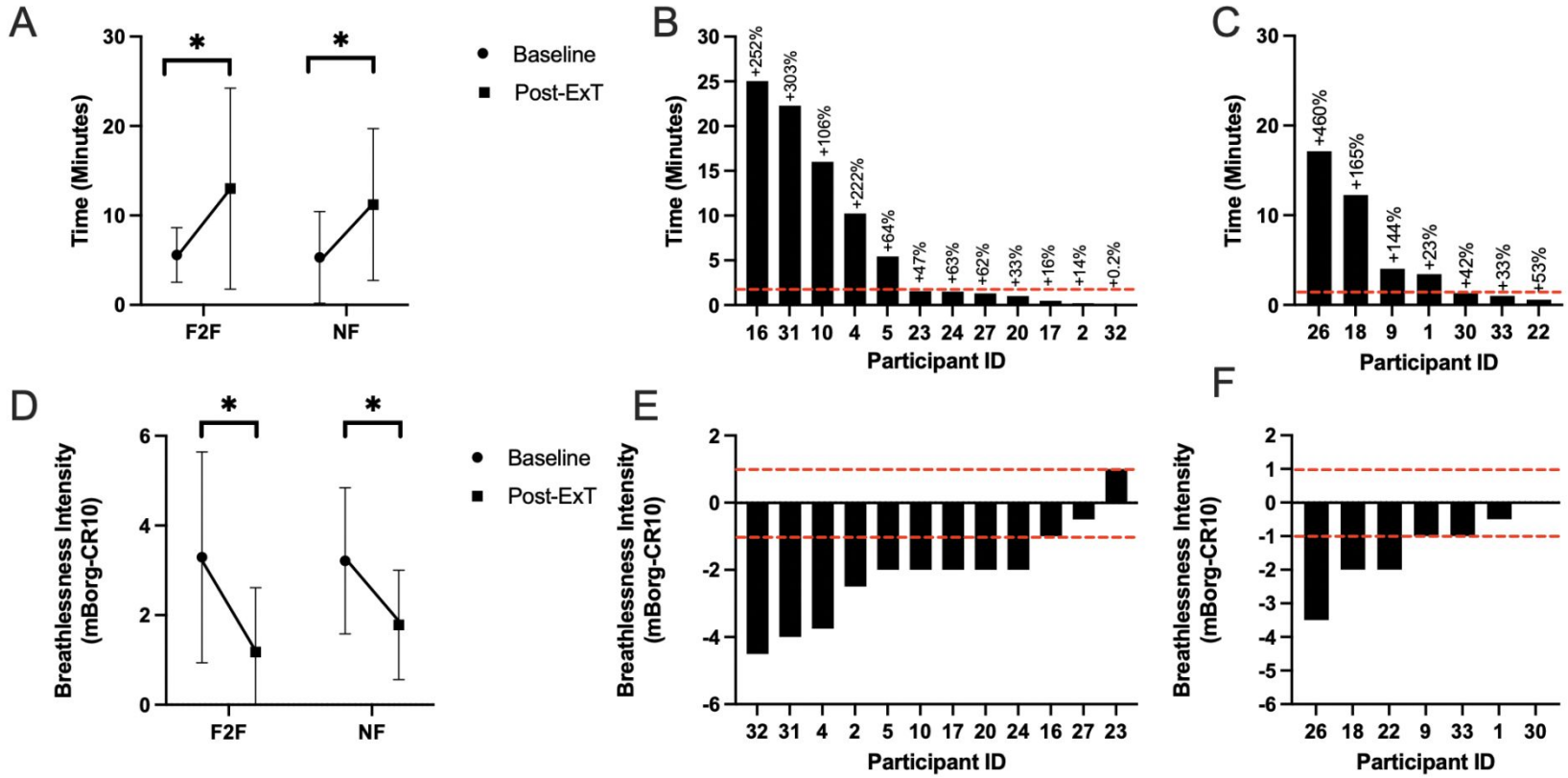
	F2F group (n=12)		NF group (n=7)	
	Value	**% Predicted**	**Value**	**% Predicted**
Female, n (%)	5 (41)	-	4 (57)	-
Age, years	67.6 ± 5.2	-	72.3 ± 6.9	-
Smoking history, pack-years	60.0 ± 43.2	-	45.5 ± 18.8	-
Body mass, kg	77.5 ± 33.6	-	71.8 ± 21.6	-
Body mass index, kg/m^2	28.4 ± 10.9	-	28.9 ± 8.6	-
Clinical Diagnosis, n (%)				
COPD				
GOLD stage 1	1 (8)	-	1 (14)	-
GOLD stage 2	2 (16)	-	2 (28)	-
GOLD stage 3	6 (50)	-	3 (42)	-
GOLD stage 4	3 (25)	-	1 (14)	-
Medication Summary, n (%)				
SABA	7 (58)	-	5 (63)	-
SAMA	1 (8)	-	0 (0)	-
SABA + SAMA	1 (8)	-	0 (0)	-
LABA	4 (33)	-	0 (0)	-
LAMA	2 (16)	-	3 (36)	-
LABA + LAMA	6 (50)	-	4 (54)	-
ICS	2 (16)	-	3 (27)	-
LABA + ICS	3 (25)	-	4 (63)	-

LABA + LAMA + ICS	3 (25)	-	0 (0)	-
Domiciliary Oxygen	1 (8)	-	0 (0)	-
Breathlessness and health status				
mMRC dyspnea score (0-4)	2.5 ± 1.4	-	1.6 ± 0.8	-
mMRC ≥ 2, n (%)	9 (75)	-	3 (42)	-
CAT score (0-40)[#]	21.6 ± 11.1	-	18.6 ± 6.3	-
CAT ≥ 10, n (%)	7 (58)	-	4 (57)	-
Baseline Dyspnea Index (0-12)	4.4 ± 1.9	-	6.3 ± 2.5	-
HADS Anxiety score (0-21)	8.0 ± 4.2	-	7.1 ± 3.1	-
HADS Depression score (0-21)	6.2 ± 4.7	-	3.7 ± 1.6	-
Post-bronchodilator lung function				
FEV_1/FVC	41.2 ± 14.9	-	47.3 ± 10.0	-
FEV_1, L	1.1 ± 0.5	46 ± 22	1.2 ± 0.3	55 ± 18
Total Lung Capacity, L	6.3 ± 1.1	113 ± 19	5.7 ± 1.0	107 ± 14
Inspiratory Capacity, L	2.0 ± 0.6	75 ± 15	1.8 ± 0.2	82 ± 25
Residual Volume, L	3.5 ± 0.9	176 ± 56	3.0 ± 0.6	162 ± 46
Functional Residual Capacity, L	4.3 ± 1.1	139 ± 38	3.8 ± 1.0	116 ± 49
D_LCO, mL/min/mmHg	14.2 ± 5.1	66 ± 24	11.6 ± 4.3	59 ± 25
R5, kPa/L/s	6.7 ± 3.1	210 ± 111	6.3 ± 3.5	208 ± 163
X5, kPa/L/s	-4.4 ± 6.4	351 ± 499	-4.6 ± 4.8	376 ± 532
R5-R20, kPa/L/s	3.9 ± 1.2	263 ± 266	2.2 ± 1.6	204 ± 157
DEXA-derived measures				
Fat Mass, kg	33.5 ± 13.0	-	28.1 ± 14.6	-
Fat Mass, % total body mass	44 ± 15	-	39 ± 11	-

Fat-Free Mass, kg	46.9 ± 13.6	-	41.5 ± 10.9	-
Fat-Free Mass, % total body mass	63 ± 11	-	58 ± 10	-
Fat-Free Mass Index, kg/m^2	1.7 ± 0.4	76 ± 13	1.6 ± 0.3	81 ± 11
Peak incremental cardiopulmonary treadmill exercise test data				
V'O_2, mL/kg/min	13.6 ± 5.1	76 ± 67	11.7 ± 2.5	83 ± 79
Power output, Watts	41.6 ± 20.4	62 ± 16	32.8 ± 13.8	62 ± 11
Reason(s) for stopping exercise, n (%)				
Breathlessness	6 (50)	-	4 (57)	-
Leg Discomfort	3 (25)	-	2 (28)	-
Breathlessness + Leg Discomfort	1 (8)	-	0 (0)	-
Other	2 (16)	-	1 (14)	-

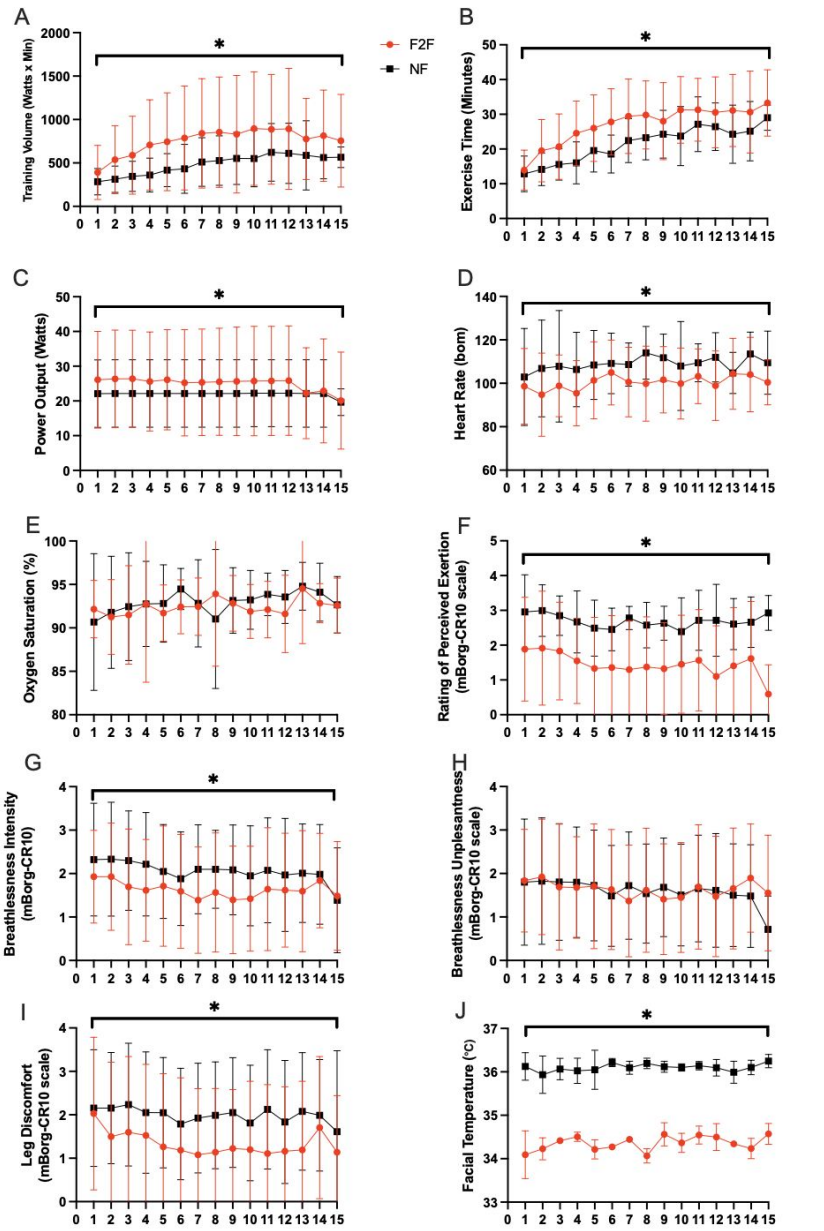
Note: Data are presented as mean ± standard deviation, unless otherwise stated. *p<0.05 between F2F and NF groups, [#] = 8 participants in the F2F group and 9 participants in the NF group completed the CAT.

Abbreviations: BMI = body mass index; COPD = chronic obstructive pulmonary disease; GOLD = Global Initiative for Chronic Obstructive Lung Disease; SABA = short-acting beta-agonist; SAMA = short-acting muscarinic antagonist; LABA = long acting beta-agonist; LAMA = long-acting muscarinic antagonist; ICS = inhaled corticosteroid; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; mMRC = modified Medical Research Council dyspnea scale; CAT = COPD assessment test; HADS = Hospital Anxiety and Depression Scale; D_LCO = diffusion capacity of the lung for carbon monoxide; R5 = resistance at 5 hertz; R20 = resistance at 20 hertz; X5 = reactance at 5 hertz; V'O_2 = rate oxygen consumption



Supplemental Material Figure 3. Changes in primary and co-primary outcome variables following a 5-week supervised exercise training (ExT) program in a sub-group analysis of participants with chronic obstructive pulmonary disease only (F2F n = 12, NF n = 7): A) mean ± standard deviation (SD) exercise endurance time (EET) from baseline to post-ExT in the fan-to-face (F2F) and no fan (NF) groups; B) individual participant changes in EET in the F2F group (with relative [%] change labels) from baseline to post-ExT; C) individual participant changes in EET in the NF group (with relative [%] change labels) from baseline to post-ExT; D) mean ± SD breathlessness intensity ratings at iso-time during the symptom-limited constant work-rate cardiopulmonary treadmill exercise test from baseline to post-ExT in the F2F and NF groups; E) individual participant changes in iso-time breathlessness intensity ratings in the F2F group; and F) individual participant changes in iso-time breathlessness intensity ratings in the NF group.

Note: *p<0.05 from baseline to post-ExT within group. The red dashed horizontal lines in panels B-C and panels E-F represent the minimally clinical important difference (MCID) of ±101 seconds for EET [29] and of ±1 modified Borg Category-Ratio 0-10 (mBorg-CR10) scale units for breathlessness intensity ratings [24], respectively.


A
Training Volume (Watts x Min)
F2F
NF
B
Exercise Time (Minutes)
C
Power Output (Watts)
D
Heart Rate (bom)
E
Oxygen Saturation (%)
F
Rating of Perceived Exertion (mBorg-CR10 scale)
G
Breathlessness Intensity (mBorg-CR10)
H
Breathlessness Unpleasantness (mBorg-CR10 scale)
I
Leg Discomfort (mBorg-CR10 scale)
J
Facial Temperature (°C)

Supplemental Material Figure 4. Exercise training (ExT) program variables during a 5-week supervised ExT program in people with chronic obstructive pulmonary disease (COPD) only in the fan-to-face (F2F) and no fan (NF) groups: A) ExT session volume; B) ExT session time; C) ExT session power output; D) ExT session heart rate); E) ExT session blood oxygen saturation; F) ExT session rating of perceived exertion; G) ExT session breathlessness intensity; H) ExT session breathlessness unpleasantness; I) ExT session leg discomfort; and J) ExT session facial skin surface temperature.
Abbreviations: mBorg-CR10 scale = modified Borg Category-Ratio 0-10 scale.
Note: Values are mean ± standard deviation. *p<0.05 between the F2F and NF groups across the 5-week ExT program.

Exploratory Post-Hoc Analysis in Participants who Completed all 15 Exercise Training Sessions

To assess for a potential bias resulting from differences in the proportion of people in the F2F and NF groups completing all 15 ExT sessions, we compared our primary and co-primary outcome variables as well as the cumulative ExT volume between the people in the F2F group (n=7) and people in the NF group (n=7) that completed all 15 ExT sessions. Both the F2F and NF groups showed significant increases in EET (5.2±5.6 min, 95% CI [4.2, 11.3] vs. 6.9±2.9 min, [6.8, 13.9] 95% CI, respectively) and decreases in iso-time breathlessness intensity ratings (-1.9±1.5 mBorg-CR10 units, 95% CI [1.1, 2.7] vs. -1.7±1.6 mBorg-CR10 units, 95% CI [1.7, 3.3], respectively) from baseline to post-ExT, with similar magnitudes of improvement observed between groups for EET (difference in change between groups = 1.7±5.5 min, 95% CI [-8.7, 5.7]) and breathlessness intensity (difference in change between groups = 0.2±1.1 mBorg-CR10 unis, 95% CI [-1.8, 0.5]).

REFERENCES

1. Vogelmeier, C.F., et al., *Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Lung Disease 2017 Report. GOLD Executive Summary.* Am J Respir Crit Care Med, 2017. **195**(5): p. 557-582.
2. Bestall, J.C., et al., *Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease.* Thorax, 1999. **54**(7): p. 581-6.
3. Mahler, D.A., et al., *The measurement of dyspnea. Contents, interobserver agreement, and physiologic correlates of two new clinical indexes.* Chest, 1984. **85**(6): p. 751-8.
4. Jones, P.W., et al., *Development and first validation of the COPD Assessment Test.* Eur Respir J, 2009. **34**(3): p. 648-54.
5. Zigmond, A.S. and R.P. Snaith, *The hospital anxiety and depression scale.* Acta Psychiatr Scand, 1983. **67**(6): p. 361-70.
6. Miller, M.R., et al., *General considerations for lung function testing.* Eur Respir J, 2005. **26**(1): p. 153-61.
7. Miller, M.R., et al., *Standardisation of spirometry.* Eur Respir J, 2005. **26**(2): p. 319-38.
8. Wanger, J., et al., *Standardisation of the measurement of lung volumes.* Eur Respir J, 2005. **26**(3): p. 511-22.
9. Culver, B.H., et al., *Recommendations for a Standardized Pulmonary Function Report. An Official American Thoracic Society Technical Statement.* American Journal of Respiratory and Critical Care Medicine, 2017. **196**(11): p. 1463-1472.
10. Stanojevic, S., et al., *ERS/ATS technical standard on interpretive strategies for routine lung function tests.* Eur Respir J, 2022. **60**(1).
11. Quanjer, P.H., et al., *Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations.* Eur Respir J, 2012. **40**(6): p. 1324-43.
12. Aarli, B.B., et al., *Reference values for within-breath pulmonary impedance parameters in asymptomatic elderly.* Clin Respir J, 2013. **7**(3): p. 245-52.
13. Myers, J., et al., *A Reference Equation for Normal Standards for VO2 Max: Analysis from the Fitness Registry and the Importance of Exercise National Database (FRIEND Registry).* Progress in Cardiovascular Diseases, 2017. **60**(1): p. 21-29.
14. *American College of Sports Medicine.* . ACSM's guidelines for exercise testing and prescription (8th ed.). , 2010. (Lippincott Williams & Wilkins.).
15. Jenkins, A.R., H. Lewthwaite, and D. Jensen, *Development and validation of reference equations for dual-energy X-ray absorptiometry-derived measures of fat-free mass in adults aged 45-85 years: results from the Canadian Longitudinal Study on Aging.* Appl Physiol Nutr Metab, 2024. **49**(10): p. 1317-1327.
16. Kocks, J.W.H., I.G. Tsiligianni, and T. van der Molen, *Responsiveness of the COPD assessment test: the minimal clinically important difference does matter.* Chest, 2012. **142**(1): p. 267-268.
17. Puhan, M.A., et al., *The minimal important difference of the hospital anxiety and depression scale in patients with chronic obstructive pulmonary disease.* Health Qual Life Outcomes, 2008. **6**: p. 46.

18. Araújo Oliveira, A.L., L. Andrade, and A. Marques, *Minimal clinically important difference and predictive validity of the mMRC and mBorg in acute exacerbations of COPD.* European Respiratory Journal. **50**(suppl 61): p. PA4705.
19. Guenette, J.A., et al., *Inspiratory Capacity during Exercise: Measurement, Analysis, and Interpretation.* Pulm Med, 2013. **2013**: p. 956081.
20. Borg, G.A., *Psychophysical bases of perceived exertion.* Med Sci Sports Exerc, 1982. **14**(5): p. 377-81.
21. Burdon, J.G., et al., *The perception of breathlessness in asthma.* Am Rev Respir Dis, 1982. **126**(5): p. 825-8.
22. Hareendran, A., et al., *Proposing a standardized method for evaluating patient report of the intensity of dyspnea during exercise testing in COPD.* Int J Chron Obstruct Pulmon Dis, 2012. **7**: p. 345-55.
23. Palmer, T., et al., *Fixed-intensity exercise tests to measure exertional dyspnoea in chronic heart and lung populations: a systematic review.* Eur Respir Rev, 2023. **32**(169).
24. Ries, A.L., *Minimally clinically important difference for the UCSD Shortness of Breath Questionnaire, Borg Scale, and Visual Analog Scale.* Copd, 2005. **2**(1): p. 105-10.
25. Lewthwaite, H. and D. Jensen, *Multidimensional breathlessness assessment during cardiopulmonary exercise testing in healthy adults.* Eur J Appl Physiol, 2021. **121**(2): p. 499-511.
26. Lewthwaite, H., et al., *Multidimensional breathlessness response to exercise: Impact of COPD and healthy ageing.* Respiratory Physiology & Neurobiology, 2021. **287**: p. 103619.
27. O'Donnell, D.E., et al., *Reliability of ventilatory parameters during cycle ergometry in multicentre trials in COPD.* Eur Respir J, 2009. **34**(4): p. 866-74.
28. Jones, N.L., *Clinical exercise testing*. 1997, Philadelphia: W.B. Saunders.
29. Puente-Maestu, L., et al., *Clinical relevance of constant power exercise duration changes in COPD.* Eur Respir J, 2009. **34**(2): p. 340-5.