Advances in Pulmonary Rehabilitation: Peripheral and Respiratory Muscle Adaptations

Monday 4th June from 12:30-14:00

Dina Brooks, Darlene Reid, Richard Debiguare, Rik Gosselink

Objectives

- to appreciate the clinical consequences of peripheral and respiratory muscle dysfunction in COPD
- to realize the beneficial effects of inspiratory muscle training and pulmonary rehabilitation this population.

Definition of COPD

- A respiratory disorder largely caused by smoking, which is characterized by progressive, partially reversible airway obstruction, systematic manifestations and increasing frequency and severity of exacerbations.
- 2 main types: emphysema and chronic bronchitis

Common Signs and Symptoms of COPD

Physical

- Shortness of breath
- Physical deconditioning
- Fatigue
- Chronic cough
- Repeated respiratory infections

Psychosocial

- Depression
- Anxiety
- Social isolation
- Decreased perception of control
- loneliness

Prevalence

- 1/5 smokers develop COPD
- 6% of men; 1-3% of women
- Prevalence underestimated by 50%
- >55 years of age: 10-15% have COPD
- Fourth leading cause of death

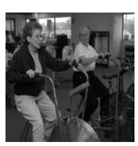
Pulmonary Rehabilitation

- "… is an evidence based multidisciplinary and comprehensive intervention for patients with chronic respiratory disease who are symptomatic and often have decreased daily life activities."

(ATS/ERS statement on PR, 2006)

Pulmonary Rehabilitation

- "Integrated into the individualized treatment of the patient, PR is designed to reduce symptoms, optimize functional status, increase participation, and reduce health care cost through stabilizing or reversing manifestations of the disease". (ATS/ERS statement on PR, 2006)



Pulmonary Rehabilitation Programs

Spectrum of strategies integrated into lifelong management to address primary and secondary impairments

- Patient Assessment
- Exercise training
- Education
- Psychological support

Training, Fatigue, and Injury of the Inspiratory Muscles in COPD

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Acknowledgements

IMT Systematic Review
Lynne Geddes
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Dr. Jeremy Road
Dr. Mark Elliot

Vancouver Foundation
University of British Columbia
The Lung Association
Ontario Respiratory Care Society
Ontario Lung Association

Outline of Presentation

- Systematic Review on IMT
- Diaphragm injury in People
- How to prescribe inspiratory muscle training

Clinical Relevance of Inspiratory muscle training (IMT)

COPD:

- Is common and results in
  - significant morbidity and mortality
  - decreased functional capacity and quality of life
  - Weak, injured, or fatigued inspiratory muscles
- Training will potentially reverse some muscle weakness of peripheral and inspiratory muscles
- Inspiratory muscle training may decrease dyspnea and increase exercise tolerance

Evidence supporting IMT

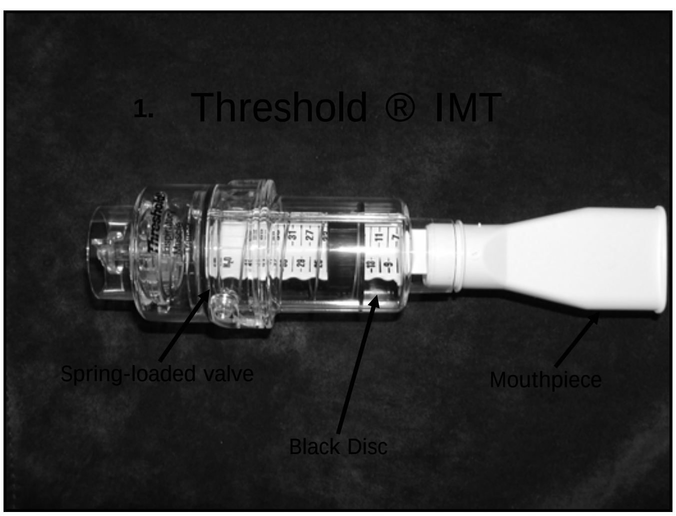
Systematic Review:

- 274 retrieved
- 16 met inclusion criteria that compared IMT with ‘sham’
  - 10 used targeted/threshold IMT
  - 6 used ‘other’ IMT without target

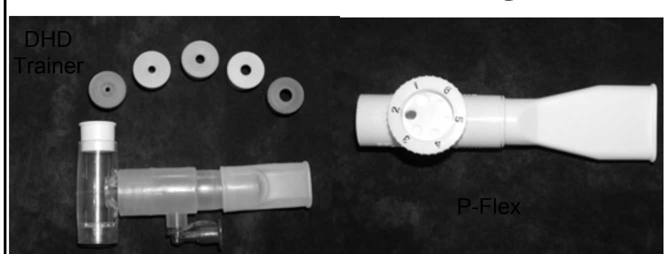
Geddes EL, Reid WD, Crowe J, O'Brien K, Brooks D. IMT in COPD: A systematic review. *Respir Med.* 2005;99:1440-1458

Categorized Types of Inspiratory Muscle Training (IMT)

1. Threshold ® device (Respironics HealthScan)
   or
   IMT device with a ***target*** e.g. Incentive spirometer with P-Flex inline
2. DHD Trainer or P-Flex ***without target***



2. IMT with no Target



- While breathing against the resistive trainer, patients can slow their breathing and thus, do not have to breathe as hard to train using this device.

Estimate of Inspiratory Muscle Force

Maximal Inspiratory Pressure

abbreviated as

Pi_{max} or MIP

- Measured at standard lung volume
- Usually at RV unless FRC can be reliably determined.

Inspiratory Threshold Loading

- ❑ Every 2-3 minutes, a weight is added imposing a higher inspiratory threshold load.
- ❑ The person breathes against progressively greater loads until they can no longer continue.

Results of Systematic Review– Targeted/thresho IMT vs Sham

Meta-analyses results (weighted mean difference):

1. **Inspiratory muscle strength**
   – PI_{max} improved by 12.3 cm H_2O
   – PI_{max} % predicted improved by 27.23%

2. **Inspiratory muscle endurance**
   – Inspiratory threshold loading improved by 10 cmH_20 (1.0 kPa).

Targeted/threshold IMT vs Sham

Meta-analyses Results (weighted mean difference):

3. **Exercise capacity**
   – Borg score for effort decreased by 2.3
   – Max work rate increased by 13.75 W
4. **Dyspnea**
   – TDI increased by 3.4
5. **Quality of Life** - 2/10 studies
   – Improvement in CRQ (Sanchez Riera et al 2001)
   – No change in Profile of Mood States, Sickness Impact Pro or Health Perceptions Questionnaire
   (Larson et al 1988)

Results - IMT with no Target

- Most studies (4/6) showed no improvements
- Only one study showed improved dyspnea and increased endurance time on cycle ergometer

Summary of Systematic Reviews

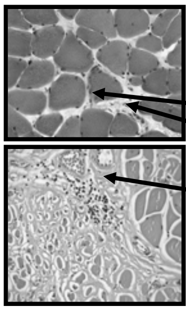
- **IMT is effective** in management of people with COPD
- **IMT must use targeted or threshold** device
- **IMT is under-utilized** in practice
- Lotters F. van Tol B. Kwakkel G. Gosselink R. Effects of controlled inspiratory muscle training in patients with COPD: a meta-analysis. Eur Respir J 2002; 20: 570-6

Can the inspiratory muscles undergo injury?

Exertion- induced Muscle Injury

- usually defined as structural disruption
  - o Light microscope
  - o Electron microscope
- Can manifest as muscle weakness

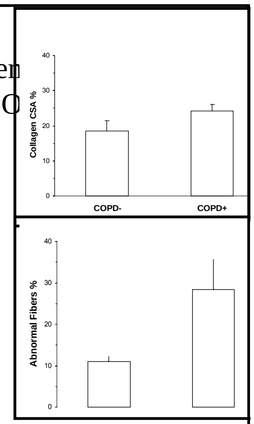
Abnormal Diaphragm Morphology – after thoracotomy and post-mortem



Light Microscope

- disruption of cytoplasm
- nuclearity (inflammation & regenerative cells),
- ↑ connective tissue

Post-morten changes in CO



Greater cross-section area of collagen & more abnormal fibres in costal diaphragm.

Scott, Wang, Road, Reid. *Eur Respir J 2006*

Human Studies

In patients going for thoracotomy

- Some injury and inflammation
- COPD and moreso after inspiratory loading had more sarcomeric disruption.

Post-mortem

- More injury and some people have increased connective tissue

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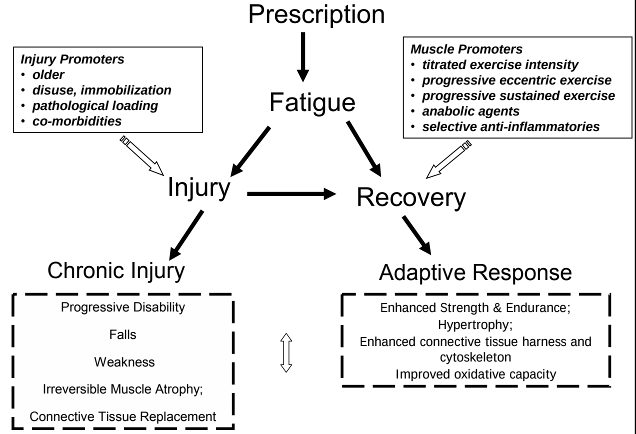
Inspiratory Muscle Exercise Prescription



How to Prescribe IMT

- Patient selection – stable COPD
  - Studies included mostly moderate to severe COPD (some included mild)
  - Not during acute exacerbation
  - Not immediately following exacerbation
  - Extreme caution should be used for those with stable hypercapnic ventilatory failure
  - Lotters – those with MIP less than 60 cmH_20

Training Device

- Targeted – Threshold ® or P-Flex with an incentive spirometer
- Do not use DHD or P-Flex alone (without the IS to provide a target) – user alters breathing pattern and does not get training effect

Frequency

- 30 mins per day (may be in 2-3 sessions)
- 4-6 days per week
- For continued benefit – continue indefinitely!

Intensity of training

- From research studies
  - Generally accepted 40 – 70% PI_{max}
  - Some studies as low as 22% - but subjects were closely supervised
- *Clinical recommendation*
  - begin at 7 cm H_20 and increase no more than 2 cm H_20 per week
- Progress slowly

Outcomes

- Inspiratory muscle
  - Strength - PI_{max}
  - Endurance – incremental test using on threshold trainer
- Dyspnea scale – TDI, Borg
- Exercise capacity – walk test
- Quality of life - CRQ

Precautions/Monitoring

To ensure adequate training protocol	Intensity of Load	Begin at a low % of PI_{max}(< 50%), progress as tolerated. Less than 5% per week to a max 70% PI_{max} according to patient tolerance.
	Mode of Load	Targeted inspiratory resistive or threshold trainer.
	Duration	Begin at low duration as tolerated (≤ 15 min) and progress to 30 minutes per day
	Frequency	4-6 times per wk for endurance effect. 1-2 days rest per week to avoid staleness, fatigue, and muscle injury
	Length of Training	Indefinitely
Signs of exercise intolerance	BP, HR, RR, other signs and symptoms of respiratory distress or inability to tolerate exercise load.	For details of signs of cardiovascular and respiratory distress, see ACSM guidelines.

Precautions/Monitoring

To avoid fatigue	Dis-coordinated chest wall movement	Observation
	Excessive dyspnea during training	Observation; monitoring respiratory rate
	Long-lasting fatigue after training	Interview
To avoid muscle injury	Signs of delayed onset muscle soreness	Interview
	Reduced strength	Reassessment of PI_{max}
	Reduced endurance	Inability to tolerate usual training load intensity and duration
To avoid hypercapnea	End-tidal CO_2	End-tidal CO_2 monitor
	SpO_2	Pulse oximeter
	Signs of headache, confusion	Interview

If possible, should be combined with aerobic & resistance training of the extremities

Summary

- Like other skeletal muscle, inspiratory muscles can be trained.
- People with stable COPD can benefit from IMT.
- IMT is under-utilized by PTs.
- Appropriate parameters (FITT) are needed, including a targeted or threshold device.
- Ideally IMT should be in conjunction with pulmonary rehabilitation.

8/8/2007 37

References

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2. Crowe J, Geddes EL, Brooks D, Reid WD.* **Inspiratory muscle training for individuals with cervical spinal cord injury or chronic obstructive pulmonary disease: a survey of Canadian physical therapists**. *Physiotherapy Canada*. 2006; 58(4):271-278.
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PERIPHERAL MUSCLE ATROPHY DEVELOPMENT IN COPD

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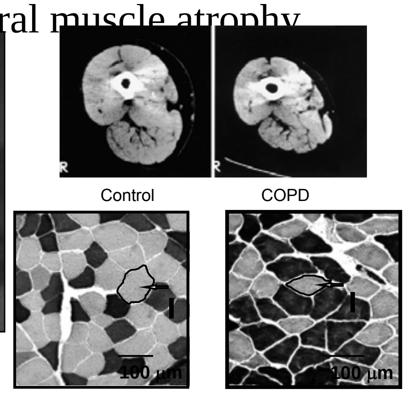
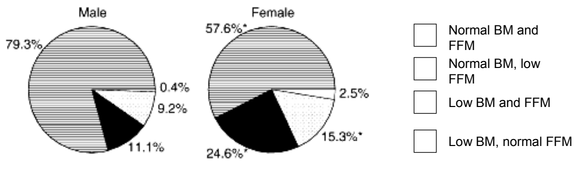
Peripheral muscle atrophy



AJRCCM, 158:629-34;1998
MSSE, 30:1467-74; 1998

Prevalence of muscle atrophy



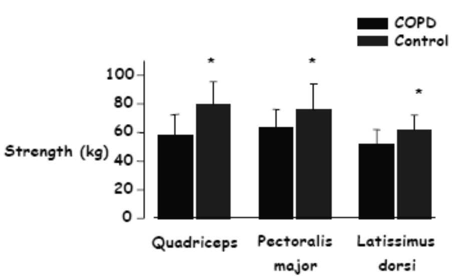
Respir Med, 100: 1349-55; 2006

Impacts on clinical outcomes

- Muscle weakness
- Decreased quality of life
- Lower functional capacity
- Increased mortality risk
- Accentuated inflammation and ROS production after exercise

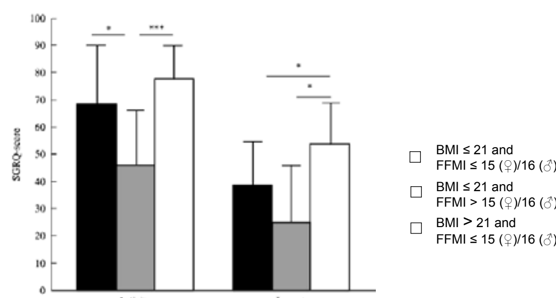
AJRCCM, 158:629-34;1998
Respir Med, 94:859-67; 2000
AJRCCM, 153:976-80; 1996
AJRCCM, 166:809-13; 2002
MSSE, 38:1543-1552; 2006

Muscle weakness



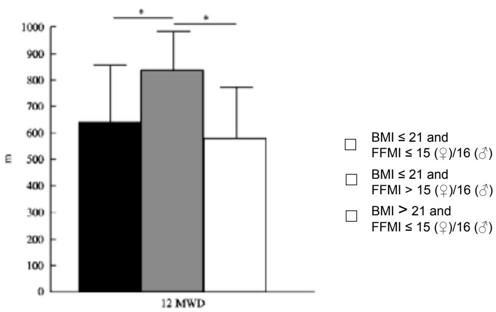
AJRCCM, 158:629-34;1998

Decreased quality of life



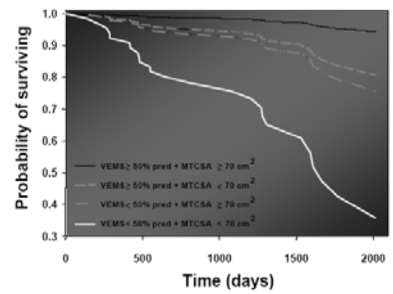
Respir Med, 94:859-67; 2000

Lower functional capacity



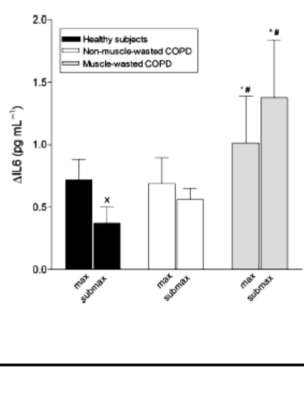
Respir Med, 94:859-67; 2000
AJRCCM, 153:976-80; 1996

Increased mortality risk



AJRCCM, 166:809-13; 2002

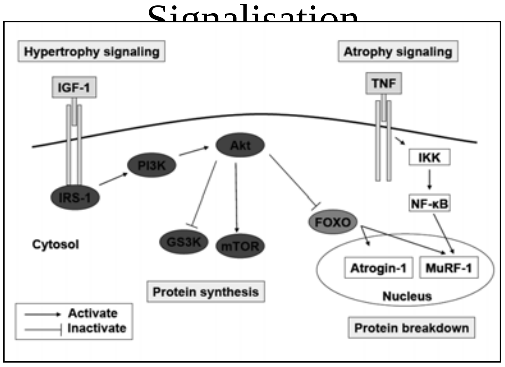
Accentuated inflammation and ROS production after exercise



MSSE, 38:1543-1552; 2006

How muscle atrophy initiates and progresses in patient with COPD?

Signalisation

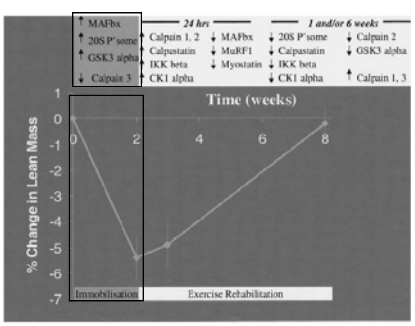


Muscle atrophy initiation

- Inactivity
- Low level of anabolic hormones
- Inflammation
- Oxidative stress
- Hypoxia

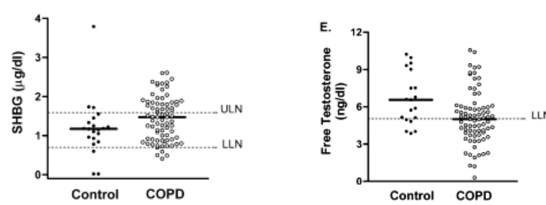
Inactivity

Left leg immobilization in a cast for two weeks.



Faseb J, 18:1025-27; 2004

Low level of anabolic hormones
Testosterone



AJRCCM, 172:1105-11; 2005

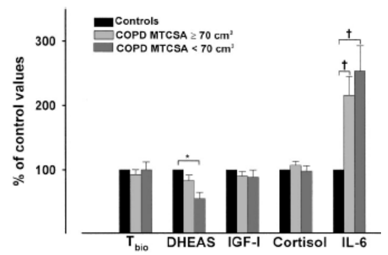
Low level of anabolic hormones Growth hormone/IGF-1

	Controls	ncCOPD	cCOPD
Age, years	54.5 ± 1.4	60.7 ± 1.6	58.0 ± 2.1
BMI, kg/m²	25.2 ± 1.1	25.6 ± 0.7	19.0 ± 0.5*
FEV_1, % pred	106.0 ± 3.2	42 ± 2.2**	30.7 ± 2.3*
GH, μg/ml	383 ± 213	912 ± 158**	1658 ± 412**
IGF-1, ng/ml	132 ± 11	133 ± 9	118 ± 11

*p < 0.05 vs controls and ncCOPD
** p < 0.005 vs controls

Int J Cardiol in press; 2007

Svstemic inflammation



Findings are inconsistent among studies.

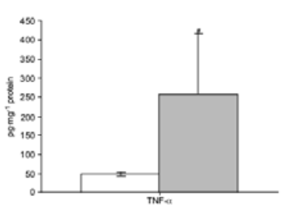
Overall,

- ↑ TNFα
- ↑ IL-8
- ↑ CRP

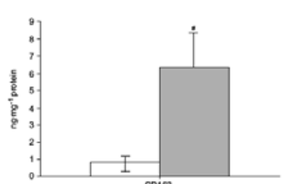
Chest 124:83-89; 2003

Peripheral muscle inflammation

TNFα



Macrophage infiltration



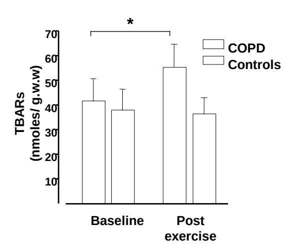
Eur Respir J, 26:390-7; 2005

- Activation of NF-κB has also been reported.

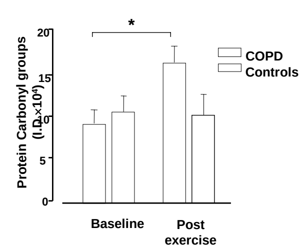
Thorax, 59:483-7; 2004

Systemic oxidative stress

Lipid damage

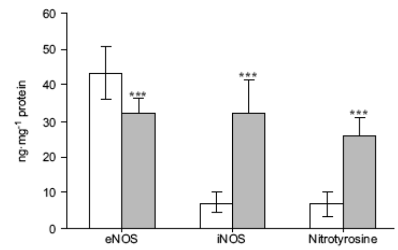


Protein damage



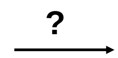
AJRCCM, 167:1664-9; 2003

Peripheral muscle oxidative stress

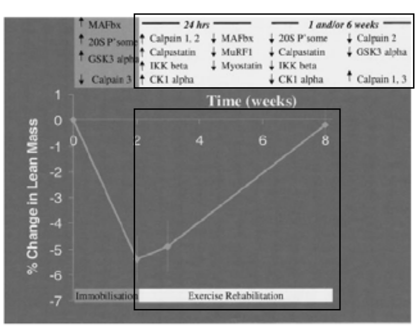


Eur Respir J, 26:390-7; 2005

Is it reversible?



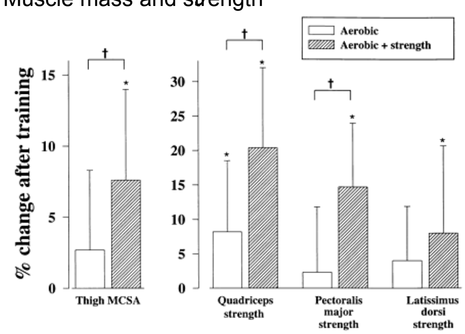
Muscle training



Faseb J, 18:1025-27; 2004

Pulmonary rehabilitation

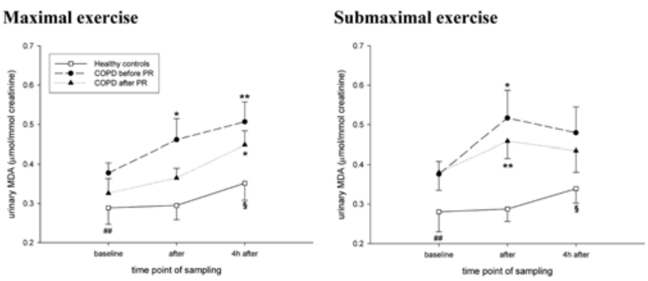
Muscle mass and strength



AJRCCM, 159:896–901; 1999

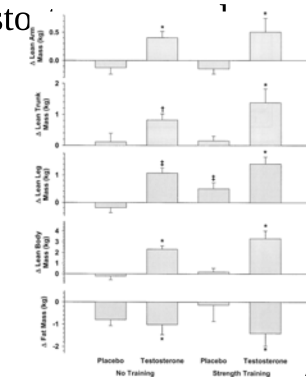
Pulmonary rehabilitation

Oxidative stress



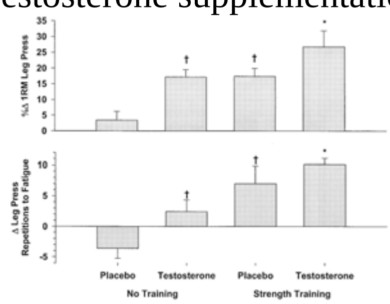
AJRCCM, 172:994–1001;2005

Testo tation



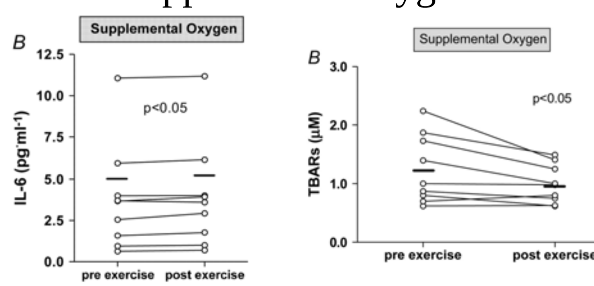
AJRCCM, 170:870–8;2004

Testosterone supplementation



AJRCCM, 170:870–8;2004

Supplemental oxygen



AJRCCM, 173:1122–29;2006

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- Annie Michaud

SUCCESFULL REHABILITATION OF COPD PATIENTS: THE CHALLENGE OF ADJUSTING THE SAILS

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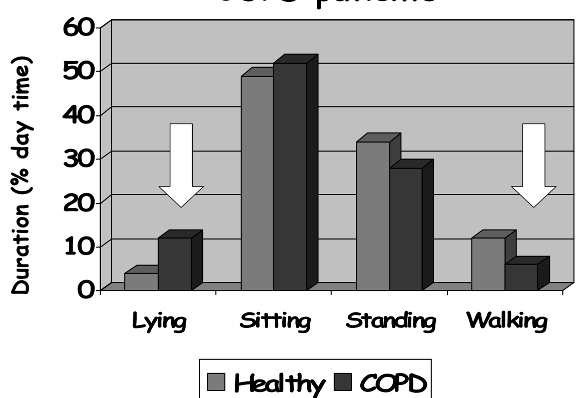
Questions

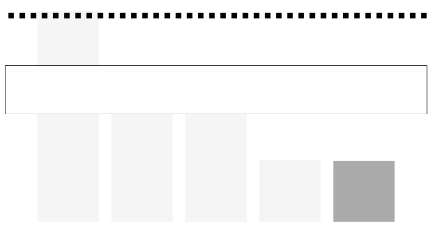
- **Physical activity in COPD patients**
- **Pulmonary rehabilitation:**

  which patient *or* which program?

Characteristics of physical activity in COPD patients

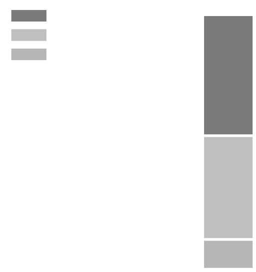


Pitta et al AJRCCM 2005



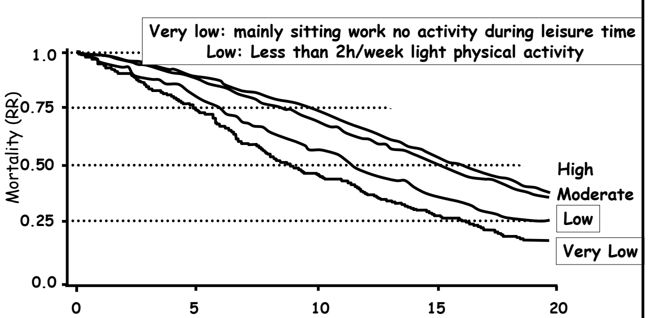
Pitta et al AJRCCM 2005 Langer et al ERS 2006

Active / Passive Time



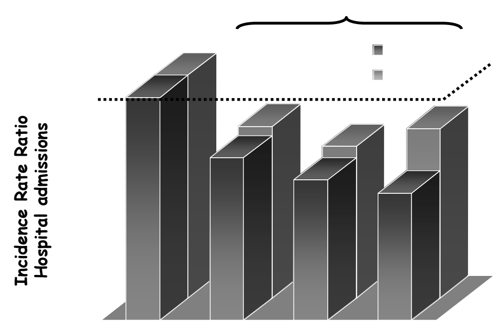
Pitta et al AJRCCM 2005 Langer et al ERS 2006

Inactivity and mortality in COPD



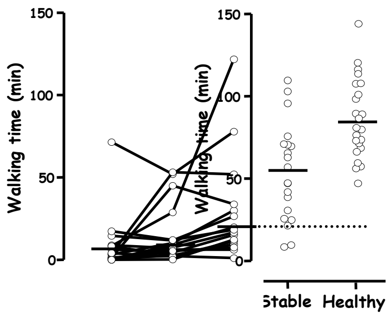
Garcia-Aymerich Thorax 2006

Inactivity and morbidity in COPD



Garcia Aymerich Thorax 2006

Exacerbations and inactivity



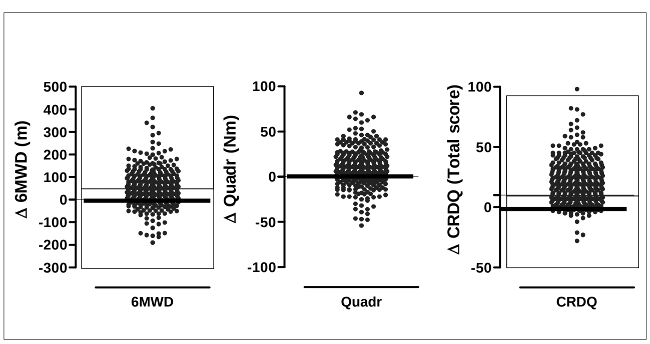
Pitta AJRCCM 2005 & Pitta Chest 2006

Clinical benefits

- ***Maximal Exercise Capacity***
- ***Walking distance - Endurance capacity***
- ***Relief of symptoms (dyspnea and fatigue)***
- ***Quality of life***
- ***Utilization of health care resources***
- ***Mortality ?***

ATS/ERS Statement on Pulmonary Rehabilitation 2006

How successful is pulmonary rehabilitation in individual patients ?



Troosters et al. ERS 2004

Keys for successful pulmonary rehabilitation ?

- **Patient selection**
- **Program components**

I Mild	II Moderate	III Severe	IV very Severe
FEV1/FVC<70% FEV1> 80%	FEV1/FVC<70% 50%<FEV1<80%	FEV1/FVC<70% 30%<FEV1<50%	FEV1/FVC<70% FEV1<30% or Resp. fail.
Avoid risk factors; influenza vaccination			
Short acting bronchodilators PRN			
	ADD 1 or more long acting bronchodilators **ADD Rehabilitation**		
		ADD ICS if repeated exacerb.	
			ADD LTOT Consider surgery

GOLD Guidelines 2006

SELECTION OF CANDIDATES

- **AGE ?**
- **PULMONARY FUNCTION ?**
- **SMOKING ?**
- **CO-MORBIDITY ?**
- **PSYCHOSOCIAL CONDITION?**
- **OTHER: *MUSCLE FORCE, EXERCISE IMPAIRMENT*…….**

NO, but *ADAPT* the PROGRAM!

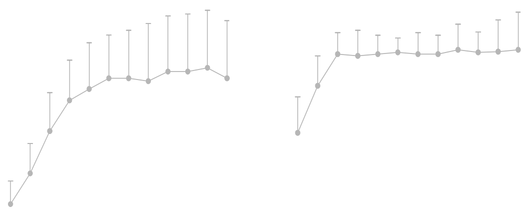
EXERCISE TRAINING: HOW?

GUIDELINES FOR TRAINING

- **INTENSITY: 55 - 90% HRmax or 40 - 85% VO_2max**
- **DURATION: 20 - 60 MIN**
- **FREQUENCY: 3 - 5 TIMES/WEEK**

ACSM Position Stand. Recommended quantity and Quality for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults, Med.Sci.Sports Med. 1998; 30:975-991

TRAINING INTENSITY



Maltais et al, Am.J.Respir.Crit.Care Med., 155, 555-61, 1997

Limitations for high intensity exercise training

- REDUCED VENTILATORY CAPACITY
  - Airflow obstruction
  - Dynamic hyperinflation
  - Respiratory muscle weakness
- INCREASED VENTILATORY REQUIREMENT
  - Early onset lactate accumulation
  - Increased dead space ventilation

SOLUTIONS

- INCREASE VENTILATORY CAPACITY
- REDUCE THE VENTILATORY REQUIREMENT

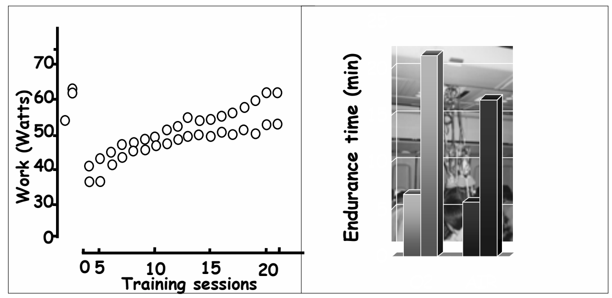
Interval training, a valid option

		Interval (n = 10)	Continuous (n = 9)
FEV_1	% pred	44 ± 6	39 ± 6
$T_{L,CO}$	% pred	51 ± 9	47 ± 8
Wpeak	W	53 ± 9	61 ± 8
Peak VE/MVV	%	88 ± 7	86 ± 6
Change in IC	L	-0.49 ± 0.09	-0.63 ± 0.07

Vogiatzis Chest 2006

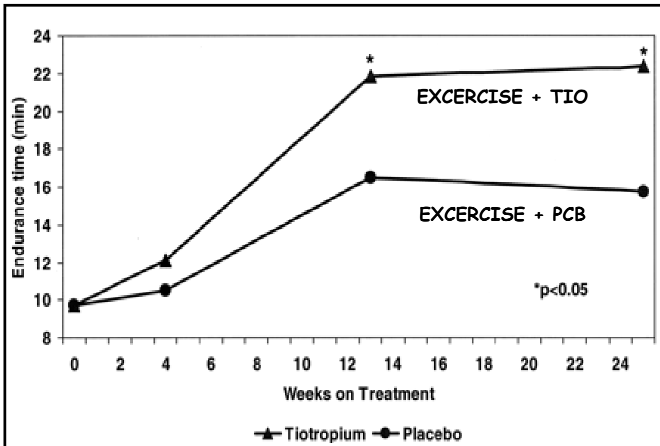
Peripheral muscle electrical stimulation

SUPPLEMENTAL OXYGEN



Δ Work (O2-Air) ≈ Training effect (R=0.50, p<0.01)

Emtner et al. *AJRCCM*: 2003; 168:1034-1042



Casaburi et al. Chest 127: 809, 2005

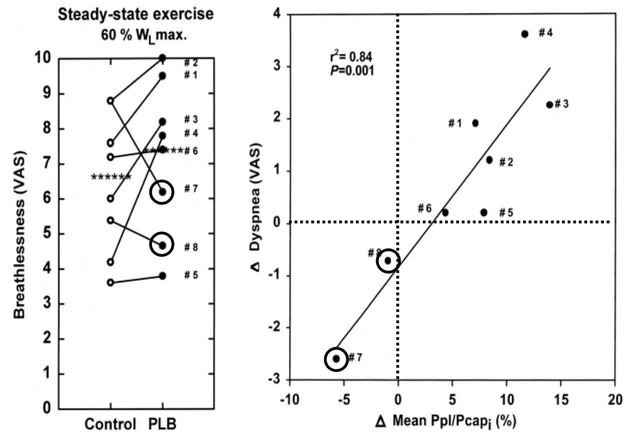
DYNAMIC HYPERINFLATION

- **PURSED LIPS BREATHING**
- ***ACTIVE EXPIRATION***

	PLB walk	Non-PLB walk
End RR (bpm)	20.9	27.2**
Change in RR from pre-exercise to post exercise	1.7	6.6**
Time to recovery (seconds)	189.5	214.5*
ISWT (m)	298.5	292.5
SpO2 postwalk (%)	90.5	90.4
Borg breathlessness score	3.8	4.0
Change in heart rate	18.9	21.3

from pre-exercise to post exercise

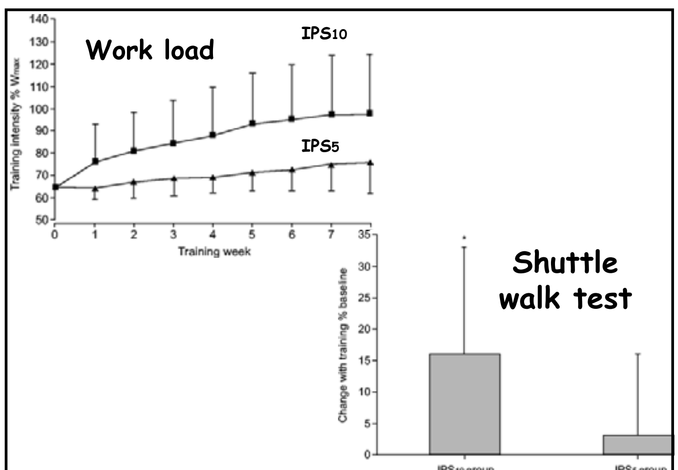
Garrod et al. Chron Resp Dis 2; 67-72, 2005.



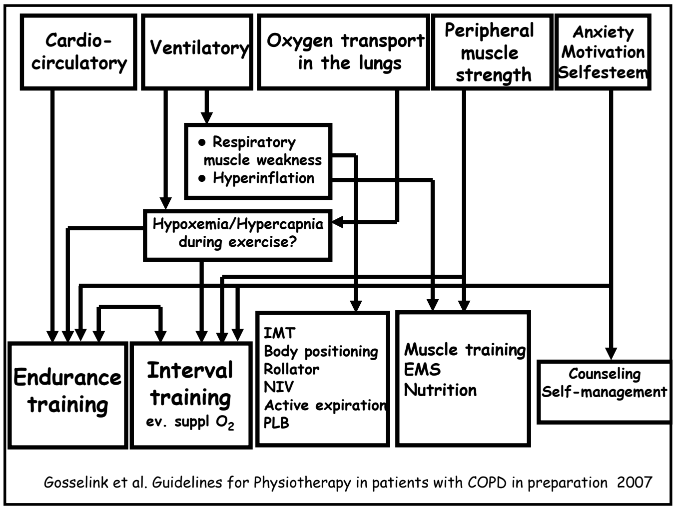
Spahija et al. Chest 2005; 128:640-650.

NON-INVASIVE VENTILATORY SUPPORT

Van 't Hull et al, Eur Respir J, 2006: 27:65-72



Van 't Hul et al, Eur Respir J, 2006: 27:65-72



Gosselink et al. Guidelines for Physiotherapy in patients with COPD in preparation 2007