Modified incremental step test test: testing exercise capacity & exercise prescription

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Background

Pulmonary rehabilitation is a highly effective treatment for people with chronic respiratory disease

✓ COPD  McCarthy *CDSR* 2015, Puhan *CDSR* 2016
✓ Bronchiectasis  Lee *Arch Phys Med Rehabil* 2017
✓ Interstitial lung disease  Dowman *CDSR* 2014
✓ Pulmonary hypertension  Morris *CDSR* 2017
✓ Asthma  Trevor *J Asthma* 2015

Program referral, uptake & completion is a worldwide challenge

Desveaux *COPD* 2015
Alternative service models

e.g. Home-based program [homebaserehab.net]

✓ Clinical equivalence [Holland Thorax 2017]
✓ Cost-effectiveness [Burge Respirology 2020]
✓ Clinical implementation [Bondarenko ERJ Open Res 2020]

Participants need pre-post program assessments
  • Safety prior to commencing exercise program
  • Accurate prescription of exercise intensity
  • Demonstrate effectiveness of the intervention

Participants still need to attend a centre for standard field walking tests
ESSENTIAL COMPONENTS OF PULMONARY REHABILITATION

1. An initial center-based assessment by a health care professional
2. An exercise test at the time of assessment
3. A field exercise test
4. Quality of life measure
5. Dyspnea assessment
6. Nutritional status evaluation
7. Occupational status evaluation
8. Endurance training
9. Resistance training
10. An exercise program that is individually prescribed
11. An exercise program that is individually progressed
12. Team includes a health care professional with experience in exercise prescription and progression
13. Health care professionals are trained to deliver the components of the model that is deployed
Home-based or remote exercise testing in chronic respiratory disease, during the COVID-19 pandemic and beyond: A rapid review

Anne E Holland¹,²,³, Carla Malaguti⁴, Mariana Hoffman¹, Aroub Lahham¹, Angela T Burge¹,²,³, Leona Downman¹,²,³, Anthony K May¹,⁵, Janet Bondarenko¹, Marnie Graco³,⁶, Gabriella Tikellis¹, Joanna YT Lee¹ and Narelle S Cox¹,³

Abstract
Objectives: To identify exercise tests that are suitable for home-based or remote administration in people with chronic lung disease. Methods: Rapid review of studies that reported home-based or remote administration of an exercise test in people with chronic lung disease, and studies reporting their clinimetric (measurement) properties. Results: 84 studies were included. Tests used at home were the 6-minute walk test (6MWT, two studies), sit-to-stand tests (STS, five studies), Timed Up and Go (TUG, 4 studies) and step tests (two studies). Exercise tests administered remotely were the 6MWT (two studies) and step test (one study). Compared to centre-based testing the 6MWT distance was similar when performed outdoors but shorter when performed at home (two studies). The STS, TUG and step tests were feasible, reliable (intraclass correlation coefficients >0.80), valid (concurrent and known groups validity) and moderately responsive to pulmonary rehabilitation (medium effect sizes). These tests elicited less desaturation than the 6MWT, and validated methods to prescribe exercise were not reported. Discussion: The STS, step and TUG tests can be performed at home, but do not accurately document desaturation with walking or allow exercise prescription. Patients at risk of desaturation should be prioritised for centre-based exercise testing when this is available.
Modified incremental step test (MIST)

- Incremental externally-paced test
- Main outcome: number of steps
- Modified version of Chester step test de Carmargo Resp Care 2011, de Andrade Respir Care 2012
  - COPD: reduced commencement rate, modified increment rate
- Reproducible
  - Bronchiectasis Camargo Braz J Phys Ther 2013
  - COPD Dal Corso Respir Med 2013
- COPD: similar responses at peak exercise (CPET, Chester step test)
- Acute respiratory admission: relationship with 6MWD; dyspnoea; FVC; & no adverse events Jose J Cardiopulm Rehabil Prev 2016
- PHT: preliminary work Vieira Respir Physiol Neurobiol 2020
MIST for pulmonary rehabilitation

Home-based exercise testing

Exercise prescription

Aims: home-based exercise testing

➢ To determine the feasibility of conducting home- and centre-based MISTs in people with chronic respiratory disease
➢ To establish the reliability of MIST undertaken in the home environment
➢ To demonstrate responsiveness of the MIST to change in exercise capacity following pulmonary rehabilitation
➢ To identify what represents a meaningful change in the MIST by defining the minimal important difference (MID)
Methods: participants

Inclusion criteria
• Referred to pulmonary rehabilitation
• Stable primary chronic lung disease (COPD, asthma, bronchiectasis)

Exclusion criteria
• Primary diagnosis of ILD, IPF, PHT or lung cancer
• Pulmonary rehabilitation within 18 months (unless admission for exacerbation)
• Unstable or brittle asthma (acute presentation within 3 months)
Methods: MIST procedure

Standardised protocol Dal Corso Respir Med 2013

Digital audio recording dictated stepping rate

As per other field walking tests*

- Two tests
- Continuous monitoring SpO₂ & heart rate
- Borg rating for dyspnoea and perceived exertion

Replicate conditions e.g. upper limb support

Methods: timing

Usual centre-based pulmonary rehabilitation Ax including 6MWT
Methods: timing

random order

BASELINE ASSESSMENT → PULMONARY REHABILITATION → PROGRAM COMPLETION
Methods: feasibility

FEASIBILITY
Frequency of conditions that preclude participation
Methods: reliability

**PULMONARY REHABILITATION BASELINE ASSESSMENT PROGRAM COMPLETION**

- **RELIABILITY**
  - ICC*
  - Standard error of measurement (SEM)
  - Agreement between results in both settings

*Sample size calculation: n=39 to detect an ICC of 0.8 assuming CI lower limit of 0.65
Methods: responsiveness

PULMONARY REHABILITATION BASELINE ASSESSMENT

RESPONSENESS

Effect size
MID Minimal detectable change (MDC_{95})

BASELINE ASSESSMENT \rightarrow PULMONARY REHABILITATION \rightarrow PROGRAM COMPLETION
Results: feasibility

- 245 candidates screened
  - 89 people excluded
    - other lung diseases
- 156 eligible candidates
  - 110 people unable to participate
    - n=32 gait aid
    - n=28 other medical conditions
    - n=24 home environment
    - n=10 history of falls
    - n=9 language
    - n=7 pain
- 46 participants recruited
- 40 participants
- 6 people one baseline test
- 22 participants reassessed
Results: participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Reliability n= 40</th>
<th>Responsiveness n = 22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>72 (9)</td>
<td>72 (11)</td>
</tr>
<tr>
<td>FEV₁, % predicted</td>
<td>61 (23)</td>
<td>62 (19)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>23 (58%)</td>
<td>12 (55%)</td>
</tr>
<tr>
<td>Diagnosis, n</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COPD</td>
<td>31</td>
<td>16</td>
</tr>
<tr>
<td>Asthma</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Bronchiectasis</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Data are mean (SD) unless indicated.
### Results: baseline

<table>
<thead>
<tr>
<th>n=40</th>
<th>Location of MIST</th>
<th>6MWT</th>
<th>Comparisons of tests, MD (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Home-based</td>
<td>Centre-based</td>
<td>6MWT</td>
</tr>
<tr>
<td>Outcome</td>
<td>58 (42) steps</td>
<td>55 (37) steps</td>
<td>434 (117) metres</td>
</tr>
<tr>
<td>Nadir SpO₂, %</td>
<td>89 (5)</td>
<td>89 (5)</td>
<td>88 (7)</td>
</tr>
<tr>
<td>Peak pulse rate, bpm</td>
<td>105 (13)</td>
<td>106 (15)</td>
<td>106 (15)</td>
</tr>
<tr>
<td>Maximum dyspnoea rating, median [IQR]</td>
<td>3 [3 to 4]</td>
<td>3 [3 to 4]</td>
<td>3 [3 to 4]</td>
</tr>
<tr>
<td>Correlation, Pearson</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data are mean (SD) unless indicated.  
bpm = beats per minute; MD = mean difference; RPE = rating of perceived exertion; s₉O₂ = oxyhaemoglobin saturation.
Results: baseline MIST (home vs. centre)

ICC 0.938 (95%CI 0.864 to 0.972)

SEM 3.2 steps
# Results: responsiveness

<table>
<thead>
<tr>
<th></th>
<th>MIST, steps</th>
<th>6MWD, metres</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>62 (41)</td>
<td>442 (113)</td>
</tr>
<tr>
<td><strong>Program completion</strong></td>
<td>75 (51)</td>
<td>472 (109)</td>
</tr>
<tr>
<td>Change following pulmonary rehabilitation, MD (95%CI)</td>
<td>13 (2 to 25)</td>
<td>30 (13 to 46)</td>
</tr>
<tr>
<td><strong>Effect size</strong></td>
<td>0.34</td>
<td>0.27</td>
</tr>
<tr>
<td><strong>MID</strong></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td><strong>MDC_{95}</strong></td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>
Background: exercise prescription

• Pulmonary rehabilitation guidelines
  • Target ≥60% of peak exercise should be used in training programs as the threshold intensity necessary to incite a physiological training response
    Garvey J Cardiopulm Rehabil Prev 2016

• Use of the MIST for exercise prescription
  • Evidence that the intensity achieved during constant rate step exercise training exceeds this threshold and achieves a steady-state response*
    Whipp J Appl Physiol 1972

* minute-to-minute variations in VO₂ <60 mL/min Zainuldin J Cardiopulm Rehabil Prev 2016
Aim: exercise prescription

➢ To investigate whether prescription of intensity for exercise training (based on MIST results) provided a physiological response within the recommended training range
Participants: exercise prescription

Recruited from pulmonary rehabilitation programs at:

- Alfred Health, Melbourne
- Wimmera Base Hospital, Horsham
- Universidade Nove de Julho, Sao Paulo, Brazil

Additional inclusion criteria:

- $SpO_2 > 90\%$ in room air
- No supplemental oxygen on previous exercise tests
- No medications that could affect exercise responses

Sample size calculation: $n = 19$ to detect a relationship between $VO_2$ & RPE ($r = 0.6$, 80% power, $\alpha=0.05$)
Methods: exercise prescription

Monitoring: MetaMax 3B (Cortex; Germany)
- Each minute: pulse rate, SpO$_2$, dyspnoea rating & RPE

MIST
- Peak VO$_2$ = highest 20-sec mean O$_2$ consumption
- Relationship between VO$_2$ & pulse rate, dyspnea rating & RPE used to determine the level at which 60% VO$_2$peak was achieved

Constant rate step training session
- Rate corresponding to MIST 60% peak VO$_2$
  - Externally paced, duration ~ 10 minutes
- Proportion of participants who achieved steady-state exercise intensity of ≥60% VO$_2$peak
## Results: exercise prescription

<table>
<thead>
<tr>
<th></th>
<th>n = 18</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>67 (10)</td>
</tr>
<tr>
<td><strong>FEV&lt;sub&gt;1&lt;/sub&gt;, % predicted</strong></td>
<td>63 (23)</td>
</tr>
<tr>
<td><strong>Female, n (%)</strong></td>
<td>11 (61%)</td>
</tr>
</tbody>
</table>

### Diagnosis, n

- COPD: 12
- Asthma: 4
- Bronchiectasis: 2

![Graph showing pulse rate vs. %VO<sub>2</sub> peak during MIST](image1)

![Graph showing rating of dyspnoea vs. %VO<sub>2</sub> peak during MIST](image2)

![Graph showing rating of perceived exertion vs. %VO<sub>2</sub> peak during MIST](image3)
By minute 4, all participants achieved ≥60% of VO$_2$ peak.

MIST level at which participants achieved 60% of VO$_2$ peak was mean 37% (95% CI 29 to 44).

By minute 4, 17 (94%) participants reached steady-state in VO$_2$.
Discussion

MIST is feasible and reliable in the home environment

• Minimal space requirements
• Not suitable for some participants for a range of reasons

Responsiveness

• Change following pulmonary rehabilitation
• A change of ≥7 steps reflects change in an individual, MID 13 steps

Prescription of exercise intensity

• Limited capacity to use symptoms or pulse rate
• 95% of participants achieved at least 60% of VO$_2$peak at 44% of their final level, and this workload was sustainable over 10 minutes
In people with chronic respiratory disease referred to pulmonary rehabilitation, the MIST is a feasible, reliable and responsive home-based test that can be used to prescribe exercise training capacity
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