

Supplementary materials to manuscript:

“Use of Singing for Lung Health as an alternative training modality within pulmonary rehabilitation for COPD: an RCT”

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Appendix S1: Overview of secondary study outcomes

Outcome	Measure	Test/Scoring	Minimal important difference (MID)
Quality of Life (QoL)	St. George's Respiratory Questionnaire (SGRQ): Disease-specific QoL and health impairment	Self-reported. SGRQ has 50 items with 76 weighted responses and four scores: Total, Symptom, Activity, Impact. Each score ranges from 0 to 100, with 100 representing worst possible health status and 0 best possible.	4 points [1]
Lung function	Forced Expiratory Volume in one second (FEV1) expressed in ml and percent of expected (FEV1%)	Assessor-collected. Reversibility test using a mobile spirometer (Medikro Pro, Product Code M915, SW version 3.1-03, OY Finland) and was categorised according to Global Initiative for Chronic Obstructive Lung Disease (GOLD): FEV1% > 80 = GOLD 1 (mild); 50 ≤ FEV1% < 80 = GOLD 2 (moderate); 30 ≤ FEV1% < 50 = GOLD 3 (severe); FEV1% < 30 = GOLD 4 (very severe) [2]. Reference values: height, age, sex and ethnicity.	MID for FEV1 is considered to be 120ml [3]
Dyspnoea	BORG CR10-dyspnoea scale: Self-perceived dyspnoea.	Self-reported. The scale ranges from 0 to 10 points, where 0 represents no dyspnoea and 10 represents maximal dyspnoea.	1 point [4, 5]
Dyspnoea	Modified Medical Research Council Dyspnoea Scale (mMRC): self-reported data on general, experienced dyspnoea and functional capacity.	Self-reported. The scale with scores from 0-4, grade 0 corresponding to "Dyspnoea only when strenuous exercise" and grade 4 corresponding to "too dyspnoeic to leave house or breathless when dressing"[23, 24]	1 point [4, 5]
Anxiety and depression	Hospital Anxiety and Depression Scale (HADS).	Self-reported. Comprising 14 items, seven related to anxiety and seven related to depression	1.32 (anxiety component) and 1.40 (depression component) [8, 9]
Expectations of singing benefits	Patient-reported (developed for the study)	Self-reported. Reported as value positive, neutral, or negative.	N/A
Adherence	PR adherence and drop-out rate (%): participation status and eventual drop-out	Facilitator-collected. Continuously registered at all training sessions by each centre. Subsequently, adherence rate was divided into four categories (quartiles), and drop-out rate was calculated. High adherence was defined as ≥75% of all sessions.	N/A

Appendix S2: Consensus on Exercise Reporting Template (CERT) for both study groups

Abbreviations used in CERT (Appendices S2 and S3)

COPD:	Chronic Obstructive Pulmonary Disease
SLH:	Singing for Lung Health
PT:	Physio therapist
ST:	Singing teacher
AE:	Adverse events

Consensus on Exercise Reporting Template (CERT) for both study groups

Item category	Item description	Singing for Lung Health	Physical Exercise Training
What: materials	1. Type of exercise equipment (e.g., weights, machines, exercise bicycle, treadmill)	<ul style="list-style-type: none"> • Music player and music (CD/smartphone) during warm-up and relaxation. • Chairs for sitting, breathing exercises, resting positions, and moving/dancing around. • Paper sheets (music and/or text), Danish and/or international exercises and songs (and appertaining games/dances). Majority of songs taught “by ear”. • Balloons, drum sticks, scarfs, umbrellas, ropes, balls, fly swappers to support movement/activity during singing. • Straw and glass with water (to make vocal sounds through a straw put into the water) • Piano (or similar) for accompaniment for some songs during the last 10 sessions. 	<ul style="list-style-type: none"> • Music player and music (CD/smartphone) during warm-up, exercises and relaxation. • Chairs, training mats/plints <p>For warm up and endurance training:</p> <ul style="list-style-type: none"> • Exercise bicycles, treadmill, cross trainer, staircases, balls, balloons, rackets etc. and individual body weight <p>For strengthening training:</p> <ul style="list-style-type: none"> • Kettle balls/filled water bottles/weights, weight training machines, elastic bands, individual body weight
	2. Qualifications, and teaching/supervising expertise of the exercise instructor	<ul style="list-style-type: none"> • Danish singing teachers (ST) with professional academic training in voice/music studies. • Participated in a mandatory workshop of 16 hours (2 days), supplemented a handout with theoretical background on pathophysiology and best-practice lung choir methodology from the British team of experts (info in the elaborated CERT below this table). • The <i>patient education</i> (see item 10) was delivered by professionals of the given topic or the PT (equal in the two groups) 	<ul style="list-style-type: none"> • Physiotherapist (or occupational therapist or nurse) (PT) employed at the local healthcare center with basic educational background. • Experienced in pulmonary rehabilitation in COPD. • The <i>patient education</i> (see item 10) was delivered by professionals of the given topic or the PT (equal in the two groups)
Who: provider			

3. Exercises performed individually or in a group?	<ul style="list-style-type: none"> Sessions were delivered in classes of approximately 10 participants. Supplementary individual supervision and guidance throughout. 	<ul style="list-style-type: none"> Sessions were delivered in classes of approximately 10 participants. Supplementary individual supervision and guidance throughout.
4. Exercises are supervised or unsupervised?	<ul style="list-style-type: none"> Exercises were supervised on class-level and individually throughout by the ST. 	<ul style="list-style-type: none"> Exercises were supervised on class-level and individually throughout by the PT.
5. How adherence to exercise is to be measured and reported	<ul style="list-style-type: none"> Number of attended sessions by each participant was registered by the ST. Adherence and progression were registered and reported in a mandatory logbook. Reporting style and form varied, since there was no template for systematic reporting. Adherence is reported in the results section of the manuscript 	<ul style="list-style-type: none"> Number of attended sessions by each participant was registered by the PT. Adherence and progression were reported in local registration system. Adherence is reported in the results section of the manuscript.
6. Details of motivation strategies	<ul style="list-style-type: none"> An encouraging and acknowledging attitude of the ST (as described in previous literature [10, 11]. Building a safe atmosphere and group dynamic. Endeavor to match levels of ability in muscle strength and endurance of each participant. Combination of endurance and strengthening training. Inclusion of participants' preferences (in musical taste). 	<ul style="list-style-type: none"> An encouraging and acknowledging attitude of the PT, especially for participants with more severe COPD (best practice). Participation based on the individual motivation to participate. Participants were screened systematically to find the individual ability level (level of dyspnea, level of loss of muscle strength). Endeavor to match the chosen exercises to the levels of ability in muscle strength and endurance individually for each participant. Combination of endurance and strengthening training to increase adherence[12, 13].
7. Specify/describe the way in which it is decided to progress through an exercise programme	<ul style="list-style-type: none"> Progression from a basic programme to build awareness and control (voice, breath, and body) and to include additional elements and complexity. Progression of strength/endurance requirements in the SLH along the way, e.g. increasingly prolonged outbreaths, extended vocal range and flexibility, and duration of standing. Ensure a positive experience to build confidence and self-esteem. 	<p>Individually progression of workload intensity, supervised by the PT every 2-3 week:</p> <ul style="list-style-type: none"> <u>Strengthening training</u> in continuum from '3 sets of 8-10 repetitions, weight increased if >10 reps'[14] to '65-80% of 1 Repetition max (RM)'. The duration of/speed during endurance training aiming at sets of 10 minutes increasing to 25 minutes [12], achieving load of continuum over 'no definition', '11-13 or 13-14 on BORG Rate of Perceived exertion scale (Borg RPE)', to '60% of VO2 max, measured on Borg CR10'.
8. Specify/describe each exercise so that it can be	<p>Examples (the following elements are available in the elaborated CERT for SLH below this table):</p> <ul style="list-style-type: none"> Physical warm-ups (stretching, 	<p>The physical training combined endurance and/or strengthening training as these training methods appear to be equally effective in rehabilitation programme for</p>

replicated (eg, photographs, illustrations, online appendixes)	<p>movement, flexibility, accelerating heartbeat, body awareness).</p> <ul style="list-style-type: none"> • Posture exercises • Breathing exercises • Rhythm and pitch games, call-response. • Vocal exercises (vocal range and flexibility, phonation, resonance, articulation) • Physical and vocal stamina • Songs with and without additional movement/dancing/activity • Relaxation and body awareness exercises • Planned choreography to support moving/dancing during singing/game songs. <p>Exercise equipment varied and was tailored to the singing class by each ST.</p>	<p>COPD patients [12, 14].</p> <ul style="list-style-type: none"> • Warm up exercises for joints, muscles, circulation and breathing. • Preferably combination of endurance and strengthening training, and secondary strengthening training alone. • Large muscle groups of the extremities were prioritized. • Daily life-related activities (sit-to-stand, gait, lifting “bags”, stair climb, bicycling) • Floor games, Circuit training • Cool down: Stretching of muscles; relaxation. • Management of dyspnea: Posture exercises, resting positioning, relaxation, breathing techniques (i.e. Pursed Lip Breathe) • Instruction in positive expiratory pressure (pep) and clearance techniques as needed.
9. Content of any home programme component	<ul style="list-style-type: none"> • Instruction and encouragement to practice methods of breathing techniques, vocal exercises/songs, relaxation, and body awareness at home, however without specific/generic requests. 	<ul style="list-style-type: none"> • Instruction and encouragement to do appropriate exercises at home (see item 14).
10. Describe the nonexercise components of the intervention (eg, cognitive behavioral therapy)	<p>Supplementary <i>patient education</i> (part of standard PR):</p> <p>Knowledge about COPD (communicated in a considerate manner that did not create unnecessary concern (best practice), behavior change, smoking cessation, correct use of inhaler devices, nutrition, sexuality, handling of stress and anxiety, early recognition of exacerbation, decision-making and taking action of symptoms, goals of motivation and maintenance post PR.</p>	<p>Supplementary <i>patient education</i> (part of standard PR):</p> <ul style="list-style-type: none"> • Knowledge about COPD (communicated in a considerate manner that did not create unnecessary concern (best practice), behavior change, smoking cessation, correct use of inhaler devices, nutrition, sexuality, handling of stress and anxiety, early recognition of exacerbation, decision-making and taking action of symptoms, goals of motivation and maintenance post PR.
11. Report adverse events (AE) that occur during an exercise intervention	<ul style="list-style-type: none"> • STs/health professionals reported any AE to the research group however, AE were not systematically collected for this trial. 	<ul style="list-style-type: none"> • PT/health professionals reported any AE to the research group however, AE were not systematically collected for this trial. • Muscle soreness was anticipated and not reported as an AE.
12. Setting in which exercise is to be performed	<ul style="list-style-type: none"> • Sessions were delivered in a standard, spacious training studio (normally used for PR) in each local health-care center. • The training studio was in a separate and undisturbed room. 	<ul style="list-style-type: none"> • Sessions were delivered in a standard, spacious training studio (normally used for PR) in each local health-care center. • The training studio was in a separate and undisturbed room.

13. Specify and explicitly describe the exercise intervention (i.e., number of exercise repetitions, number of exercise sets, number of sessions, duration of each session, duration of intervention or programme)	<p>20 sessions, i.e. twice weekly during 10 weeks.</p> <p>Each session was 90 minutes, including a 10-15 minutes break for water/tea/coffee and toilet visit.</p> <ul style="list-style-type: none"> • 20 minutes of physical warm-ups: posture and breathing exercises, warming up body • 20 minutes of vocal warm-ups and rhythm and pitch games. • 40 minutes of singing songs, often with additional games/moving/dancing (including 10-15 minutes break). • 10 minutes of cool down (e.g. mindfulness or relaxation). 	<p>20 sessions, i.e. twice weekly during 10 weeks.</p> <ul style="list-style-type: none"> • Each session was 90 minutes, including a 10-15 minutes break for water/tea/coffee and toilet visit. • 20 minutes of physical warm-up • 45-50 minutes physical training (see item 8) including handling of dyspnea • 10 minutes cool down
14. Specify whether exercises are generic or whether, and how, they are tailored to the individual	<p>Exercises and songs were generic (examples and elaboration in elaborated CERT below this table), as basic exercises/songs can easily be graduated to meet/challenge all levels of competence.</p> <p>All activities delivered at class level were combined with individual supervision and guidance throughout.</p> <p>Exercises and songs were tailored in relation to following:</p> <p>If impaired, participants were allowed to:</p> <ul style="list-style-type: none"> • Sit more often instead of standing/moving. • Perform shorter outbreath than other participants. <p>Competence:</p> <ul style="list-style-type: none"> • Each participant was instructed individually in relation to breathing technique, posture, and muscle work/tension/relaxation. • Participants with prior musical competence were asked to add advanced elements to songs. <p>Preferences:</p> <ul style="list-style-type: none"> • ST's/participants' personal taste in musical repertoire [10, 15]. 	<p>Exercise were tailored by the PT depending on:</p> <ul style="list-style-type: none"> • The severity of COPD of the individual participant. • Personal preferences of combination (or uni-method use) of strengthening and endurance training. • Physical limitations (e.g. injured joint, paresis): modifications of exercises as needed to prevent damage and improve function. <p>Furthermore:</p> <ul style="list-style-type: none"> • Participants who were unable to do endurance (anaerobic) training due to high level of dyspnea, were encouraged to do strengthening training alone. • The PTs followed the Danish national clinical guideline[16] if this was decided by the local health-care centre, therefore the physical training was not standardized but represent the real world clinical practice in Danish municipalities.
15. Decision rule that determines the starting level at which participants commence exercise (i.e., beginner,	<ul style="list-style-type: none"> • No prior exercise or vocal/musical competences were required. • Individuals with COPD with mMRC<2, and potentially weak/untrained, but able to participate in the rehabilitation programme. • Since the intervention and background methodology is new in Denmark, all participants were regarded as 	<ul style="list-style-type: none"> • No prior exercise competences were required. • Individuals with COPD with mMRC<2, and potentially weak/untrained, but able to participate in the rehabilitation programme, thus starting level was typically regarded 'beginner'. • However, participants with better fitness were regarded intermediate.

intermediate, or advanced)

- beginners.
- However, participants with experience/competence within singing were regarded intermediate and were challenged, e.g. with adding polyphony.

16. How adherence or fidelity to the exercise intervention will be assessed or measured

- Each ST received supervision throughout by study investigator (MK) at visits twice and telephonic contact.
- ST were encouraged to build peer-network with knowledge-sharing.
- In case of absence of ST, sessions were conducted by local health professional (singing together) or cancelled.
- Each ST kept a logbook of all sessions, including reporting of reflective practice.
- Subsequent video interview of experiences of the ST.
- In case of absence of PT, sessions were conducted by other local health professional.

Appendix S3: CERT – Elaborated version for intervention group (SLH)

WHAT: materials

Item no. 1: Type of exercise equipment (e.g., weights, machines, exercise bicycle, treadmill)

Materials for preparation:

Initially, singing teachers (ST) participated in a mandatory workshop to gain knowledge and ideas for exercises, songs, and physical movements, and to prepare the singing sessions. Further, they were equipped with a handout and a CD for inspiration: "Singing for breathing", link: <https://www.rbhcharity.org/shop/singing-for-breathing-audio-cd>

The intervention in Sing-a-Lung was conducted with inspiration from the best-practice approach within singing for lung patients ("Singing for Lung Health"/"Singing for Breathing"), based on a decade's thorough, empirical fieldwork and offered to British lung choir singing teachers through the British Lung Foundation.[17] Content of workshop, handout, and CD represented the "Singing for Lung Health"/"Singing for Breathing" concept as it was delivered in the UK in 2017.

The British team of experts (concept founders, music therapist and singing teacher, BMus Hons, PGDip MT, MA, Phoebe Cave, The Musical Breath (<http://www.themusicalbreath.com>), and Respiratory Physiotherapist, Dr. Adam Lewis (Physiotherapy and Physician Associate, Department of Health Sciences, College of Health, Medicine and Life Sciences, Brunel University, London, UK) developed the basic materials (handout and CD), and conducted the mandatory workshop.

Handout was translated into Danish by study investigator, Mette Kaasgaard and research secretary, Hella Kastbjerg (Center for Music in the Brain, Dept. of Clinical Medicine, Aarhus University, Denmark) with supplementary materials suited for Danish context (background literature, and repertoire for exercises, songs, and games/dances).

Session structure, focus, and approach were predefined. Exercises, songs, and recorded music (for movements and relaxation) were selected by the ST in concurrence with recommendations in workshop and handout. Focus of sessions and in the selection of exercises, music, and approach: Meeting the disease-specific, pathophysiological challenges and the psychosocial needs of patients with COPD, e.g., through:

- 1) Extending outbreaths through sung phrases.
- 2) Improving respiratory muscle strength and co-ordination.
- 3) Returning to an optimum breathing pattern and reduce 'top up' breaths, improve using diaphragm and abdominal muscles (such as the internal and external obliques and the transverse abdominus) rather than accessory respiratory muscles (these include primarily upper trapezius, scalene, sternocleidomastoid, levator scapulae, and pectoralis minor).
- 4) Building physical and vocal stamina and ensure safe, balanced, and efficient phonation and articulation.
- 5) Building positive group dynamics through interaction and having fun.

Overview of content elements:

- Physical warm-ups
- Posture exercises
- Breathing exercises
- Rhythm and pitch games, call-response
- Vocal exercises (flexibility, ambitus, phonation, resonance, articulation)
- Exercises for physical and vocal stamina
- Songs with and without additional movements/dancing/activity/use of artefacts
- Relaxation and body awareness exercises

Materials for sessions:

Musical materials:

- Paper sheets (music and/or text), Danish and/or international songs and game songs/dances. Songs mostly learned by ear/heart, eventual text/music sheets on paper. Singing teachers mainly used music from standard Danish song books (e.g. "Sangbogen 1-5"[18])(collections of classic, traditional, and popular songs), supplemented by international (mainly English/American) songs and by ST's own materials/songs and/or participants' suggestions for material/songs. Further, they applied e.g. African work songs, native songs from all over the world, children songs, non-verbal songs, and rounds and circle songs. Improvisation and imitation (call-response) was also included, especially during warm-up (as instructed in workshop and handout). Alongside, the ST focused on musical content and interpretation, and introduced different moods, genres, and expressions via exercises, games, and songs.
- Music player for recorded music during warm-up and relaxation.
- After 10 sessions (halfway through the intervention), singing teachers were allowed to introduce piano (or similar) accompaniment for some songs, however, with singing still mainly performed "a cappella" (without accompaniment) in the circle.
- Some singing teachers occasionally included other instrumental accompaniment, e.g. African drum (djembe), guitar, bells, and singing bowls.

Non-musical materials:

- Chairs for sitting down (when needed), for breathing exercises, for resting positions, and for moving/dancing around.
- Additional artefacts to supplement exercises and songs: E.g. balloons, drum sticks, scarfs, umbrellas, ropes, balls, and fly swappers to support movements/activity during singing.
- Straws and glasses with water (to make vocal sounds through a straw put into the water).
- Planned choreography to support movements/dancing during singing/game songs, and either predefined or participant-invented. Exercises and songs were combined with movements or dancing whenever possible, both to add an endurance aspect, and to underline the social aspect and joy of singing together.
- Exercise equipment varied and was tailored to the singing class by each singing teacher.

WHO: provider

Item no. 2: Qualifications, teaching/supervising expertise and/or training of the exercise instructor

- Inclusion criteria for the Danish singing teachers were prior academic professional training in voice/music studies. In the job advertisement and subsequent screening process, we asked for personal and social competences such as openness, empathy, and humour, as previously recommended for lung choir teachers [3][8][9]. No prior healthcare education or experience within lung diseases or lung choirs was required.
 - 20 singing teachers were selected and prior to the intervention, all 20 singing teachers participated in the mandatory, specialised training workshop (see item 1) of 16 hours during 2 days with the British team of experts.
 - During trial conduct, singing teachers were further supervised twice at visits and were allowed support by telephone with the study investigator, Mette Kaasgaard, who is trained in classical singing and voice pedagogy. Also, they were encouraged to build peer-network with knowledge-sharing and mutual support. Besides the workshop handout and the singing-for-Breathing-CD for inspiration, singing teachers had access to a closed Facebook-group with video examples of songs and exercises (recorded during the workshop) and posting of ideas, and a Dropbox-folder for mutual sharing of materials.
 - Eight singing teachers participated in the training workshop but did not participate fully in the trial due to other employment or their geographical area related to the subsequent randomisation. However, they were facilitators in the trial. Some of them (n=5) led only one singing class whereas others led two (n=1) or three (n=2) classes.
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- The *patient education* (see item 10) was delivered by professionals of the given topic or the local physiotherapist (equal in the two study groups).

HOW: delivery

Item no. 3: Whether exercises are performed individually or in a group

- Sessions were delivered in classes of approximately 10 participants (range 7-16) across 14 classes totally.
- Whenever appropriate, the singing teacher explained relevant aspects of respiratory anatomy and physiology to the class (tailored to the participants in the class and individually when needed) and transferred these explanations to practical breathing/vocal exercises and songs.
- Exercises, song, and games/dances were performed in classes.

Item no. 4: Whether exercises are supervised or unsupervised

- Sessions were supervised throughout by each singing teacher, both on class-level and individually. The participants and the singing teacher formed a circle, mostly standing up, but also sitting down for an exercise, or when needed, e.g., because of tiredness or dizziness.
- The ST provided immediate individual observation, supervision, and correction of each participant, e.g., in relation to breathing pattern, vocal functioning, posture, jaw tension, muscle work, flexibility, unintended tension, vocal function, articulation, sound, expression/interpretation, relaxation, and body awareness.
- The circle allowed for the singing teacher to be able to be close to every participant, and for an experience of participants being mutually equal. Furthermore, the circle position allowed easy implementation of different activities and improved dynamics in the session, e.g. combining singing with movements, dancing, and using/playing with various artefacts (see Item 1 and Item 8).

Item no. 5: Measurement and reporting of adherence to exercise

- Adherence to exercise was registered on group level and reported in the logbook, which each singing teacher was asked to use (the log book further included a section with self-evaluation the for ST). Reporting style and form varied, as no standardized template for reporting was provided.
- Number of attended sessions by each participant was registered (in a predesigned matrix) by each singing teacher. Adherence is reported in the result paragraph.

Item no. 6: Details of motivation strategies

- We focused on building a safe atmosphere and group dynamic, e.g. through an encouraging and acknowledging attitude of the singing teacher[10, 11, 17] and creating a space in which participants would be among peers in an accepting atmosphere and having fun giving a positive experience of singing together, while building new competences, strategies, and self-esteem.[10, 11, 17]
- The singing teacher made endeavor to match levels of ability in muscle strength and endurance of each participant, and the session content consisted of both endurance and embedded strengthening training for posture and respiratory muscles.
- Inclusion of participants' preferences (in musical taste).
- During the 10-15 minutes break, some of the classes received tea/coffee/cocoa milk and biscuit/fruit (varied from centre to centre aligned to the local habits in the community).

Item no. 7: Decision rules for progressing the exercise programme

- Along the way, the singing teachers supervised growth and progress, both in the class and in individuals, and gradually increased/challenged the level of strenght and endurance for posture and respiratory muscles.
- 1) Starting with a basic programme to build knowledge, and initial awareness, stamina and control (vocal, breathing (in- and exhalation, posture, articulation, avoid accessory muscle tension).

- 2) Continuing with the basic elements and adding elements, strength, endurance, and complexity along the way.
 - 3) Progression of strength/endurance requirement in the singing, for example gradually prolonging outbreaths, extending vocal tone range (ambitus), or duration of standing up.
- Progression was registered and reported in the log book (definition of log book, see Item 5).
 - Beside from the Danish handout and supplementary materials, there was no specific and detailed protocol for the intervention or for progression. SLH, therefore, to some extent was delivered diversely across the centers, due to variety in singing teachers' background and personal styles, and to specific composition and dynamics in each class (pragmatical design).

Item no. 8: Each exercise is described so that it can be replicated (e.g. illustrations, photographs)





- Inclusion of aspects of respiratory anatomy and physiology, refer to item 3.
- See Item no. 7 for description of diversity and progression.

Overview of key activities/content elements:

- Physical warm-ups (stretching, movement, flexibility, accelerating heartbeat, body awareness).
- Posture exercises
- Breathing exercises
- Rhythm and pitch games, call-response.
- Vocal exercises (vocal range and flexibility, phonation, resonance, articulation)
- Physical and vocal stamina
- Songs with and without additional movement/dancing/activity
- Relaxation and body awareness exercises
- Planned choreography to support moving/dancing during singing/game songs.

Exercise equipment varied and was tailored to the singing class and the individual participants by each singing teacher.

Elaboration of content elements (see Item no. 1):

Content	Description of content	Music/exercise examples, links, illustrations/photographs
Physical warm-ups	<ul style="list-style-type: none"> Recorded music to support each activity – starting slowly and increasing energy and tempo (Energizing up-tempo music for warm-up) <p>Seated and/or standing:</p> <ul style="list-style-type: none"> Body and breathing awareness Stretching and “opening”/awaken the the whole body (all directions: up, “picking apples”, to the sides, down) Moving/stretching lips/mouth/jaw/face/tongue Massage of jaws/chin/neck (own and others’) Yawning, sighing, sirening: wakening breath and voice) Lower body: Hip circles, knee bends/lifts, ankle rolls, feet movement Upper body: Side bend, head, neck and shoulder rolls, arm swings, rotating spine/centre 	<p>Examples of recorded music for warm-ups: The Temptations: “My Girl” Leo Mathiesen: “Take it easy, boy, boy” Tommy Steele: “A Handful Of Songs” Michael Bublé: “Everything” Van Morrison: “Brown Eyed Girl”</p>  
Posture exercises	<p>Seated and/or standing:</p> <p>Body “walk-through”/body awareness (from feet to the top of the head). Focus on:</p> <ul style="list-style-type: none"> Lengthening the spine and neck Balance between back and front A feeling of space inside the body: space for the breath, space for the voice Soft joints (ankles, hips, knees, shoulders, neck) Avoiding collapse of posture and thorax 	
Breathing exercises	<p>Seated: Examples:</p> <ul style="list-style-type: none"> Leaning forward, resting elbows and back of the forearms on thighs. <p>Focus on:</p> <ul style="list-style-type: none"> Feeling the breath in the back of the body Freeing the neck/jaw/face Allowing the inbreath – relax and release tummy Controlled, long exhaling on unvoiced sounds (FFFFFF/SSSSSS) and voiced sounds (VVVVV/ZZZZZZ), and allow a spontaneous, deep 	

inbreath afterwards

Standing (or seated):

First step (examples):

- Observing the breathing
- Connecting breath to movement. Participants asked to illustrate breathing, e.g.: Watch their hands while opening and closing hands like a flower (opening on inhale, closing on exhale). Further, breathing/vocal sound may be illustrated with movement with the arms or by moving the whole body forwards and backwards in rhythm with inhalation and expiration.
- Using the imagination: Smelling a beautiful rose (fosters a deep diaphragmatic inhalation)

Second step (examples):

- Controlling outbreath to sounds: Playing with exhaling on unvoiced (FFFFFF/SSSSSS) and voiced (VVVVV/ZZZZZZ) sounds. Prolonging the exhalations gradually.
- Wakening and strengthening breath support muscles function and coordination through natural sounds and impulses: laughter, cough, sneeze, surprise etc.
- Using voiced fricatives (unpitched and pitched) in a rhythmic pattern (e.g. VVV VVV VVV or ZZZ ZZZ ZZZ with inhalation between sounds).
- Noticing movement in waistband: Placing hands in waistband and feel the muscles engaging under the hands, while the belly draws gently inwards towards spine during the exhalation. Singing teacher may assist participants and put a hand on abdomen/sides/back to enhance the body awareness.
- Breathing/humming/singing through a large straw (at least 10 mm) into a glass of water, keeping airflow consistent when beginning to phonate: "Straw phonation".[19]

Examples of elements/activities:

- Making "body percussion": clapping on the body, stomping with feet etc. while making vocal sounds, words, sentences, rhymes, sung phrases.
- "Call and response" - making nonsense sounds or short spoken/sung sentences, eventual with additional movement/dancing: The singing teacher makes a sound and the class replies (repeats/imitates).
- Exploring rhythm, pitch, dynamics, duration and different vocal qualities: High and low sounds, loud and quiet, fast and slow, vowels and consonants, legato and staccato, parts of scales, arpeggios, expressing different moods (e.g. sad, happy, excited, angry, tired).
- Humming: Closed vowels (e.g., E) and open



Singing teacher supports awareness of breathing (inhalation and exhalation)

"Straw phonation"



Example of body percussion warm-ups (clip from search on Youtube):
<https://www.youtube.com/watch?v=INbZLgg5Oy0> (Source: Musical Futures)

Example of call and response (clip from search on Youtube):
<https://www.youtube.com/watch?v=hsl8pnsacx8> (Source: Musical Futures)

Example of included artefacts:

Balloons, drum sticks, scarfs, umbrellas, ropes, balls, fly swappers to support movement/activity during singing.

Vocal exercises (flexibility, vocal tone range (ambitus), phonation, resonance, articulation)

vowels (e.g., A), and voiced and unvoiced fricatives (unpitched and pitched), e.g., in a rhythmic pattern.

- Using artefacts for implementing play/movement while making sounds or spoken/sung phrases.

First step (examples):

- Sirening (freely playing with sounds e.g.: “SING”, “ING”, “NG” – focus on the “NG” sound and ensure tongue and soft palate forming a seal).
- “Crying”: “Cry” vocal quality (e.g.: “Oh dear” – with descending sounding sad/whiney) to encourage optimal vocal fold closure.
- Speaking: “Modal/speech” vocal quality (“uh-oh”, “hey”, “yeah”) to experiment with glottal onset and thicker vocal folds.

Second step (examples):

- Major/minor scales and arpeggios to different vowels – up and down, expanding the tone range.
- Melodic exercises to different sounds such as the vocal sirening, the lipbuzz/liprolled rrr.
- Articulation exercises, e.g. nonsense words/sentences, “tongue twisters”, or call-response vocal games using lots of different consonants.
- Variation in tempo, dynamics, legato/staccato.
- Continuously extending of the phrase length (= prolonging of the outbreath).

Examples of elements/activities:

- Prolonging time of standing up.
- Strengthening posture and endurance (through extending complexity, duration and intensity of exercises, songs, and movement/dancing).
- Varying and extending exercises and songs in speed/tempo, dynamics, legato/staccato, strengthening phonation, articulation, and vocal tone range, flexibility, and strength.
- Prolonging expiration through exercises and sung phrases, improving respiratory muscle strength and co-ordination (inspiration and expiration).

Repertoire:

- Regular unison songs, and simple polyphonic songs, rounds, and circle songs.
- Music from standard Danish song books, supplemented by international (mainly English/American) songs.
- African and/or native songs, children songs, and non-verbal songs.

Physical and vocal stamina

Songs with and without additional movement /dancing



Examples of songbooks:

Sangbogen 1-5 (5 books with a selection of Danish and international songs from different time periods and genres), Edition Wilhelm Hansen, ISBN 9788759808801)[18]

Examples of suitable songs (recognizable to English readers):

- “My Bonnie is over the ocean”

Approach and focus:

- The singing teacher introduced both new and unfamiliar material and familiar material (for example popular songs from the time of participants' youth, e.g. from the 1950-70's).
- Participants were also able to suggest songs to ensure the maximum level of identification, pleasure, and comfort, as well as the experience of relevance, variety in emotional expressions, and acknowledgement of preferences.[11, 15]
- Songs were mostly learned by ear/heart, eventual with text/music sheets on paper for support.
- The singing teacher also focused on musical content and interpretation, and introduced different mood and genres to stimulate various emotions and to enhance social cohesion and a sense of belonging in the class.
- The singing teacher Included as much choreography and movement/dancing as possible, either predefined or participant-invented. Purpose: Both to add an endurance/training aspect, and to underline the social aspect and joy of singing together.
- Artefacts were often included to add elements of play and to support/supplement dancing/movements during singing.

- "Moon river"
- "On the road to Mandalay" (in Danish: "Åh, den vej til Mandalay")
- "The Lion Sleeps Tonight" (in Danish: "Vimmersvej")

Examples of songs with additional movement/dancing

(video clips from search on Youtube):

- <https://www.youtube.com/watch?v=Utr-V7OeJOE> (Source: Efcie Va)
- <https://www.youtube.com/watch?v=wWzQ-Pj4Xt0&list=PLEC531643A4FE480D&index=6> (Source: Vincent Bates)
- <https://www.youtube.com/watch?v=GXqCyp7GUiw> (Source: Vincent Bates)



Example of included artefacts:

Balloons, drum sticks, scarfs, umbrellas, ropes, balls, fly swappers to support/supplement dancing/movement during singing.



Examples of elements/activities:

- Relaxation/body and breathing awareness in the beginning and ending of each session.
- Guided mindful meditation and body "walk-through" (see above).
- Accompanied by calm, slow music (recorded music, played through music equipment) for mindful relaxation and body awareness.



Examples of recorded music:
Chopin - Nocturne op.9 No.2
Pachelbel - Canon In D Major
Yiruma: Kiss The Rain

Item no. 9: Content of any home programme component

- Participants were encouraged to practice exercises and methods from the sessions at home, e.g. breathing techniques, vocal exercises/songs, and body awareness. However, there were no specific requests or programme for this.

Item no. 10: Nonexercise programme

Supplementary *patient education* (part of standard PR):

- Knowledge about COPD (communicated in a considerate manner that did not create unnecessary concern (best practice), behavior change, smoking cessation, correct use of inhaler devices, nutrition, sexuality, handling of stress and anxiety, early recognition of exacerbation, decision-making and taking action of symptoms, goals of motivation and maintenance post PR.

Item no. 11. How adverse events that occur during exercise are documented and managed

- Singing teachers were instructed to seek assistance and contact local health professionals immediately in case of any adverse event (AE). Further, singing teachers and health professionals of the local health-care center were asked to contact the research group in doubt or in case of any AE.
- However, data on AE were not systematically collected for this trial.

WHERE: location

Item no. 12: Setting in which exercises are performed

- Sessions were delivered in a standard, spacious training studio (normally used for PR) in each local health-care center.
- The training studio was in a separate and undisturbed room.

WHEN, HOW MUCH: dosage

Item no. 13: Detailed description of the exercises (e.g. sets, repetitions, duration, intensity)

Overview of intervention:

- In total, 20 sessions, i.e. twice weekly during 10 weeks.
- Each session had a duration of 90 minutes, including a 10-15 minutes break for water/tea/coffee and toilet visit.

Session structure:

- 20 minutes of physical warm ups: posture and breathing exercises
- 20 minutes of vocal warm up's and rhythm and pitch games
- 40 minutes of singing songs
- 10 minutes of cool down (mindfulness or relaxation)

TAILORING: what, how

Item no. 14: Whether exercises are generic (“one size fits all”) or tailored to the individual

- Exercises and songs were generic and suitable for all, however tailored to each class.
- Basic exercises/songs could easily be graduated to meet/challenge all levels of vocal/musical/physical competence.

Exercises and songs were however tailored in relation to following:

If impaired, participants were allowed to:

- Sit more often instead of standing/moving.
- Perform shorter outbreath than other participants.

Competence:

- Each participant was instructed individually in relation to breathing technique, posture, and muscle work/tension/relaxation.
- Participants with any prior musical competence were asked to add advanced elements to songs, e.g. second/extra voice and/or rhythms.

Preferences:

- Singing teachers’ personal taste in repertoire/genres.
- Participants’ personal taste in repertoire.[11, 15]

Item no. 15: Decision rule that determines the starting level for exercise

- No prior exercise or vocal/musical competences were required.
- Individuals with COPD with mMRC<2, and potentially weak/untrained, but able to participate in the rehabilitation programme.
- Since the intervention and background methodology is new in Denmark, all participants were regarded as beginners in relation to singing.

HOW WELL: planned, actual

Item no. 16: Whether the exercise intervention is delivered and performed as planned

- Singing teachers kept a registration of attending frequency by participants.
- Each singing teacher used a logbook of all sessions, reporting of reflective practice as a singing teacher.
- Each singing teacher received supervision throughout by study investigator (MK) at visits twice and telephonic contact to ensure deliverance according to workshop and handout guidelines.
- Singing teachers were encouraged to build peer-network with knowledge-sharing.
- There was no specific and detailed protocol for the intervention. SLH, therefore, was to some extend delivered diversely across the centers, due to variety in singing teachers’ background and personal styles, and to specific composition and dynamics in each class.
- Video recordings and interviews were made at two sites.
- At the end of the intervention period, video interviews were made about the experiences of the singing teacher.
- In case of cancelled sessions due to absence of singing teacher, sessions were conducted by another singing teacher in the project, by a local health professional (singing together with the participants), or cancelled.

Appendix S4: Baseline characteristics in intention-to-treat-population

	Singing for Lung Health (n=145)	Physical Exercise Training (n=125)	Between- group difference (<i>p</i> -value)
Educational level, n (%)			
Low education	55 (37.9%)	48 (38.4%)	0.98
Medium education	56 (38.6%)	49 (39.2%)	
High education	34 (23.4%)	28 (22.4%)	
Occupational status, n (%)			
Full- or part time job	15 (10.3%)	15 (12.0%)	0.70
Unemployed/retired	130 (89.7%)	110 (88.0%)	
Income, n (%)			
Low income	114 (78.6%)	94 (75.2%)	0.39
Medium income	23 (15.9%)	27 (21.6%)	
High income	8 (5.5%)	4 (3.2%)	
Living place, n (%)			
Urban	9 (6.2%)	7 (5.6%)	0.44
Mixed urban-rural	37 (25.5%)	41 (32.8%)	
Rural	99 (61.3%)	77 (61.6%)	
Marital status, n (%)			
Married/co-habiting	84 (57.9%)	82 (65.6%)	0.21
Single/widowed	61 (42.1%)	43 (34.4%)	
Medication, number of all COPD controller drugs, n (%)			
None	20 (13.8%)	15 (12.0%)	0.67
Usage of 1 type of medication	16 (11.0%)	17 (13.6%)	
Usage of 2 types of medication	56 (38.6%)	45 (36.0%)	
Usage of 3 types of medication	47 (32.4%)	46 (36.8%)	
Usage of 4 types of medication	6 (4.1%)	2 (1.6%)	

Table S4 text: Data are presented as mean \pm SD unless otherwise stated. BMI: body mass index; FEV1: forced expiratory volume in 1 second; mMRC: modified Medical Research Council dyspnoea score; GOLD: Global Initiative for Chronic Obstructive Lung Disease; LAMA inhaled long-acting muscarinic antagonists; LABA: inhaled long-acting beta-2-agonists; ICS: inhaled corticosteroids; OCS: oral corticosteroids; COPD: chronic obstructive lung disease.

Appendix S5: Per protocol analyses *i.e.* excluding patients who dropped out before study completion

		Singing for Lung Health (n=108)		Physical Exercise Training (n=87)		Between- group difference (<i>p</i> -value)
Age		70.5	±8.4	69.0	±7.4	0.18
Female sex, n (%)		61	(56.5%)	61	(70.1%)	0.05
BMI		28.3	±5.8	29.9	±6.0	0.05
FEV1 (baseline)		1.2	±0.5	1.2	±0.5	0.92
FEV1 % predicted (baseline)		50.9	±16.0	51.9	±15.6	0.65
Expectations towards benefits of singing	Positive	74	(68.5%)	61	(70.1%)	0.12
Adherence to the intervention	0-24%	0	(0.0%)	2	(2.3%)	0.18
	25-49%	5	(4.6%)	1	(1.1%)	
	50-74%	18	(16.7%)	18	(20.7%)	
	75-100%	85	(78.7%)	66	(75.9%)	
6MWD (at baseline), metres		387.3	±104.7	400.4	±96.3	0.37
6MWD (follow-up), metres		407.3	±97.2	420.6	±101.8	0.37
Change from baseline, metres		17.2	±40.8	20.1	±37.1	0.61
6MWD MID (30m) reached		31	(38.7%)	31	(35.6%)	0.30
FEV1 MID (120ml) reached		27	(25.2%)	17	(19.5%)	0.35
SGRQ total score MID		51	(47.2%)	35	(40.2%)	0.33
FEV1 and SGRQ MID reached		17	(15.7%)	4	(4.6%)	0.01

Appendix S6: Relationship between training modality and accomplishing minimal important difference of 6MWD (30 metres)

Variable	OR	95% CI	P-value
Training modality			
Physical Exercise Training	1.00		
Singing for Lung Health	0.89	0.47 - 1.68	0.711
Age			
-60	1.00		
61-70	0.67	0.24 - 1.93	0.462
71-80	0.45	0.15 - 1.35	0.156
>80	0.25	0.05 - 1.18	0.079
Sex			
Woman	1.00		
Male	0.67	0.33 - 1.34	0.258
Gold class			
1	0.93	0.15 - 5.76	0.940
2	1.00		
3	0.77	0.39 - 1.53	0.450
4	0.28	0.07 - 1.13	0.073
mMRC			
mMRC 0-2	1.16	0.52 - 2.56	0.717
mMRC 2	1.00		
mMRC 3	0.42	0.11 - 1.57	0.196
mMRC 4	1.00	0.38 - 2.64	0.998
BMI			
<18.5	2.71	0.33 - 22.26	0.354
18.5-24.9	1.00		
25-29.9	1.33	0.58 - 3.06	0.497
30 -	1.22	0.53 - 2.82	0.646
Expectations towards benefits of singing			
Neutral or negative	1.00		
Positive	0.86	0.43 - 1.74	0.681
Adherence to training			
0-49%	1.00		
50-74%	6.12	1.50 - 25.07	0.012
75-100%	12.56	3.48 - 45.30	<0.001
6MWD at baseline			
Q1	1.00	Reference	
Q2	0.33	0.12 - 0.86	0.023
Q3	0.37	0.13 - 1.03	0.056
Q4	0.23	0.08 - 0.70	0.010
Site			
Site number (1 - 11)	0.0*	0.0 - 0.0	-

* Constant term from the random-effect. Odds ratios (ORs) were computed using univariable logistic regression and multilevel mixed-effects logistic regression.

Appendix S7: Baseline characteristics and physical performance of patients with high adherence (75% or more) to the interventions

	Singing for Lung Health	Physical Exercise Training	P-value
Baseline characteristics			
N	88	71	
Age, mean (SD)	70.8 (7.8)	70.0 (7.5)	0.48
Sex			
Female	51 (58%)	47 (66%)	0.29
Male	37 (42%)	24 (34%)	
BMI, mean (SD)	27.8 (5.9)	27.8 (5.9)	0.99
FEV1 (baseline), median (IQR)	1.1 (0.9, 1.4)	1.2 (0.9, 1.5)	0.28
FEV1 % predicted (baseline), median (IQR)	49.0 (37.0, 62.0)	51.0 (44.0, 66.0)	0.11
Expectations towards benefits of singing			
Negative	0 (0%)	2 (3%)	0.27
Neutral	26 (30%)	19 (27%)	
Positive	62 (70%)	50 (70%)	
Physical performance			
6MWD at baseline, median (IQR)	406.5 (321.5, 455.5)	419.0 (355.0, 451.0)	0.45
6MWD (follow-up), median (IQR)	427.0 (367.5, 467.0)	438.5 (375.5, 480.0)	0.23
Change from baseline, mean (SD)	16.3 (40.5)	19.1 (36.8)	0.65
MID (30 m) reached	24 (27%)	25 (36%)	0.25

Appendix S8: Factors associated with high adherence (75% or more) to the interventions

Variable	OR	95% CI	P-value
Intervention			
Physical Exercise Training	1.00	Reference	0.41
Singing for Lung Health	1.24	0.74 - 2.08	
Age			
<60 years	1.00	Reference	
61-70 years	1.41	0.63 - 3.16	0.41
71-80 years	2.01	0.89 - 4.56	0.09
>80 years	1.85	0.62 - 5.55	0.27
Sex			
Woman	1.00	Reference	
Male	1.17	0.67 - 2.03	0.58
GOLD class			
1	1.72	0.39 - 7.55	0.47
2	1.00	Reference	
3	1.51	0.85 - 2.68	0.16
4	0.63	0.27 - 1.46	0.28
BMI			
<18.5	0.32	0.05 - 1.91	0.21
18.5-24.9	1.00	Reference	
25-29.9	0.84	0.45 - 1.59	0.59
30 -	1.08	0.56 - 2.06	0.82
Expectations towards benefits of singing			
Neutral or negative	1.00	Reference	
Positive	1.65	0.95 - 2.89	0.08

Odds ratios (ORs) were computed using multivariable logistic regression. ORs > 1 indicate an increased probability of high adherence.

Appendix S9: Baseline characteristics of Per protocol population (“Completers” vs. “Non-completers”)

	Completers (both study groups) (n=195)		Non-completers (both study groups) (n=75)		Between- group difference (p-value)
Age	69.9	±8.0	68.7	±9.5	0.35
Sex (female), n (%)	122	(62.6%)	46	(62.6%)	0.89
BMI	28.2	±5.9	27.1	±6.3	0.23
Educational level, n (%)					0.07
Low education	71	(36.4%)	32	(42.7%)	
Medium education	72	(36.9%)	33	(44.0%)	
High education	34	(23.4%)	28	(22.4%)	
Occupational status, n (%)					1.00
Full- or part time job	22	(11.3%)	8	(10.7%)	
Unemployed/retired	173	(88.7%)	67	(89.3%)	
Income, n (%)					0.08
Low income	143	(73.3%)	65	(86.7%)	
Medium income	42	(21.5%)	8	(10.7%)	
High income	10	(5.1%)	2	(2.7%)	
Living place, n (%)					0.10
Urban	8	(4.1%)	8	(10.7%)	
Medium	60	(30.8%)	18	(24.0%)	
Rural	127	(65.1%)	49	(65.3%)	
Marital status, number, n (%)					0.03
Married/co-habiting	123	(63.1%)	43	(57.3%)	
Single/widowed	72	(36.9%)	32	(42.7%)	
Smoking Status, n (%)					0.004
Current	38	(19.5%)	29	(38.7%)	
Former	144	(73.8%)	41	(54.7%)	
Never	13	(6.7%)	5	(6.7%)	
Pack years	40.5	±16.8	40.5	±22.9	1.00
FEV1 (% of predicted)	51.3	±15.8	51.6	±19.4	0.91
mMRC, n (%)					0.01
0	11	(5.6%)	2	(2.7%)	
1	68	(34.9%)	17	(22.7%)	
2	67	(34.4%)	21	(28.0%)	
3	19	(9.7%)	9	(12.0%)	
4	30	(15.4%)	26	(34.7%)	
GOLD classification, n (%)					0.01
Class 1	5	(2.6%)	4	(5.4%)	
Class 2	97	(50.0%)	37	(50.0%)	
Class 3	76	(24.3%)	18	(39.2%)	
Class 4	16	(8.2%)	15	(20.3%)	
Medication, n (%)					
LAMA	138	(70.8%)	53	(70.7%)	1.00
LABA	148	(75.9%)	61	(81.3%)	0.42
ICS	93	(47.7%)	37	(49.3%)	0.86
OCS	7	(3.6%)	6	(8.0%)	0.20
Roflumilast	0	(0.0%)	1	(1.3%)	0.28
Theophylline	1	(0.5%)	1	(1.3%)	0.48
Medication, number of all COPD controller drugs					0.89
None	27	(13.8%)	8	(10.7%)	
Usage of 1 type of medication	25	(12.8%)	8	(10.7%)	
Usage of 2 types of medication	72	(36.9%)	29	(38.7%)	
Usage of 3 types of medication	66	(33.8%)	27	(36.0%)	
Usage of 4 types of medication	5	(2.6%)	3	(4.0%)	
Home-oxygen therapy, n (%)	7	(3.6%)	2	(2.7%)	0.74

Positive expectations towards benefits of singing, n (%)	135	(69.2%)	44	(58.7%)	0.11
Baseline test performance					
6MWD, metres	393.1	±101.0	352.5	±101.2	0.004
BORG CR 10 - after 6MWD	6.8	±2.7	7.1	±3.1	0.53
St. George's Respiratory Questionnaire (SGRQ)					
Total score	43.2	±16.5	50.1	±17.7	0.004
Symptoms score	46.8	±22.4	52.5	±22.5	0.07
Activity score	62.2	±20.5	71.5	±20.8	0.01
Impact score	31.2	±17.4	37.2	±19.4	0.02
Hospital Anxiety and Depression Scale (HADS)					
Anxiety score	4.8	±3.7	5.1	±3.7	0.65
Depression score	2.9	±2.9	3.8	±3.4	0.03

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