EXERCISE TRAINING: EFFECTS ON DYSPNEA AND DYNAMIC HYPERINFLATION

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What can we do ???

COPD
How common is breathlessness with activity? A telephone survey of COPD

*20% breathless sitting or lying still
*24% talking.
*33% doing light housework or getting washed or dressed,
nearly 70% walking up a flight of stairs.

COPD associated with a considerable burden, affecting many things fundamental to everyday life.
Goal of COPD treatment

- Relieve symptoms
- Improve exercise tolerance
- Improve health status
- Prevent and treat exacerbations

- Prevent and treat complications
- Prevent disease progression
- Reduce mortality

Short term

Better living and longer life

Long term

GOLD 2007 updated
Inactivity and mortality in COPD

Very low: mainly sitting work no activity during leisure time
Low: Less than 2h/week light physical activity

Garcia-Aymerich Thorax 2006
Ventilatory Limitation

Dyspnea

Reduction of activity

Deconditioning
Exercise limitation and dyspnea in COPD

(K. Wasserman, 1991)

COPD

- V/Q mismatch
  - $\uparrow V_d/V_T$
  - $\downarrow P_{A}O_2$ $\downarrow$ pH
  - $\uparrow$ ventilatory requirement

- Work of breathing
  - Airflow
  - Obstruction
  - Elastic recoil

- $\downarrow$ Ventilatory capacity

Exercise Limitation (Dyspnea)
JOINT R (chest wall displ)

Golgi (muscle tension)

SPINDLES (muscle displ).

STRETCH R (volume)

AIRWAY R (flow)
IMPAIRED EXERCISE IN COPD

VENTILATION
Reduced ventilatory capacity

LUNG MECHANICS
Expiratory flow limitation
Dynamic hyperinflation
Respiratory muscles inefficiency

BLOOD GASES
Hypoxemia
Impaired peripheral oxygen delivery

PERIPHERAL MUSCLES
Structural changes and disfunction
Lower lactate threshold

ENHANCED SYMPTOMS
Reduced Ventilation in COPD

Two main factors limit exercise performance: the reduced total ventilatory capacity and the increased hyperinflation during effort.

(from Pellegrino R et al. JAP 1999; 87: 1697-1704)
Dynamic Hyperinflation causes inspiratory muscle weakness

- DH alters length tension relationships compromising pressure generation, particularly affecting the diaphragm.
- Tachypnoea during exercise increases the velocity of inspiratory muscle shortening and also contributes to functional weakness.
- In exercise the ratio of effort to the tidal volume response is much higher than in health and this imbalance may be a major contributor to the sensation of dyspnoea.
Dynamic Hyperinflation

Normal

Static Hyperinflation

Dynamic Hyperinflation

Air trapping at rest
Years - Decades

Air trapping from exertion
Seconds - Minutes

TLC | IC | IRV | VT
---|----|----|----
FRC | ERV | RV

Normal

Static Hyperinflation

Dynamic Hyperinflation
Dynamic hyperinflation serves to optimise tidal expiratory flow, but imposes 3 mechanical penalties:

- Breathing at high lung volumes seriously restricts further volume expansion during exercise
- Loads inspiratory muscles
- Causes functional inspiratory weakness

Thus intrathoracic pressure is positive at end-expiration
Impaired exercise in COPD

Peripheral muscle disfunction

muscle metabolism changes ...

✅ reduction in muscle aerobic enzymes and in oxygen uptake kinetics

✅ low lactic acidosis threshold

✅ rapid fall in intramuscular pH
Muscle function in severe COPD

Quadriceps sectional area

Steady State

Strength: 33 %
Endurance: 57 %

Allaire, Thorax, 2004
Debigare, Eur Respir J, 2003

Allaire, Thorax, 2004
Debigare, Eur Respir J, 2003
“…chronic inactivity and muscle deconditioning are important factors in the loss of muscle mass and strength”
Neuro-ventilatory Coupling

Inspiratory effort (Pes%MIP)

Tidal volume (%VC)

COPD

Elastic and resistive load

CONTROLS

Dyspnea
REDUCE DYNAMIC HYPERINFLATION
Effect of therapeutic interventions on exercise-induced Dynamic Hyperinflation (DH)

- **Bronchodilators**
  - (O’Donnell et al. 2004)
  - IC increased by 200 ml
  - Reduced DH

- **LVRS**
  - (Dolmage et al; 2004)
  - IC increased by 250 ml

- **O₂ Suppl**
  - (O’Donnell et al. 2001)
  - IC increased by 250 ml

% Improvement in exercise tolerace

* * p < 0.01
* p < 0.05
Pulmonary Rehabilitation has the potential to affect dynamic hyperinflation

- Breathing exercises
- Exercise training
EXERCISE TRAINING

SOLUTIONS

- REDUCE THE VENTILATORY REQUIREMENT
  - INTERVAL TRAINING
  - REDUCE ACTIVE MUSCLE MASS
  - SUPPLEMENTAL OXYGEN
- INCREASE VENTILATORY CAPACITY
  - RESPIRATORY MUSCLE TRAINING
  - VENTILATORY SUPPORT
  - BRONCHODILATORS

Figure 1. Targets of Exercise Training as Part of a Pulmonary Rehabilitation Program for Patients with COPD.
PRINCIPLES OF TRAINING

1. **High intensity** *(60-85% of max VO\textsubscript{2})*

2. **Frequency** *(daily/weekly)* and duration *(8 weeks and up to 15-20 sessions)*

3. **Specificity** *(muscle mass site and training modality such as strength or endurance)*

**INDIVIDUALIZED PROGRAM** *(patient’s and diagnosis-related characteristics)*

1. A minimum of 20 sessions, 3 x week, 2 supervised
2. High intensity produces greater physiological benefit
3. Interval training may be useful
4. Upper and lower limb extremity training
5. Combination of endurance and strength generally has multiple beneficial effects and is well tolerated

**Endurance training should exceed 60% of maximal work rate**
**Total effective training time should ideally exceed 30 minutes**
**Strength training 2-4 sets, 6-12 repetitions, 50-85% 1RM**
THE WAY TO EXERCISE COPD

- Lower limb exercise (cycling, treadmill, walking)
- Upper limb Training) (Arm ergometer)
- Respiratory muscle training

Protocols:
Endurance training
Strength training

Assessment:
Intensity
Duration
Frequency
ENDURANCE /AEROBIC TRAINING COPD

- Aim: To prolong the exercise duration
- Condition
- To exercise the great muscle group/high intensity

Maughan, Gleeson and Greenhaff, 2007
A well planned, long term aerobic training programme will bring about many changes in our body. Aerobic training produces:

- a stronger, larger heart;
- increased stroke volume;
- slower resting heart rate;
- increased artery size;
- reduced blood pressure;
- greater oxygen carrying capacity;
- more air breathed in;
- more oxygen taken out of the air;
- increased capillary network;
- increased VO₂ max.
STRENGTH TRAINING

Resistance (weights/ multi-gym/dynamometer)
- For each exercise (biceps, triceps, latissimus)
- Assess 1RM (one-repetition maximal)
- 3x10 repetitions of 70% 1RM
- Increment at intervals through the programme
EXERCISE RELIEVES DYSPNEA IN SEVERAL WAYS

- Changes in resting breathing pattern alterations:
  - Reduce frequency
  - Increased expiratory time → Lung deflation
  - Improve static inspiratory muscle strength (at rest)
    - Alter inspiratory capacity

- Resting Inspiration Capacity improved significantly after exercise training by 0.3 L compared with control

Effects of leg aerobic training

(endurance)

### Effects of leg training on HRQoL

* (dyspnea)

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**Review:** Pulmonary rehabilitation for chronic obstructive pulmonary disease

**Comparison:** 03 Rehabilitation vs Usual care

**Outcome:** 04 QoL, CRQ-Dyspnea

<table>
<thead>
<tr>
<th>Study</th>
<th>Rehab N</th>
<th>Mean (SD)</th>
<th>Usual care N</th>
<th>Mean (SD)</th>
<th>Weight (%)</th>
<th>Weighted Mean Difference (Random) 95% CI</th>
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Total (95% CI):

- 277
- 242

Test for heterogeneity chi-square=7.03 df=8 p=0.5331
Test for overall effect=9.09 p<0.00001

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Lacasse et al Cochrane Database of Systematic Reviews. 1, 2006. (Last major update 2001)
Exercise Training Decreases Ventilatory Requirements and Exercise-Induced Hyperinflation at Submaximal Intensities in Patients With COPD
Janos Porzsasz, Margareta Emmner, Shinichi Goto, Attila Somfay, Brian J. Whipp and Richard Casaburi
*Chest* 2005;128:2025-2034
DOI: 10.1378/chest.128.4.2025

**Figure 3.** Changes in IC as a function of time (left, A) and of \( \Delta f \) (right, B) during CWR exercise prior to and after the training program in a representative subject. The dashed arrows connect the isotime values.
Exercise Training Decreases Ventilatory Requirements and Exercise-Induced Hyperinflation at Submaximal Intensities in Patients With COPD

Janos Porszasz, Margareta Emmner, Shinichi Goto, Attila Somfay, Brian J. Whipp
and Richard Casaburi

_Chest_ 2005;128:2025-2034

DOI: 10.1378/chest.128.4.2025

**FIGURE 4.** Training-induced differences (Δ) in VE (left, A), f (center, B), and IC (right, C) at isotime and end-exercise for the CWR test. Error bars indicate ± SE. End-exerc = value at end-exercise; bpm = breaths per minute. *p < 0.05; **p < 0.01.
The effects of training on dynamic hyperinflation in stable chronic obstructive pulmonary disease (COPD)
- 28 subjects with FEV(1) = 42.5 %pred
- 20 matched controls [FEV(1) = 44.9 %pred]

Training consisted of 45 min/day, 4 days/week on a cycle-ergometer for six weeks.

At 5 min,
- EELV decreased 0.1 L and 0.31L and at end of moderate exercise
- EELV decreased by 0.09 L and 0.15 L at the end of high-intensity exercise

Dyspnea also decreased significantly at both exercise intensities.

Exercise training has beneficial effects on respiratory pattern and dynamic hyperinflation that may partially explain the reduction in dyspnea and the improvement in exercise tolerance.
Effect of rehabilitation on lung volumes

Total chest wall volumes

Pre-Rehab

End-inspiration

End-expiration

Post-Rehab

IRV

VT

IC

Volume (L)

Workload (%peak pre)

n=20
Exercise to treat dynamic hyperinflation

Why are patients limited in upper limb activities?

- Postural difficulties
- Severe breathlessness causing habitual use of accessory muscles
- Tension and muscle spasm of trapezius
- Weakness, fatigue
- Cardiovascular limitations

What goals do patients want to achieve using upper limbs
The arm training program (6-week of unsupported arm exercise and arm training with an arm ergometer until 80% of the peak work rate (WR):

- increases arm endurance,
- modulates dynamic hyperinflation,
- and reduces symptoms.
Upper extremity exercise training in COPD demonstrated:

• improvement in upper limb exercise capacity
• reduced ventilation

Unsupported endurance training of the upper extremities is beneficial in patients with COPD and should be included in pulmonary rehabilitation programs. Grade of recommendation, 1A
Inspiratory muscle training in COPD patients: a meta-analysis

Effect on Inspiratory muscle strength

Effect on general exercise capacity

(from Lotters F. et al. ERJ 2002; 20 : 570-576)
Respiratory muscle training

- Lotters et al ERJ 2002; 20:570
  Effects of controlled inspiratory muscle training in patients with COPD. A meta-analysis

  - The scientific evidence does not support the routine use of inspiratory muscle training as an essential component of pulmonary rehabilitation.
  Australian Journal of Physiotherapy 50: 169–180

- Conclusions:
  IMT improves respiratory muscle strength and dyspnoea
  No clear effect on general exercise performance

ACCP/AACVR Guidelines 2007
Respiratory muscle training was once common, but it is now known that even with improvement of respiratory muscle strength, functional capacity usually does not improve.
Non-pharmacological treatment for chronic obstructive pulmonary disease

Enrico Clini¹, Stefania Costi², Silvano Lodi², Giuseppina Rossi¹

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SCP – Smoking Cessation Program; LTOT – Long Term Oxygen Therapy; NPPV – Noninvasive Positive Pressure Ventilation; Surgery – includes Bullectomy, Lung Volume Reduction Surgery (LVRS) and Lung Transplantation;

- - do not consider;
+ - to be considered;
++ - moderately recommended;
+++ - highly recommended;
* in patients with coexisting chronic hypoxia;
** in patients with coexisting chronic respiratory failure and hypercapnia