Fixed-intensity exercise tests to measure exertional dyspnoea in chronic heart and lung populations: a systematic review

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Considerable methodological variety of fixed-intensity exercise tests to assess exertional dyspnoea exist. There does not currently appear to be a simple, universal test for measuring exertional dyspnoea in the clinical setting. https://bit.ly/3CkUfp2

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Abstract

Introduction Exertional dyspnoea is the primary diagnostic symptom for chronic cardiopulmonary disease populations. Whilst a number of exercise tests are used, there remains no gold standard clinical measure of exertional dyspnoea. The aim of this review was to comprehensively describe and evaluate all types of fixed-intensity exercise tests used to assess exertional dyspnoea in chronic cardiopulmonary populations and, where possible, report the reliability and responsiveness of the tests.

Methods A systematic search of five electronic databases identified papers that examined 1) fixed-intensity exercise tests and measured exertional dyspnoea, 2) chronic cardiopulmonary populations, 3) exertional dyspnoea reported at isotime or upon completion of fixed-duration exercise tests, and 4) published in English.

Results Searches identified 8785 papers. 123 papers were included, covering exercise tests using a variety of fixed-intensity protocols. Three modes were identified, as follows: 1) cycling (n=87), 2) walking (n=31) and 3) other (step test (n=8) and arm exercise (n=2)). Most studies (98%) were performed on chronic respiratory disease patients. Nearly all studies (88%) used an incremental exercise test. 34% of studies used a fixed duration for the exercise test, with the remaining 66% using an exhaustion protocol recording exertional dyspnoea at isotime. Exertional dyspnoea was measured using the Borg scale (89%). 7% of studies reported reliability. Most studies (72%) examined the change in exertional dyspnoea in response to different interventions.

Conclusion Considerable methodological variety of fixed-intensity exercise tests exists to assess exertional dyspnoea and most test protocols require incremental exercise tests. There does not appear to be a simple, universal test for measuring exertional dyspnoea in the clinical setting.

Introduction

Exertional dyspnoea is the key diagnostic symptom for people with chronic lung and heart disease and is defined as an individual's subjective experience of breathing discomfort that varies in intensity and occurs during exertional activities such as activities of daily living (ADLs) or exercise [1–3]. In clinical settings, exertional dyspnoea is typically assessed by using recall questionnaires or during field-based exercise tests such as the self-paced 6-min walk test (6MWT) where participants self-report dyspnoea on a visual rating scale (*e.g.* the modified Borg scale). Currently, there is no single assessment that encompasses all components of exertional dyspnoea [4] and the symptom remains frequently under-recognised and/or inaccurately assessed [5]. The sole use of questionnaires to quantify exertional dyspnoea, particularly to assess efficacy of interventions, can be inaccurate and unreliable because they 1) are dependent upon patient recall, 2) do not take into consideration activity avoidance behaviour or 3) contain limited questions specifically related to exertional dyspnoea [6–9]. Consequently, an external stimulus (*e.g.* walking or cycling) to induce and therefore assess exertional dyspnoea should be used.

The cardiopulmonary exercise test (CPET), using an incremental protocol to exhaustion, is recognised as the gold standard exercise test for determining the cardiopulmonary aetiology of exertional dyspnoea. The primary outcome of the incremental CPET is exercise capacity, a measure of the stimulus, rather than exertional dyspnoea [7, 10, 11]. Typically, the CPET reports a maximal exertional dyspnoea, which is likely insensitive to longitudinal therapeutic interventions [7, 11–13]. Moreover, CPETs require specialised equipment, are infrequently completed in clinical practice and expertise is required to interpret the data [7]. Field-based walking tests, such as the 6MWT, inconsistently measure exertional dyspnoea as they are not a fixed-intensity challenges but rather patient-controlled exercise capacity tests, whereby participants are able to modify their level of exertion. Like the incremental CPET, exertional dyspnoea is not the primary outcome of the 6MWT; instead, the primary outcome is the 6-min walk distance (6MWD). Hence the 6MWT, like the incremental CPET, is a measure of the stimulus (exercise capacity) rather than the response (exertional dyspnoea).

Most individuals with a cardiopulmonary disease are limited by symptoms during exercise [14] with exertional dyspnoea being the primary complaint. Hence, there remains a clear need to reliably quantify the intensity of exertional dyspnoea during an exercise test. The most recent American Thoracic Society (ATS) and European Respiratory Society (ERS) exercise testing statements [14–16] and others [7, 8, 17] recommend submaximal constant work rate/fixed-intensity exercise tests to measure exertional dyspnoea, particularly when making clinical decisions regarding symptom management [12]. Fixed-intensity exercise tests are typically prescribed at either a relative intensity that is an individualised intensity, such as 75% workload of a maximal exercise test (*i.e.* CPET), or an absolute intensity where all participants complete the same intensity (*i.e.* treadmill walking speed $3\ km \cdot h^{-1}$). In their review of exercise tests to measure exertional dyspnoea, STENDARDI *et al.* [17] noted that the optimal exercise test protocols should use pre-set, fixed-intensity workloads or workloads that improve the accuracy and reliability of exertional dyspnoea measures over time and in response to interventions [6, 7, 11, 12]. However, no single recommended exercise modality (*e.g.* walking, cycling, *etc*.), exercise intensity or exercise duration has been adopted for measuring exertional dyspnoea and the optimal protocol remains unknown.

To date, there has been no critical appraisal of the fixed-intensity exercise testing protocols used to measure exertional dyspnoea in people with chronic lung and heart disease. Hence, this systematic review aimed to comprehensively describe and evaluate all types of fixed-intensity exercise tests used to assess exertional dyspnoea in chronic respiratory and cardiac populations and, where possible, report the reliability and responsiveness of the tests.

Methods

A systematic review was undertaken using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. The review was registered on PROSPERO (ID: CRD42021274504).

Search strategy

The PubMed, CINAHL, Embase, Medline and Cochrane databases were searched from conception to September 2022 (figure 1). The search was completed using the following keyword search strategy: dyspnoea OR breathlessness OR "shortness of breath", AND "perceived exertion" OR "breathlessness scale" OR Borg, AND exercise OR "exercise test" OR "paced test" OR "walk test" OR ergometry. Keyword variations were utilised to ensure diversity of the search strategy (see supplementary table of search terms in appendix A). Two independent reviewers (T.P. and C.R.A.) screened articles initially by title and abstract, then by full text to determine if inclusion criteria were met. Consensus between reviewers was required. A third reviewer (N.R.M.) discussed and resolved disagreements between the two initial reviewers.

After database articles were finalised, an author search was completed through Scopus for additional articles not initially found in database searches. This search was conducted for all lead authors of included articles from the database search and finalised in September 2022. Agreement on all additional articles was completed by T.P. and C.R.A.

Inclusion and exclusion criteria

Articles were included if they 1) were an original manuscript including randomised controlled trials, cross-sectional, cohort or experimental study designs that reported exertional dyspnoea during exercise testing using a fixed-intensity exercise test, with a constant intensity/workload set at either a relative or absolute intensity for fixed-duration or endurance tests, 2) reported exertional dyspnoea scores either at isotime for endurance exercise tests or on completion of a fixed-duration exercise test, 3) examined a sample

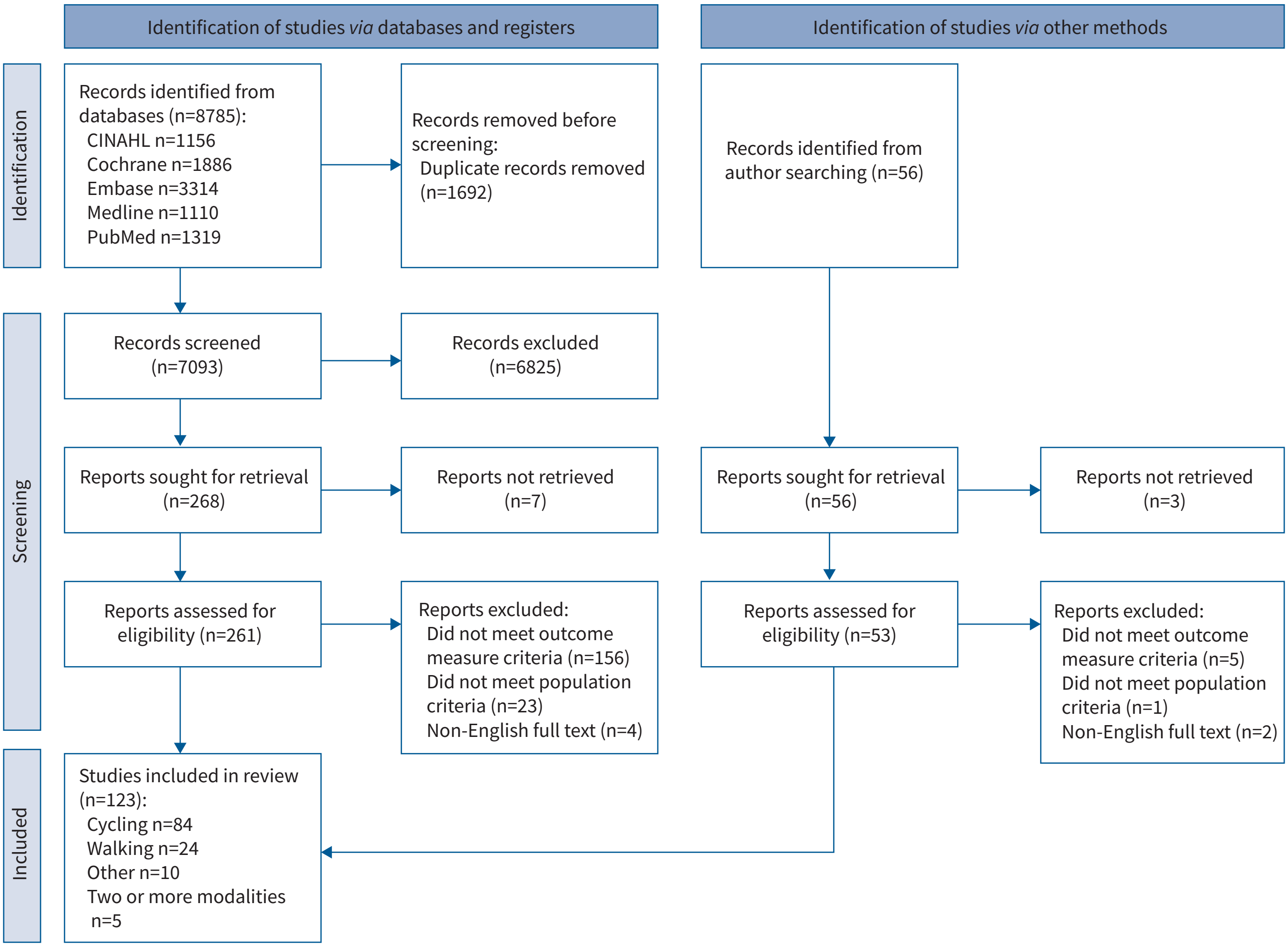

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) diagram of the reporting process.

population of adults with either chronic respiratory or cardiac conditions, and 4) were published as full text in English. Articles were excluded if they 1) were not full-text publications or 2) included an incremental, self-paced or maximal exercise test. Note that isotime refers to when measurements (*i.e.* exertional dyspnoea, heart rate, *etc.*) are taken at a specific time point (*i.e.* at 2 min). Endurance exercise tests exercised participants to exhaustion defined as either "limit of tolerance" or "symptom limitation".

Data extraction and quality assessment

The lead author used a standardised form to extract relevant data from all included articles. Data were categorised based on exercise mode, as follows: 1) cycling; 2) walking, including treadmill and overground walking; and 3) other, which included step tests and upper limb tests. Additional data extracted included the 1) study population, 2) exercise test protocol, including the relative and absolute intensity and workloads, duration of the exercise test and if an incremental maximal exercise test was performed to establish the intensity for the fixed-intensity exercise test, 3) psychometric and clinimetric properties, which included statistical scores for reliability, measurement error and/or responsiveness to an intervention, and 4) patient-reported scale for measuring the level of exertional dyspnoea, including when exertional dyspnoea was reported throughout exercise test (see the supplementary table of results in appendix B). Key exercise protocol data were graphically illustrated in a frequency sunburst plot (figure 2). For studies that reported reliability, measurement error and/or responsiveness, the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) checklist was used to evaluate methodological quality [18]. Using the COSMIN terminology and definitions of measurement properties, articles were rated as very good, adequate, doubtful or inadequate [19].

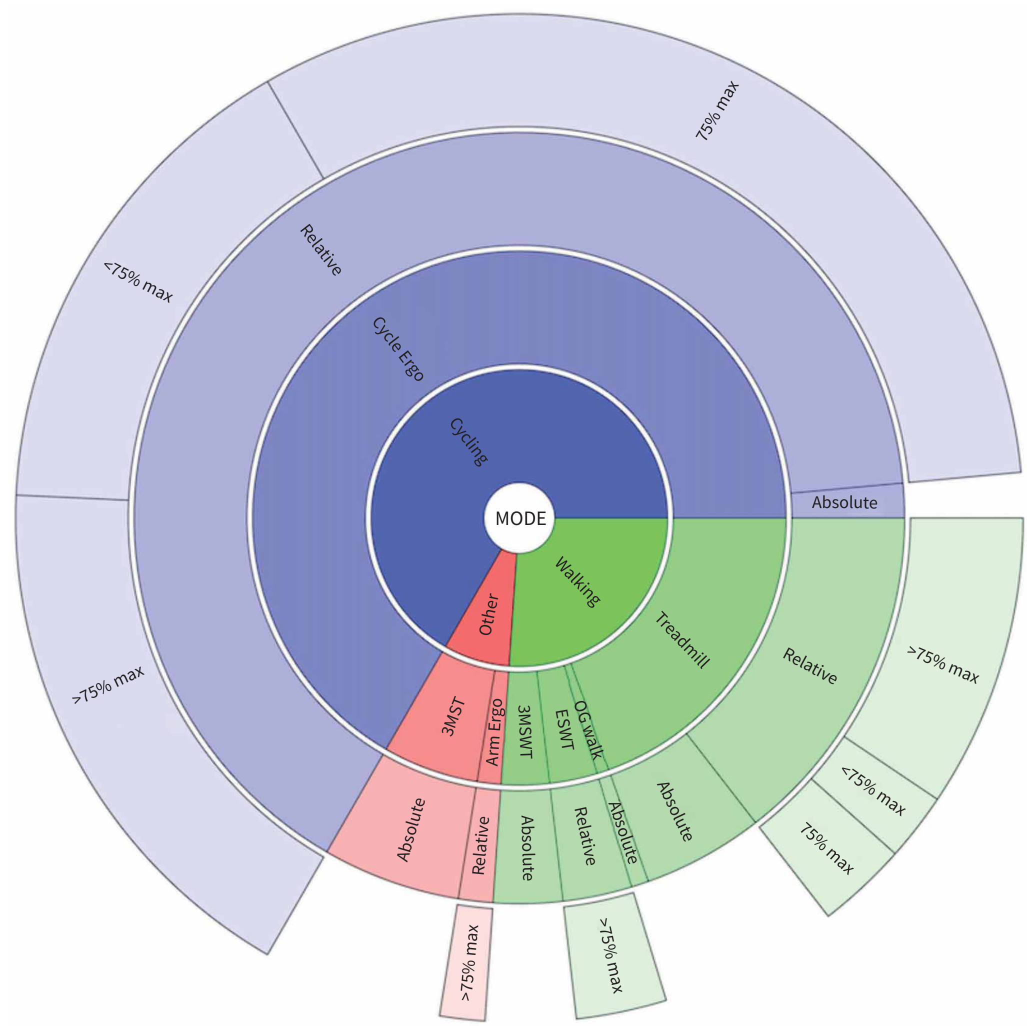

FIGURE 2 Sunburst frequency plot of exercise test protocols. Cycling tests are shown in blue, walking tests are shown in green and other tests (*e.g.* upper limb and step tests) are shown in red. Inner ring: mode of exercise. Second ring: exercise test or ergometer – cycle ergometer, treadmill, overground walking (OG walk), endurance shuttle walk test (ESWT), 3-min shuttle walk test (3MSWT) (includes both the constant speed shuttle walk test and the 3MSWT), 3-min step test (3MST) and arm ergometer (Arm Ergo). Third ring: intensity (relative *versus* absolute). Outer ring: intensity (percentage of maximum) – less than 75% intensity (<75% max), 75% maximum intensity (75% max), greater than 75% maximum intensity (>75% max).

Results

Study selection

The initial electronic search identified 8785 articles. After duplicates were removed and title and abstract screens were completed, 268 articles remained. Of these, 261 full-text articles were retrieved, with 78 deemed eligible for final inclusion (figure 1). An additional 45 eligible articles were identified from the author searches using the Scopus database. A total of 123 articles were then eligible for final inclusion. A summary of the exercise test protocols as a function of the exercise mode (cycling, walking or other) is shown in figure 2 and briefly outlined in table 1. More detailed descriptions of the individual exercise tests used in each study can be found in appendix B. Based on the ATS and ERS recommendations [14–16] for the optimal test for determining exertional dyspnoea, we have summarised our findings for the main types of tests used to determine exertional dyspnoea in table 2. In table 2, the tests are grouped according to the mode of exercise used, *i.e.* cycling, treadmill walking, overground walking or arm ergometry. Three tests were listed separately, namely the Dyspnoea Challenge (a 2-min, fixed-intensity graded treadmill walk test), the 3-min shuttle walk test (3MSWT)/constant speed shuttle test (CSST) and the 3-min step test (3MST), this was because these tests have specifically been designed to assess exertional dyspnoea and follow the ATS and ERS recommendations.

TABLE 1 Summary of exercise tests including psychometric/clinimetric properties

Exercise test	Prior exercise test required	Test protocol (relative or absolute intensity)	Test duration (range)	Populations tested	Psychometric/clinimetric properties		
					Reliability	Measurement error	Responsiveness
Cycling	Incremental cycle CPET	Relative: 30–95% or percentage of ventilatory threshold or HRR Absolute: 20 or 30 Watts	2 min–exhaustion (symptom limited)	COPD/CAL HF ILD CF Acute ischaemic heart disease	COPD: 20 Watts and 50–75% relative intensities – good–excellent reliability		Short-acting bronchodilators# Long-acting bronchodilators# Opioid¶ Cannabis¶ Abdominal binder¶ Exercise training#/¶ Exercise training +mental exercises# Oxygen# Exercise training +ventilation feedback# NIV +/− oxygen#/¶ Weekly encouragement# Chest wall vibrations# Fatigue¶ Facial masks¶ Vitamin C¶ Heliox and oxygen# Exercise training +inspiratory muscle training# Long-acting anti-inflammatory¶ Inspiratory muscle training# CF modulator drug¶ Music# Air pollution¶ Images#
Walking							
Treadmill	Incremental treadmill CPET	Relative: 60–95% or a workload below maximum Absolute: individualised or 2.7 $km \cdot h^{-1}$ with incline 4.3°	5 min–exhaustion (symptom limited)	COPD/CAL HF ILD Stable angina	COPD: 75% relative intensity unclear statistics reported	COPD: 75% relative intensity unclear statistics reported HF: 80% relative intensity VAS and Borg reproducibility coefficients of 38–83%	Long-acting bronchodilators# Beta blockers¶ Dyspnoea scales# PEEP device# Opioid inhibitors#/¶ Bronchoprovocation test¶ Exercise training +heliox, oxygen and breathing retraining# Exercise training +dyspnoea self-management#
2-min graded, constant load treadmill test: Dyspnoea Challenge	6MWT	Absolute: 80% speed of 6MWD and incline set to achieve Borg score >4	2 min	COPD HF	COPD: good–excellent reliability	COPD: LoA NRS score 2.03–2.94	
Overground walking		Absolute: individualised pace		COPD			Music#

Continued

TABLE 1 Continued

Exercise test	Prior exercise test required	Test protocol (relative or absolute intensity)	Test duration (range)	Populations tested	Psychometric/clinimetric properties		
					Reliability	Measurement error	Responsiveness
3-min shuttle walk tests (CSST and 3MSWT)		Absolute: 10-m shuttle walk ($km \cdot h^{-1}$)	3 min	COPD	Excellent reliability		Short-acting bronchodilators[#] Long-acting bronchodilators[#]
ESWT	Incremental shuttle walk test	Relative: 75–85%	Exhaustion (symptom limited or unable to keep up with shuttle timing)	COPD			Long-acting bronchodilators[#] Oxygen[#] TENS[#]
Other							
3MST		Absolute: step rate ($steps \cdot min^{-1}$)	3 min	COPD CF	Excellent reliability	CF: LoA 15-count score −0.5–0.7; Borg: −1.5–1.5 and −4.5–1.3	Short-acting bronchodilator at 14 and 16 $steps \cdot min^{-1}$[#] Intravenous antibiotics[#]
Step test		Absolute: individualised pace	5 min	COPD			
Arm ergometry	Incremental arm ergometry	Relative: 80%	Exhaustion (symptom limited)	COPD			
Unsupported arm exercise	Incremental unsupported arm exercise test	Relative: 80%	Exhaustion (symptom limited)	COPD			

Reliability: intraclass correlation coefficient (ICC) – good (ICC 0.75–0.9) and excellent (ICC >0.9). Measurement error using limits of agreement (LoAs) (mean±1SD or mean±2SD for differences). #: Statistically significant improvement of exertional dyspnoea. ¶: No statistically significant improvement of exertional dyspnoea. 3MST: 3-min step test; 3MSWT: 3-min shuttle walk test; 6MWD: 6-min walk distance; 6MWT: 6-min walk test; CAL: chronic airway limitation; CF: cystic fibrosis; CPET: cardiopulmonary exercise test; CSST: constant speed shuttle test; ESWT: endurance shuttle walk test; HF: heart failure; HRR: heart rate reserve; ILD: interstitial lung disease; NIV: noninvasive ventilation; NRS: numerical rating scale; PEEP: positive end-expiratory pressure; TENS: transcutaneous electrical nerve stimulation; VAS: visual analogue scale.

Exercise mode

Cycling

Cycling was the most common exercise modality used to induce exertional dyspnoea, with 87 (71%) of included articles using this approach [20–106] (figure 2, inner ring: mode of exercise). All cycling studies used cycle ergometers and are more commonly referred to as constant work rate cycle exercise tests (figure 2, second ring: exercise test or ergometer). Five studies compared cycling to other modes of exercise. Two of these studies also assessed participants on a treadmill [52, 106], one article compared cycle, treadmill and arm ergometry [75], and a further two articles compared cycling to the endurance shuttle walk test (ESWT) [62, 63] (figure 2, second ring).

Exercise test protocols

Participants were required to complete an incremental CPET to set the exercise workload in 98% (n=85 of 87) of the cycling studies (figure 2). In 82 (94%) of these studies, the workload was set relative to peak power measured in Watts (W_{peak}) (figure 2, third ring: intensity – relative *versus* absolute), with most using a workload corresponding to 75% W_{peak} (figure 2, outer ring: intensity – percentage of maximum). Other relative intensities ranged from 30 [104] to 95% [91] of W_{peak} (appendix B). The remaining three (4%) articles set the required workloads at 90% of the ventilatory threshold [38], the W_{peak} maintained for 6–8 min throughout the maximal test [87] and 55–65% of the heart rate reserve [36].

Two (2%) articles had participants cycling at a pre-set, fixed absolute intensity, one set at 30 W [49] and the other compared 20 W to a percentage (%) of W_{Peak} [33]. Another article used a target workload of 33% of the predicted W_{Peak} [30].

TABLE 2 Exercise tests used to assess exertional dyspnoea mapped against the American Thoracic Society and European Respiratory Society's recommendations

Exercise test	Cycle ergometry	Treadmill walking tests excluding Dyspnoea Challenge	Dyspnoea Challenge[#]	Overground walking tests excluding 3-min shuttle walk test	3-min shuttle walk test[¶]	3-min step test	Arm ergometry
Primary outcome is exertional dyspnoea	X	X	✓	X	✓	✓	X
Exertional dyspnoea measured spontaneously and at isotime[+]	✓	✓	✓	✓	✓	✓	✓
Exercise test quick and easy with no equipment needed	X	X	! Treadmill required	X	✓	! Step required	X
Pre-exercise testing not required	X	X	X	X	✓	✓	X
Mimics ADLs that initiate dyspnoea, *i.e.* uphill walking, stairs, upper limb exercise, *etc.*	X	✓	✓	✓	✓	✓	✓
Individualised workload[§]	✓	✓	✓	✓	X	X	✓
Workload internally controlled by exercise test protocol[ƒ]	X	✓	✓	X	✓	✓	X
Fixed-intensity exercise test protocol	✓	✓	✓	✓	✓	✓	✓

#: The Dyspnoea Challenge is a 2-min treadmill test with individualised speed set from a 6-min walk test and inclined to achieve a Borg score of 4. ¶: The 3-min shuttle walk test includes the constant speed shuttle test and the 3-min shuttle walk test. +: Isotime is the time point when measurements, *e.g.* exertional dyspnoea, heart rate, are taken (*i.e.* at 2 min). §: Exercise test workload is individualised to each participant. ƒ: Exercise test protocol does not allow the participants to alter the workload, *i.e.* treadmill speed controlled, where cycle ergometers require participants to cycle at repetition but it is not machine controlled. X: exercise test does not meet criteria; ✓: exercise test meets criteria; !: exercise test partially meets criteria (quick and easy test); ADLs: activities of daily living.

Exercise test duration

21 (24%) studies used cycling tests with either a fixed or maximum duration ranging from 2 to 30 min (appendix B). The remaining studies (n=66, 76%) exercised participants to exhaustion defined as either "limit of tolerance" or "symptom limitation".

Population

Most studies examined exertional dyspnoea in chronic lung disease (n=83 of 87, 95%). Of these, the most common condition was COPD (n=78 studies, 90%), followed by interstitial lung disease (ILD) (n=4, 5%) [43, 65, 95, 96] and cystic fibrosis (CF) (n=1) [92]. Of the four studies that included participants with chronic cardiac disease, three (3%) included heart failure [28, 79, 83] and one included acute ischaemic heart disease [36].

Psychometric/clinimetric properties

Five (6%) studies evaluated the test–retest reliability of cycle test protocols [33, 64, 73, 77, 104]. Two studies assessed the reliability of the Borg scale at an isotime during a relative-intensity endurance test. Both studies were rated as "very good" on the COSMIN checklist, with intraclass correlation coefficients (ICCs) ranging from 0.58 [73] to 0.79 [77]. One study [33] reported coefficients for the Borg scale in COPD participants ranging from 0.81 to 0.90 and rated "adequate" on the COSMIN. The remaining two studies [64, 104] were rated "inadequate" due to inadequate reporting of reliability.

No studies evaluated the measurement error of cycle exercise protocols.

69 (75%) studies evaluated the responsiveness of cycling tests to measure changes in exertional dyspnoea. 13 (11%) studies compared exertional dyspnoea between two subgroups with all participants meeting the same inclusion criteria, with the remaining (n=55, 63%) being interventional studies. One study was scored "doubtful" on the COSMIN due to no power calculation or estimation [49]. Seven (8%) studies scored "adequate" and the remaining studies scored "very good" (appendix B). A range of interventions were

used to assess the responsiveness of exercise to detect changes in exertional dyspnoea, with the majority assessing the impact of bronchodilators (n=33, 48%) (appendix B). Some of the other interventions included opioids [22, 50, 65], exercise training [28, 32, 53, 75, 90, 103], noninvasive ventilation [35, 44, 79, 82, 87, 89] and oxygen [31, 48, 66, 80, 86, 89, 96, 98]. The full list and details of the interventions used to assess responsiveness can be seen in the supplementary table of results (appendix B).

Walking tests

Walking tests were used in 31 studies (25%) (figure 2, inner ring). Of these, the majority (n=22, 71%) were on a treadmill [10, 52, 75, 106–122] and the remaining nine (29%) studies used overground walking tests (figure 2, second ring). Of these nine studies, three used the 3-min constant speed shuttle walk test [123–125], four used the ESWT [62, 63, 126, 131], one compared the 3MSWT to the 3MST [127] and one study included an overground paced walking test [128] (figure 2, second ring).

Exercise test protocols

24 of the 31 (77%) studies required a prior exercise test to set the fixed intensity to assess exertional dyspnoea. A variety of prior exercise tests were used, including the incremental CPET (n=18, 75%), the 6MWT (n=2, 8%) and the incremental shuttle walk test (ISWT) (n=4, 17%).

18 of the 22 (82%) articles that used treadmills required participants to complete an incremental CPET to set the exercise intensity [32, 52, 75, 106–109, 112–118, 120, 122, 126, 128]. Of these, 11 (61%) used a percentage of maximum workload [52, 75, 106, 108, 110–113, 117, 121, 126] (figure 2, outer ring) and three (17%) used the workload one level below the maximum workload achieved on the incremental CPET [109, 120, 122]. For the remaining four studies, one reported an individualised speed set at the highest achieved on the incremental CPET and incline set to achieve a 10-min bout at a high intensity of breathlessness [118], one allowed participants to self-select the walking speed then repeat the test at an intensity of 20% and then 40% faster and slower [116], and the remaining two studies had all participants complete the exercise test at an absolute intensity with treadmill speed fixed at 2.7 $km \cdot h^{-1}$ with an incline of 4.3°, which was level four of the incremental CPET completed beforehand (figure 2, third ring) [114, 115].

Of the four studies (18%) that did not complete incremental CPETs, three used a 2-min graded treadmill walking test (the Dyspnoea Challenge), with two of these studies setting the treadmill speed at 80% of the average speed achieved in a 6MWT completed in advance [10, 129] and one study used the same treadmill speed and incline for all participants [130]. The other study set the treadmill speed as the speed required to achieve >5 on the modified Borg scale [119] during flat-level walking.

Four (13%) studies used the ESWT, with all participants completing a prior ISWT from which a relative workload of 75% or 85% of maximal walk speed was set as the fixed intensity for the EWST (figure 2, third and outer rings) [62, 63, 126, 131].

The CSST was used in three studies. Workloads were set at the highest shuttle speed (*e.g.* 2.5, 3.25, 4.0, 5.0 or 6.0 $km \cdot h^{-1}$) the participant could sustain for the full 3 min [123–125]. Another study used the 3MSWT (previous name for the CSST) at speeds of 1.5, 2.5, 4.0 and 6.0 $km \cdot h^{-1}$ [127]. In this study, participants completed the test at all four speeds for a fixed duration of 3 min or until they could not maintain the cadence required or ceased the test due to symptom limitation [127].

Exercise test duration

Fixed exercise test duration was completed in 13 (42%) studies. Durations ranged from 2 min for the Dyspnoea Challenge [10, 129, 130], 3 min for the CSST and 3MSWT studies [123–125, 127] to 5–20 min on treadmill tests [52, 107, 108, 116, 118, 119]. The remaining 18 (58%) studies exercised participants to exhaustion, reported as either the limit of tolerance or symptom limitation.

Population

Most studies (n=27, 87%) examined exertional dyspnoea in chronic lung disease and, of these, all but one (ILD) [116] included participants with COPD (n=26, 84%). Studies in cardiac patients included heart failure (n=3, 10%) [114, 115, 117] and stable angina (n=1, 3%) [121].

Psychometric/clinimetric properties

Two studies evaluated the test–retest reliability of walking test protocols. One study was rated “very good” on the COSMIN checklist with ICCs reported numerical rating scale (NRS) scores of 0.88 and 0.93 for low and high intensities, respectively [10]. The other study scored “inadequate” on the COSMIN checklist due to inadequate reporting of reliability [107].

Three studies evaluated the measurement error of walking exercise protocols. Methodological quality using the COSMIN checklist resulted in scores of "very good" [10], "adequate" [117] and "inadequate" [107], with this study reporting an inadequate statistical method used. AITKEN *et al.* [10] reported limits of agreement (LoAs) (mean±1SD) for the NRS score at high (LoA=−2.03–2.94) and low (LoA=−2.16–2.35) exercise intensities. GRANT *et al.* [117] reported reproducibility coefficients for the visual analogue scale (VAS) and Borg scale at isotime points throughout the endurance test. The coefficients for the VAS and Borg scale at 5 min and 10 min were 83% and 66%, and 48% and 38%, respectively.

In terms of responsiveness, 21 (68%) studies evaluated the impact of interventions on exertional dyspnoea using walking exercise protocols. Studies compared between groups (n=6, 29%) and pre- and post-intervention in all participants (n=15, 71%). The methodological quality of two studies was "adequate" [122, 125] and the remaining (n=19, 90%) studies were "very good" [62, 63, 75, 106, 108–111, 113, 114, 118–121, 123, 124, 126, 128, 131]. Interventions used to assess the changes in exertional dyspnoea varied, with most assessing the impact of bronchodilators (n=9, 43%) [62, 63, 106, 108, 110, 122–125]. Other interventions included opioid inhibitors [113, 118], exercise training [75, 109, 111], heliox [111] and oxygen [111, 131]. The supplementary table of results (appendix B) shows the full list of interventions used to evaluate the responsiveness of walking tests.

Other exercise tests

10 studies (8%) examined exertional dyspnoea using exercise tests that did not involve cycling or treadmill/overground walking [127, 132–140]. Seven studies examined the 3MST [127, 132, 133, 135, 137–139]. One study examined a different step test protocol based on body weight [134] and the remaining two included upper limb tests using either unsupported arm exercise [140] or arm ergometry [136].

Exercise test protocols

The seven studies that completed the 3MST used a variety of step rates to set the exercise intensity. Studies that were completed in the CF population (n=4, 57%) completed the 3MST at a step rate of 30 steps·min^{-1} [132, 137–139]. The other three studies used step rates of 14, 16, 20 and 24 steps·min^{-1} [133], 18, 22, 26 and 32 steps·min^{-1} [127], and 16 steps·min^{-1} [135]. The remaining step test study [134] used a workload of 350 kg·min^{-1}.

Two articles reported upper limb exercise tests [136, 140]. One study used a maximum incremental arm ergometry test and had participants complete a fixed intensity exercise test at 80% of max workload [136]. The other study used an unsupported arm exercise test lifting both arms straight symmetrically and laterally from the side of their body to a 90° angle at a frequency of 30 per minute and workload of 80% of an incremental maximal test using weights [140].

Exercise test duration

Fixed durations of 3 min were completed for the 3MST (n=7, 70%) [127, 132, 133, 135, 137–139] and 5 min for the other step test completed at a workload ventilatory cost of 350 kg·min^{-1} [134]. The upper limb exercise tests were performed until symptom-limited exhaustion [136, 140].

Population

Only chronic lung disease groups were examined using these other tests. Of the 10 studies, six (60%) included participants with COPD [127, 133–136, 140] and four (40%) included participants with CF [132, 137–139].

Psychometric/clinimetric properties

One study evaluated the test–retest reliability of the 3MSWT and 3MST to measure exertional dyspnoea scored using the Borg scale [127]. Methodological quality using the COSMIN checklist was "very good", with an ICC reported for the 3MSWT of 0.91 and for the 3MST of 0.91.

Two studies evaluated the measurement error using LoA (mean±2SD for differences) of the 3MST. One study scored "very good" for methodological quality, with LoAs for the 15-count score being −0.5–0.7 and the Borg score being −1.5–1.5 [139]. The other study was scored "adequate" because it was unclear on patient stability throughout testing [132]. This study reported an LoA for the Borg score of −4.5–1.3.

Two studies evaluated the responsiveness of the 3MST [133, 138]. The methodological quality on the COSMIN checklist of both studies was "very good". One study investigated the impact of short-acting bronchodilators [12], while the other looked at the difference in dyspnoea after 10–14 days of inpatient intravenous antibiotics amongst CF patients [138].

Dyspnoea scales

The most common tool used to evaluate exertional dyspnoea was the Borg scale (n=109, 89%). Two of the 109 (2%) articles used the 6–20 Borg scale version [38, 114], with the remaining 107 (98%) articles using the modified 0–10 Borg scale (appendix B). In total, nine different dyspnoea scales were used to measure exertional dyspnoea, as follows: VAS 0–100 (n=7, 6%) [84, 93, 113, 117, 121, 137, 138]; 0–10 continuous scale (n=3, 2%) where participants rated on a computer or tablet throughout the exercise tests as they felt their dyspnoea was increasing [10, 106, 118]; NRS (n=1) [90]; 15 count score (n=1) [139]; count scale (n=1) [104]; Dyspnoea Index (n=1) [134]; Japanese multidimensional dyspnoea profile questionnaire (n=1) [135]; and a scale −5–+5 (n=1) [87].

Time points of when exertional dyspnoea was collected throughout the exercise tests varied. The most common method was collecting exertional dyspnoea data at the beginning of the exercise test then at regular timepoints throughout, with 1 min (n=45, 37%) and 2 min (n=38, 31%) being the most common repeated timepoints used. 11 (9%) studies collected exertional dyspnoea pre- and post-fixed duration exercise tests, with a further three (2%) only collecting it at the completion of the exercise test. Isotime exertional dyspnoea measures were collected in 11 studies (9%) and seven (6%) collected it continuously throughout using a tablet or computer setup with participants increasing or decreasing the scale throughout the exercise test.

Discussion

The current study is the first systematic review to focus on fixed-intensity exercise tests used to measure exertional dyspnoea. The aim was to identify the type of fixed-intensity exercise tests used to assess exertional dyspnoea in chronic respiratory and cardiac disease populations and report the reliability and responsiveness of the tests. The main findings of this review are that cycle ergometry is the most common mode of exercise used to measure exertional dyspnoea, followed by walking tests. A fixed intensity of 75% W_{Peak} was the most frequently used intensity in cycling, whereas an intensity of >75% peak oxygen uptake was mostly used in treadmill walking tests. Responsiveness was the most frequent psychometric/clinimetric property reported following the assessment of interventions, of which the most popular intervention was bronchodilators. Despite 123 articles being eligible for review, there was considerable heterogeneity in test design preventing consensus on identifying the optimal exercise modality or test protocol for measuring exertional dyspnoea in chronic heart and lung disease populations. Three tests stood out, namely the 2-min graded treadmill test (Dyspnoea Challenge), the 3MSWT and the 3MST; this was because these tests have specifically been designed to assess exertional dyspnoea in the clinical setting and follow the ATS and ERS recommendations.

Exercise test protocols

In this review, approximately 96% of all exercise tests used to measure exertional dyspnoea used either cycling (71%) or walking (25%). These exercise modes are consistent with the exercise testing guidelines for assessing exertional dyspnoea from the ATS and the ERS [14–16] that recommend using exercise modes that engage a relatively large muscle mass (table 2). The predominant use of cycle ergometry for exercise testing may be because it is reliable when measuring complex physiological and metabolic parameters, easier to standardise workloads, nonweightbearing, and safe for most patients [17, 141–144]. As highlighted in table 2, the use of cycling exercise tests found in this review were limited to laboratory settings, which might limit its translation into clinical practice and the requirement for an incremental CPET to set the target submaximal exercise intensity. Incremental CPETs require specialist staff and equipment, limiting their use in many clinical settings [11, 14–16].

Walking tests were the second most common mode used with an array of different protocols being employed. Like cycling, a prior incremental CPET was required to standardise the target workload in 82% of the treadmill tests examined, which again limits the broad clinical applicability of these tests (table 2). As highlighted in table 2, two walking exercise tests (the Dyspnoea Challenge and the 3MSWT/CSST) meet the majority of the ERS and ATS recommendations. Both tests can be easily completed quickly in the clinical setting and have demonstrated reliability within the cardiopulmonary disease populations.

Arm ergometry and unloaded arm exercise tests comprised only a small portion (<2%) of the studies included in the review. Both studies included participants with COPD and reported that exercise testing was limited by arm fatigue rather than exertional dyspnoea. In line with the ATS and ERS recommendations (see table 2) for assessing exertional dyspnoea, unsupported upper limb exercise better mimics ADLs than supported upper limb exercises [136]. We note that the upper limb exercise tests used to assess exertional dyspnoea are more commonly used in oncology and palliative care populations [145–147]. As the current review focused on cardiopulmonary diseases, these populations were outside the scope of this manuscript.

The ERS and others have noted that exercise tests used to assess exertional dyspnoea should mimic ADLs (*i.e.* walking up hills and stairs) that typically induce exertional dyspnoea in patients with chronic cardiopulmonary diseases [16, 127, 141, 148] (see table 2). Activities that mimic ADLs reflect the subjective nature of reporting dyspnoea and the emotional response linked to dyspnoea-provoking activities [3, 7, 8, 149]. Therefore, it is surprising that cycle ergometry is so widely used as cycling does not mimic typical ADLs; however, in laboratory-based exercise testing the use of cycle ergometry is easily accessible and includes safe and well-controlled protocols. Indeed, we found that only 38 (31%) of the 123 studies examined exercise tests that mimic ADLs (table 2): treadmill tests with an incline (hills) (n=20), overground walking tests (n=9), step tests (stairs) (n=8) and unsupported upper limb tests (n=1).

While there is currently no consensus on the optimal fixed exercise intensity for tests to measure exertional dyspnoea, higher-intensity protocols appear to be the most popular, with 78% (n=96) of the included studies using a workload ranging 50–80% W_{peak}. Furthermore, 89% of protocols included in the review used an incremental exercise test (a CPET or an ISWT) to set the target exercise intensity (figure 2). In contrast, other tests (3MSWT/CSST and 3MST) do not require exercise testing, but rather require participants to complete multiple fixed-duration tests at various work rates. These protocols have been created to elicit a dyspnoea score within the mid-range of the scale used (*e.g.* modified Borg score ⩾4), which allows these tests to be used to detect measurable changes in exertional dyspnoea with treatment [15, 123–125]. Borel *et al.* [12] outlined the need for the 3MSWT/CSST and the 3MST to have algorithms to calculate walk speed and step rate rather than having to complete repeated tests at different speeds/rates. Notably, the Dyspnoea Challenge appears to require the completion of 6MWTs to fix the treadmill walking speed; however, the 6MWT is a common, simple test that does not require specialised equipment for interpretation. Therefore, the Dyspnoea Challenge may potentially be more practical to implement in the clinical setting and mimics an exertional dyspnoea inducing activity (*i.e.* uphill walking) over a short duration.

Exercise test duration

Our review found no consistency on the duration of a test to determine exertional dyspnoea. More than 70% (n=86) of studies completed endurance tests with exertional dyspnoea measured at a fixed isotime. The ATS and ERS statements [14, 16] outline that isotime exertional dyspnoea comparisons are the most robust approach for comparing intervention effects during exercise tests. Endurance exercise tests are not solely designed to assess exertional dyspnoea and are more commonly used to determine exercise capacity. If end-exercise dyspnoea was the only dyspnoea recorded in these endurance tests, then the measure of exertional dyspnoea will be more reflective of the maximal values obtained during an incremental CPET [14–16]. The ERS statement [16] has recommended that workloads used in endurance exercise tests must be high enough that patients reach exhaustion within 180–480 s. As outlined in table 2, very few tests found in this review were short in duration. A limitation of endurance exercise tests without isotime exertional dyspnoea measurements is that patients can limit the intensity of symptoms (*i.e.* dyspnoea) by prematurely terminating the test. Whilst the 6MWT is of fixed duration, the fact that walking speed (and hence 6MWD) may change with a therapeutic intervention or disease progression limits the longitudinal validity of exertional dyspnoea measurements obtained at the completion of the 6MWT in any one individual [6–8, 150]. However, there is no consensus on the exact intensity or duration that should be used for exercise tests to assess exertional dyspnoea [12]. Still, it is recommended that short-duration, high-intensity constant load protocols that elicit a mid-range score of exertional dyspnoea (*e.g.* Borg ⩾4) are more responsive to therapy [15].

Dyspnoea scales

The two Borg scales were the most common dyspnoea scales found in this review (n=109) and they are consistently noted across the literature [6, 14, 73, 151, 152], with the modified Borg scale (0–10, n=107) the most predominant. Exercise intensities used to induce exertional dyspnoea were typically set high enough to induce mid-range exertional dyspnoea scores (*e.g.* Borg ⩾4) to allow for improvement and worsening dyspnoea to be detected [153]. For the modified Borg scale, a minimum score of 3–4 is recommended for responsiveness studies to allow for improvement in exertional dyspnoea post-intervention [154], with the minimal clinical important difference (MCID) of the Borg documented to be 1.0 [155].

Psychometric/clinimetric properties

More than 80% of studies investigated psychometric and clinimetric properties of the exertional dyspnoea test. In this review, we used the COSMIN checklist to rate quality, with most studies scoring “good” or “very good” for their methodological quality. Responsiveness was the most frequently examined psychometric property and was reported in 88 studies. Responsiveness was conveyed by self-reported improvements in exertional dyspnoea on the dyspnoea scales. Few studies reported changes relative to the scales MCID; however, most reported exertional dyspnoea improvements of >1.0 on the modified Borg scale or VAS. Only eight studies reported reliability, with three of them, according to the COSMIN checklist, not reporting adequate statistical calculations, *i.e.* ICC, Kappa or linear or quadratic regressions. Perrault *et al*. [127] reported good reliability (ICC=0.75–0.9) for both the 3MSWT/CSST and the 3MST and Aitken *et al*. [10] reported good to excellent reliability of the Dyspnoea Challenge, highlighting that these tests are reliable and could be recommended for use when assessing exertional dyspnoea in the COPD population. Furthermore, these tests fit the ATS and ERS statements [14–16] recommendations that exercise tests used to measure exertional dyspnoea are short in duration, achieve an intensity that elicits a mid-range score of exertional dyspnoea (Borg ⩾4), are reliable, are simple field-based tests that mimic ADLs and do not require an incremental CPET or maximal testing as a pre-requisite.

Limitations

There are a few limitations to this review. Firstly, only full published texts in English were included, with some abstracts that may have been relevant excluded on this basis. Secondly, unless studies reported clearly that they assessed exertional dyspnoea before and after a fixed-duration exercise test or at isotime points throughout endurance fixed-intensity exercise tests, they were excluded. Thirdly, we chose to only include studies that included chronic respiratory and cardiac disease populations. Additional populations found included healthy, obese, oncology and palliative care patients. We chose to focus on the chronic cardiopulmonary disease populations as the aetiology of exertional dyspnoea is a consistently reported symptom in these populations, responsiveness testing of interventions is frequently completed and to limit the size of the current review. Arguably, by excluding the other populations this review could not have captured all exercise tests used to assess exertional breathlessness. The final limitation of this review is that the heterogeneity of the studies we included has limited further analysis of the data and therefore we are unable to make recommendations about the best exercise test/mode to use when assessing exertional dyspnoea.

Recommendations

This review highlights that considerable research has been completed on exertional dyspnoea and its management. However, many of the exercise tests we found in this review were laboratory-based and not field-based exercise tests. Of the field-based exercise tests outlined in this review, the 3MSWT/CSST, the 3MST and the Dyspnoea Challenge showed good reliability and ease of completion within COPD studies and best meet the ATS and ERS recommendations (table 2). Further research should focus on assessing the reliability of these field-based tests in other populations with a primary complaint of exertional dyspnoea, such as chronic cardiac conditions. Also, additional work needs to be completed on these tests regarding efficiency of setting workloads [12], sensitivity and validity to ensure consistency of their exertional dyspnoea results.

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