MAYO
CLINIC

RESPIRATORY MUSCLE DYSFUNCTION IN CHRONIC DISEASE STATES:

CLINICAL IMPORTANCE AND IMPLICATIONS FOR CARDIOPULMONARY REHABILITATION

ISCVPR ANNUAL MEETING
INDIANAPOLIS, IN
THURSDAY APRIL 25TH, 2024

SESSION LEARNING OBJECTIVES

Learning objective 1: Compare different techniques used to assess respiratory muscle function and understand the metrics used to define respiratory muscle dysfunction.

Learning objective 2: Identify the prevalence and clinical importance of respiratory muscle dysfunction in different cardiopulmonary disease states.

Learning objective 3: Evaluate the potential role for specific respiratory muscle training as a rehabilitative strategy in patients undertaking phase II cardiopulmonary rehabilitation.

Learning objective 4: Recognize the practical considerations for including respiratory muscle function assessment and specific inspiratory muscle training in the phase II cardiopulmonary rehabilitation setting.

INSPIRATORY MUSCLE WEAKNESS & DYSFUNCTION:

CLINICAL SIGNIFICANCE & HOW TO MEASURE IT

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NO DISCLOSURES

WHAT IF I SAID…

THE ASSESSMENT OF INSPIRATORY MUSCLE FUNCTION SHOULD BE STANDARD IN ALL PATIENTS ENROLLED IN PHASE II CR OR PR.

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Inspiratory muscle weakness in cardiovascular diseases: Implications for cardiac rehabilitation

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Editorial

Respiratory Muscle Weakness in Patients with Heart Failure: Time to Make It a Standard Clinical Marker and a Need for Novel Therapeutic Interventions?

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Leeds, UK

LEARNING OBJECTIVES

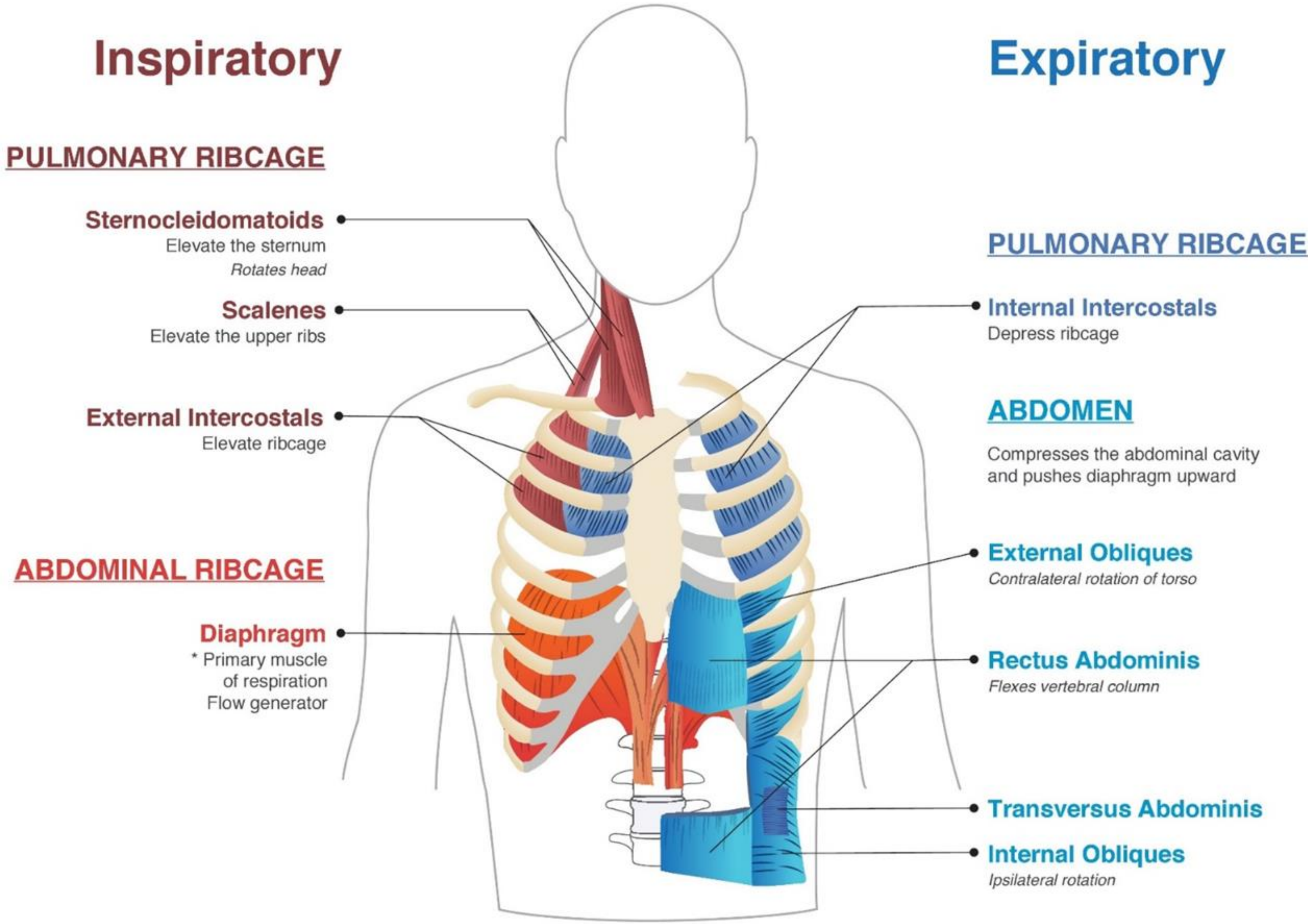
Learning objective 1: Identify the key muscles of breathing; understand their basic structure and function.

Learning objective 2: Define respiratory muscle dysfunction and weakness. Identify the clinical importance of inspiratory muscle dysfunction in different cardiopulmonary disease states.

Learning objective 3: Compare different techniques used to assess inspiratory muscle function and understand the metrics used to define respiratory muscle dysfunction.

1 THE RESPIRATORY MUSCLES

THE RESPIRATORY MUSCLES



Welch *et al*., Curr Opin Physiol, 10 (2019); 102-109

2 INSPIRATORY MUSCLE WEAKNESS & DYSFUNCTION

WEAKNESS & DYSFUNCTION

ANY PROCESS THAT INTERFERES WITH DIAPHRAGMATIC INNERVATION, CONTRACTILE MUSCLE FUNCTION, OR MECHANICAL COUPLING TO THE CHEST WALL.

Aging, sarcopenia

General muscle atrophy, fiber type shift (II → I), contractile protein wasting

Accelerated in CHF, COPD, etc.

Increased oxidative stress, increased proteolysis

Lung hyperinflation

Mechanical weakening of the diaphragm (e.g., COPD)

Paralysis & elevation

Unilateral or bilateral; neurologic or trauma (phrenic nerve)

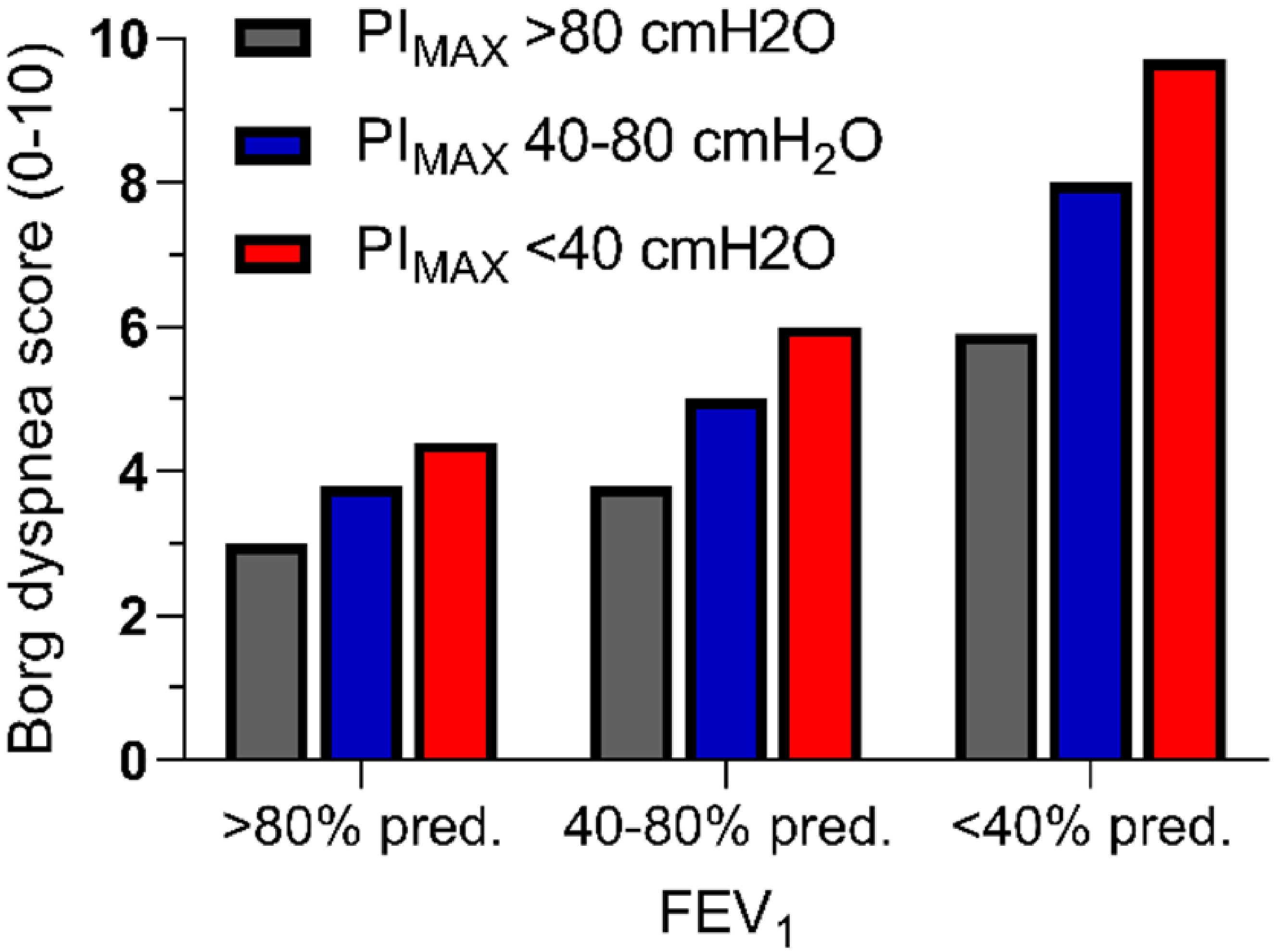
Diaphragm weakness, dysfunction

Decreased muscle mass, contractility (*thickening*), excursion (*motility*)

WHAT IS THE CLINICAL SIGNIFICANCE OF INSPIRATORY MUSCLE WEAKNESS & DYSFUNCTION?

WEAKNESS & DYSFUNCTION: CLINICAL SIGNIFICANCE

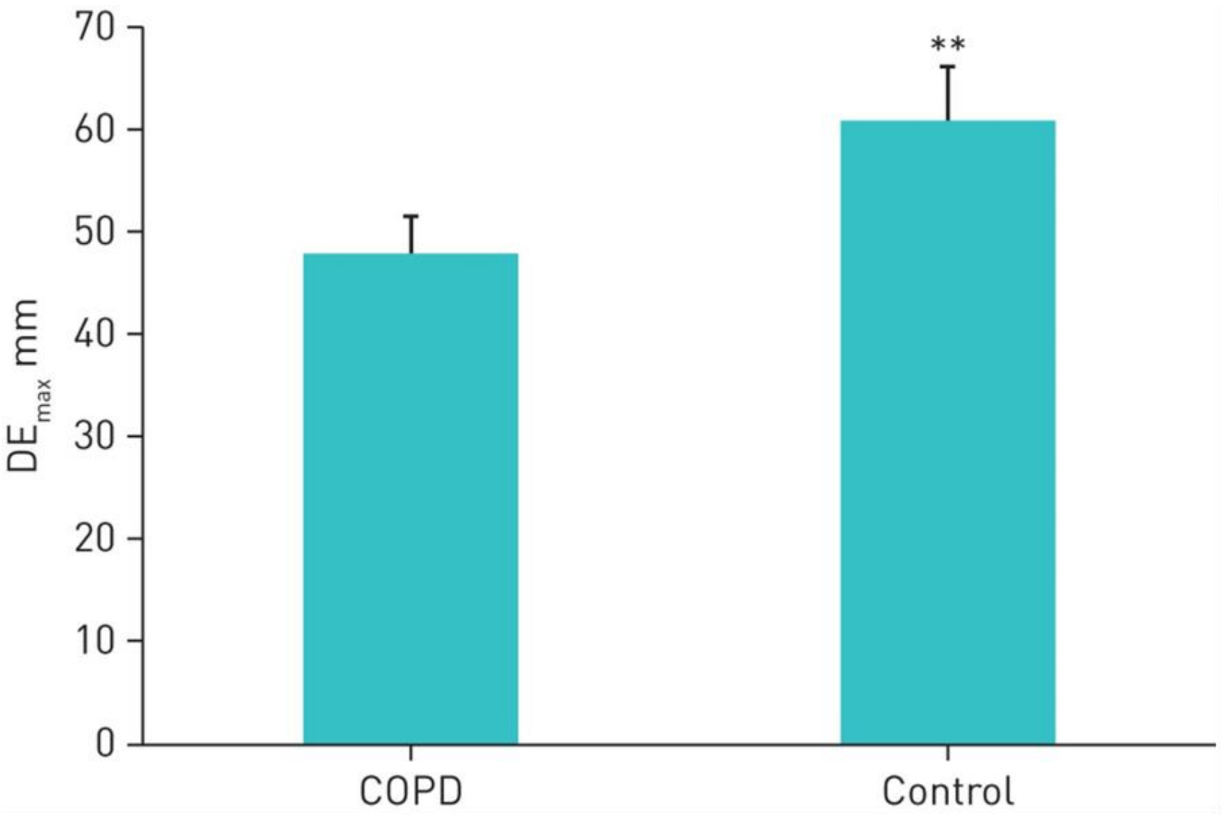
GREATER BREATHLESSNESS DURING EXERCISE WITH LOWER INSPIRATORY MUSCLE STRENGTH

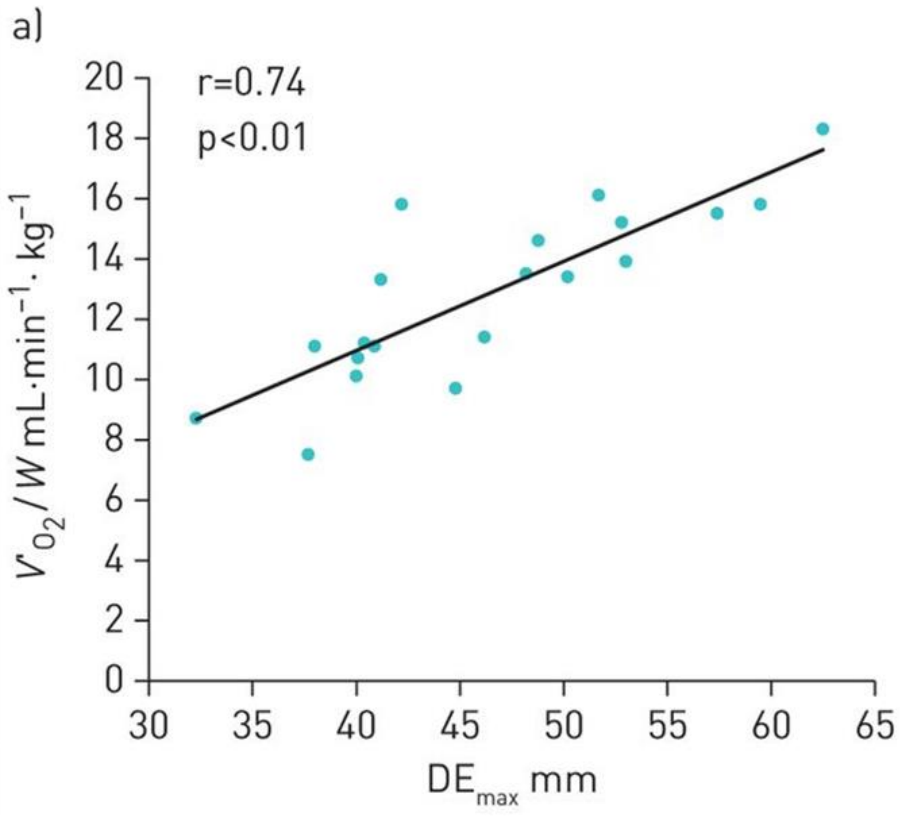


Killian & Jones, Clin Chest Med, 9 (1988); 237-248

WEAKNESS & DYSFUNCTION: CLINICAL SIGNIFICANCE

REDUCED DIAPHRAGM MOTILITY RELATED TO DECREASED EXERCISE CAPACITY IN COPD

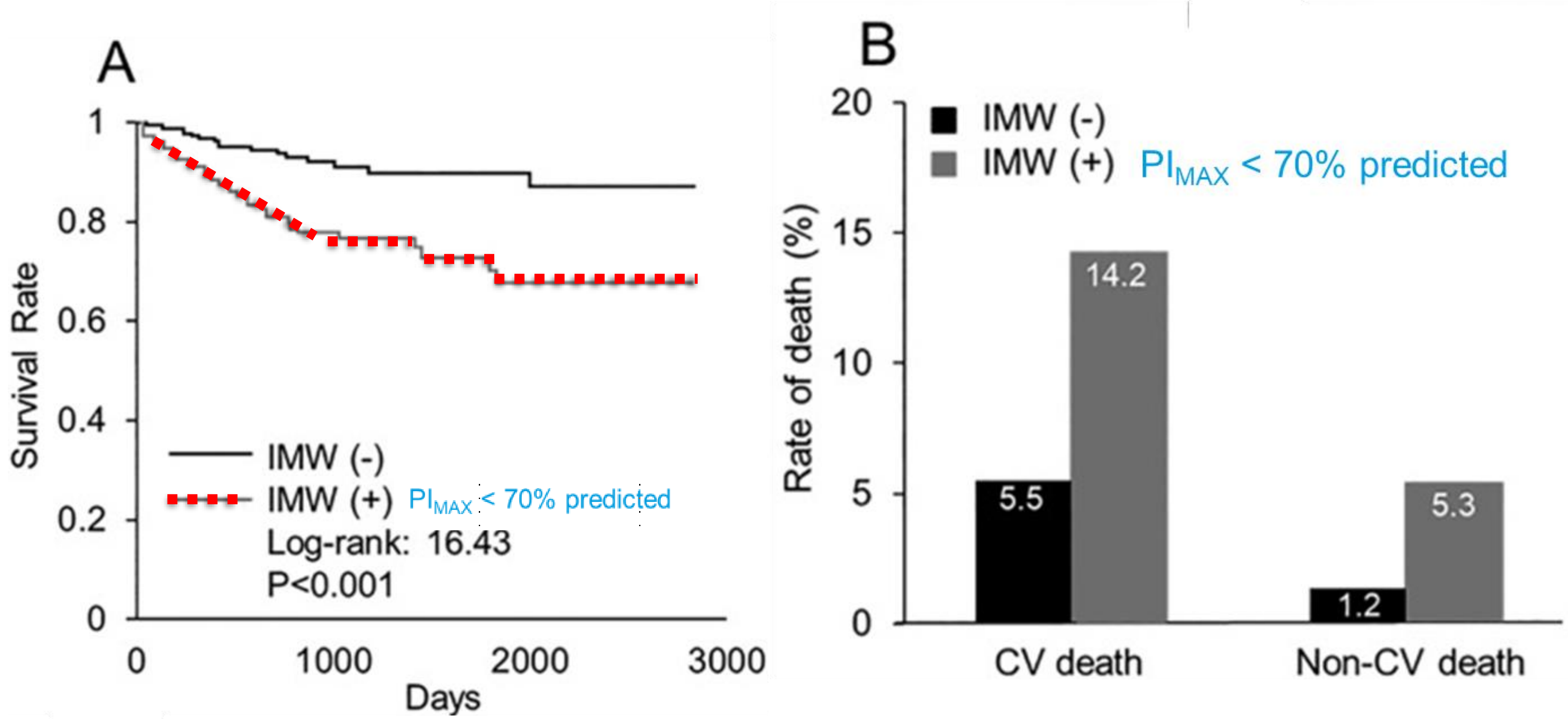




Shiraishi *et al.*, ERJ Open Research, 6 (2020); 00589-2020

WEAKNESS & DYSFUNCTION: CLINICAL SIGNIFICANCE

INSPIRATORY MUSCLE WEAKNESS INCREASES RISK OF DEATH IN HEART FAILURE WITH REDUCED EJECTION FRACTION



43% of HFrEF had IMW; median follow-up = 1.8 years

Hamazaki *et al.*, Respiratory Medicine, 161 (2020); 105834

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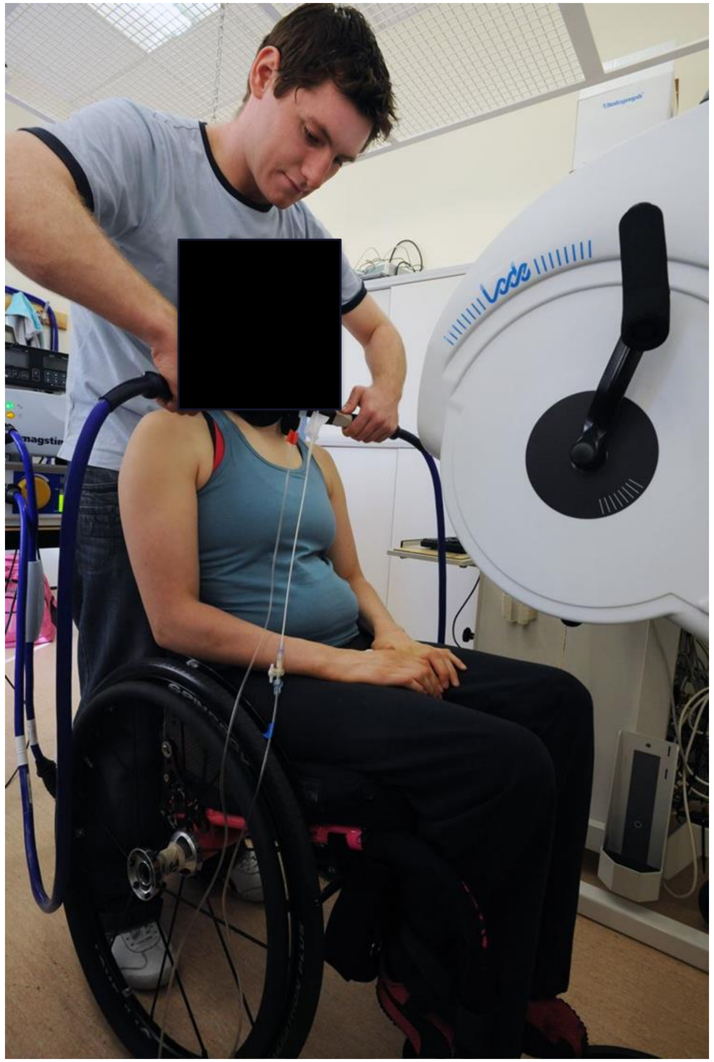
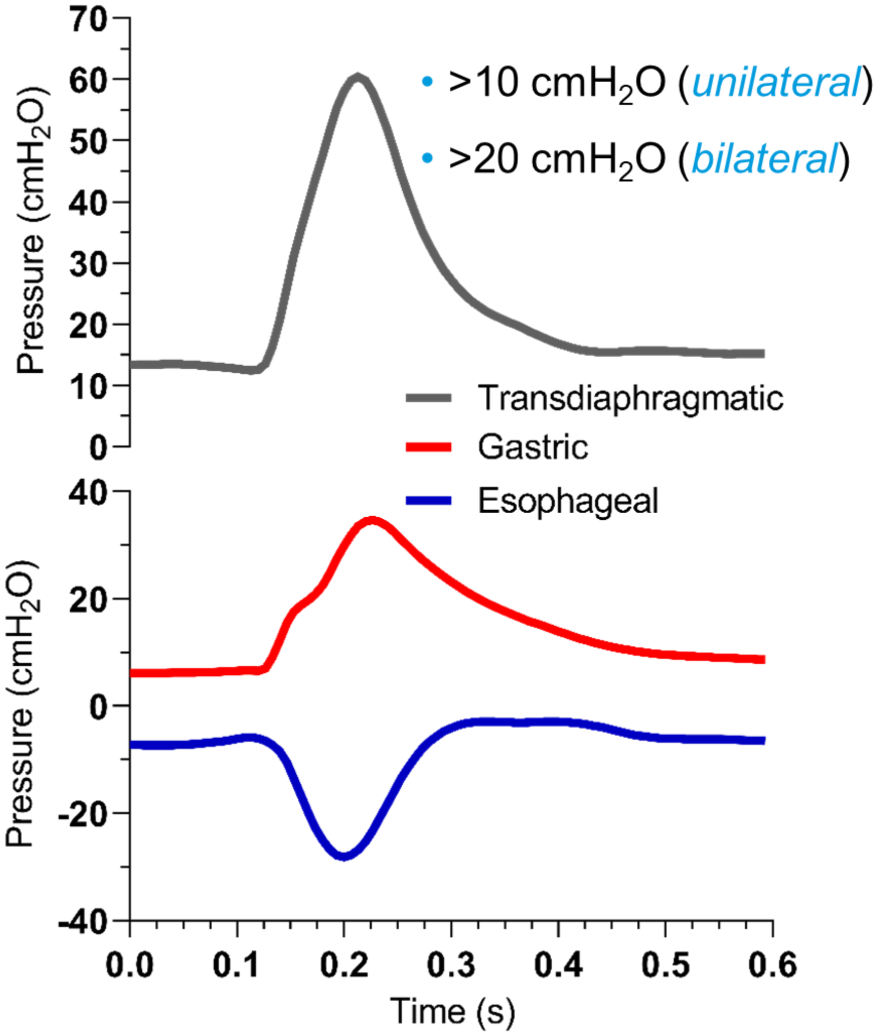
HOW DO WE ASSESS INSPIRATORY MUSCLE FUNCTION, WHAT IS NORMAL?

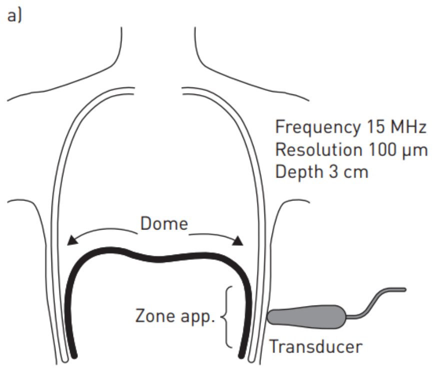
ASSESSING THE DIAPHRAGM EVOKED DIAPHRAGM TWITCH PRESSURE

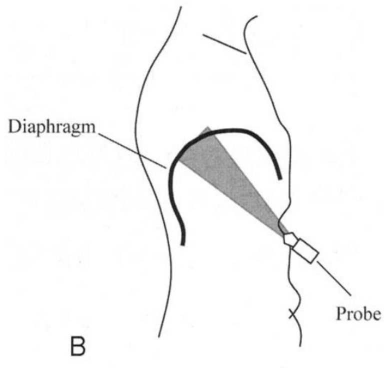


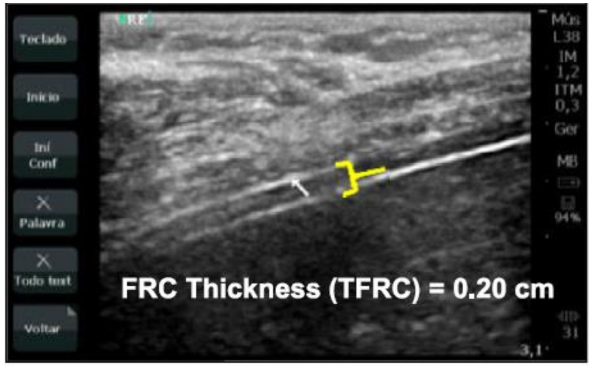


Hardy *et al., J Appl Physiol*, 130 (2021); 421-434; **Taylor** *et al., J Appl* Physiol, 109 (2010); 358-366; **Taylor** *et al., J Appl* Physiol, 100 (2006); 1554-1562

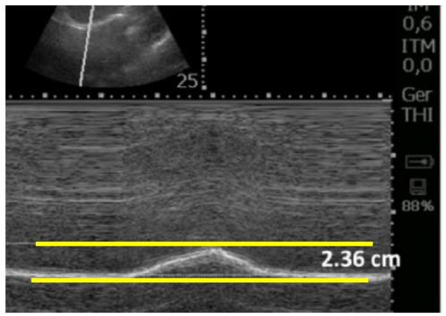
ASSESSING THE DIAPHRAGM
ULTRASOUND IMAGING

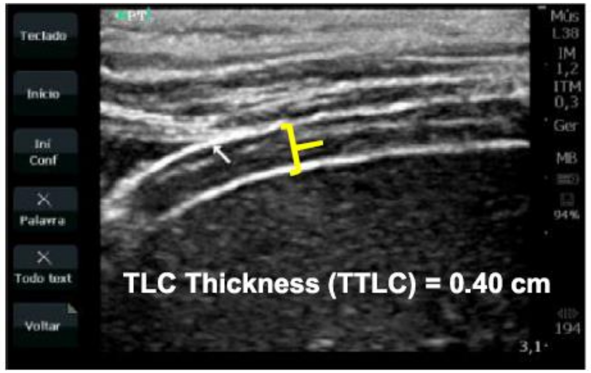




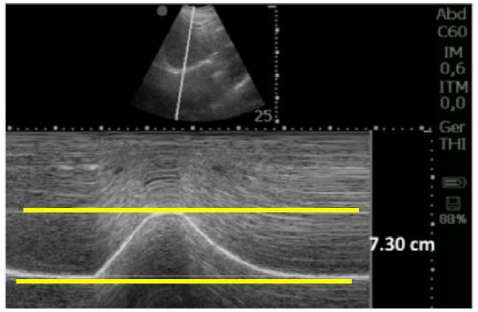


QUIET BREATHING





DEEP BREATHING



End-expiratory thickness
- LLN 0.15 cm

Thickening fraction
- LLN 20-30%
- Frequently >100%

Excursion (*deep breath*)
- LLN 3.6 cm (female)
- LLN 4.7 cm (male)

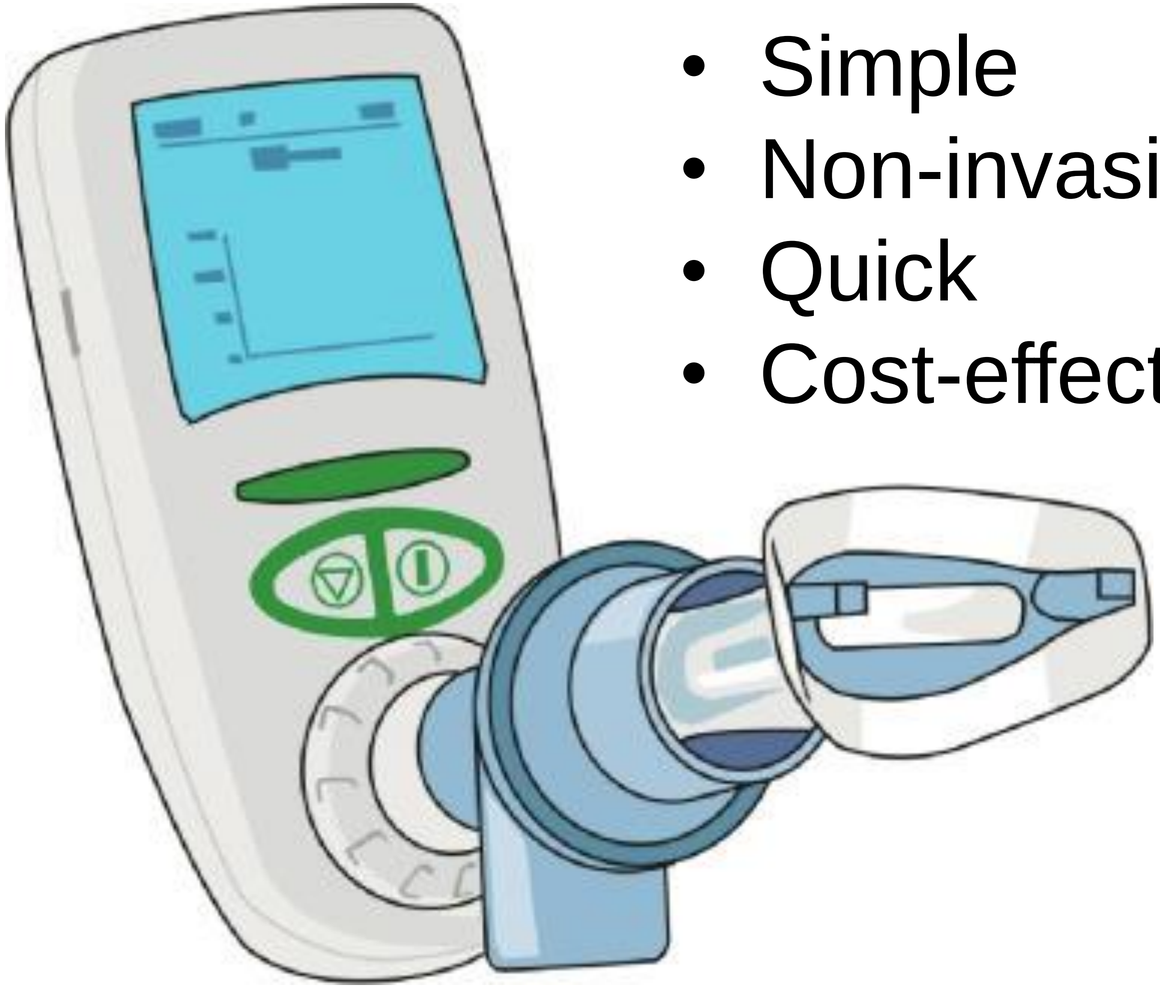
ASSESSING THE DIAPHRAGM
CHEST CT OR X-RAY

- **Neuropathic**
  Disease states that cause nerve damage or demyelination of phrenic nerve
- **Inflammatory**
  Secondary to viral and potentially some bacterial infections; noninfectious inflammatory causes also noted (e.g., sarcoidosis)
- **Idiopathic**
  Cause considered unknown; ~20% of cases
- **Traumatic**
  Cardiothoracic surgery; freezing injury due to necessary cooling; direct trauma (e.g., CABG)

Unilateral elevation of ***right*** hemidiaphragm >2 cm higher than left

INVASIVE, COSTLY, TIME-CONSUMING, REQUIRES EXPERT TRAINING & COMPLICATED ANALYSIS; *NOT WELL SUITED TO ROUTINE ASSESSMENT IN CR & PR…*

ASSESSING THE DIAPHRAGM
MAXIMAL INSPIRATORY PRESSURE



- Simple
- Non-invasive
- Quick
- Cost-effective

Smith & Taylor, Prog Cardiovasc Dis, 70 (2022); 49-57

MAXIMAL INSPIRATORY PRESSURE

PRACTICAL CONSIDERATIONS

Volitional

Patient encouragement required

Posture

Seated, upright, no 'holding on'

Length-tension relationship

Typically recommended MIP is measured at RV

Practice & warm-up

Learn correct technique; warm-up improves reliability

'Sustained' effort

MIP recorded as highest over 1 s (maintain for ~3-4 s)

Acceptable reproducibility

Highest value from 3 efforts that vary by ≤10%

MAXIMAL INSPIRATORY PRESSURE

PRACTICAL CONSIDERATIONS; WHAT IS NORMAL?

CAUTION WHEN USING PREDICTIVE EQUATIONS WHEN CONSIDERING WHAT IS NORMAL

RODRIGUES ET AL., CHEST, 152 (2017); 32-39…

- PREVALENCE OF WEAKNESS RANGED FROM 33.4 TO 66.9% (6 EQNS)
- THE CHOICE OF MIP REFERENCE VALUES STRONGLY IMPACTS ON THE PREVALENCE OF WEAKNESS

MAXIMAL INSPIRATORY PRESSURE

PRACTICAL CONSIDERATIONS; WHAT IS NORMAL?

Age, y	MEN		WOMEN	
	Studies/sample size	MIP, cmH_2O (95% CI)	Studies/sample size	MIP, cmH_2O (95% CI)
18-29	6/96	128 (116-140)	6/92	97 (89-105)
30-39	6/69	129 (119-139)	6/66	89 (85-94)
40-49	6/72	117 (105-129)	6/71	93 (78-107)
50-59	5/61	108 (99-118)	5/60	78 (75-85)
60-69	5/65	93 (85-101)	5/66	75 (67-83)
70-83	5/63	76 (66-86)	5/59	65 (58-73)

Pessoa *et al.*, *Can Respir J*, 21 (2014); 42-501562. 249-261

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MAXIMAL INSPIRATORY PRESSURE

PRACTICAL CONSIDERATIONS; WHAT IS NORMAL?

Age (yrs)	PImax (cmH_2O)		
	Men*		Women+
< 40	63	Associated with "higher" likelihood of inspiratory muscle weakness	58
40-60	55		50
61-80	47		43
> 80	42		38

MIP of ≥80 cmH_2O (*males*) or ≥70 cmH_2O (*females*) thought to exclude clinically significant inspiratory muscle weakness

Pessoa *et al.*, *Can Respir J*, 21 (2014); 42-501562. 249-261

INTERIM SUMMARY

- Inspiratory muscle weakness & dysfunction is associated with dyspnea, exercise intolerance, & prognosis in CVD and chronic lung disease
- Maximal inspiratory pressure is the most viable method for standard assessment of inspiratory muscle function in CR & PR

INSPIRATORY MUSCLE WEAKNESS IN CR/PR: PREVALENCE AND REHABILITATIVE STRATEGIES

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DISCLOSURES

- No disclosures

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OVERVIEW

- Prevalence of inspiratory muscle weakness in CR and PR populations?

- Impact of exercise-based CR and PR on inspiratory muscle function

- Addition of inspiratory muscle training on inspiratory muscle function in the CR/PR setting

- Practical guidance for inspiratory muscle training in the CR/PR setting

1 PREVALENCE OF INSPIRATORY MUSCLE WEAKNESS

WHAT IS THE PREVALENCE OF INSPIRATORY MUSCLE WEAKNESS IN CR & PR?

INSPIRATORY MUSCLE WEAKNESS IN CR & PR

Study	Population	N=	Measure (vs CTL)	Prevalence
Hamazaki, 2020	HFrEF	445		MIP <70% pred; ~43%
Hamazaki, 2020	HFpEF	578		MIP <70% pred; ~39%
Miyagi, 2018	HFr/pEF	77	Ultrasound; dia. thickness @ TLC	<4.0 mm; ~44%
Meyer, 2001	HFrEF	244	MIP: 77 ± 34 vs. 107 ± 38 cmH_2O	
Fernandes, 2018	HTxp	23	MIP; 60 ± 30 cmH_2O (~48-55% pred)	

Inspiratory muscle weakness is associated with all-cause and CV mortality in HFrEF and HFpEF.

INSPIRATORY MUSCLE WEAKNESS IN CR & PR

Study	Population	N=	Measure (vs CTL)	Prevalence
Stein, 2009	CABG	20	MIP; 65 ± 16 cmH_2O (60% pred.)	
Morsch, 2009	CABG	108	MIP; 66 ± 29 cmH_2O	
Palaniswamy, 2010	Valve	20	MIP: 51 ± 10 cmH_2O (~49% pred.)	

The values above are pre-surgery. CABG and heart valve surgeries are associated with a ~17-36% reduction in inspiratory muscle strength and can persist for several weeks to months.

INSPIRATORY MUSCLE WEAKNESS IN CR & PR

Study	Population	N=	Measure (vs CTL)	Prevalence
Kofod, 2019	COPD	97	MIP: 63 vs. 76 cmH_2O	MIP <50% pred; ~10% MIP <60 cmH_2O; ~40%
Basso-Vanelli, 2016	COPD	25	MIP: 64 ± 17 cmH_2O (67% pred.)	

Evidence that inspiratory muscle weakness in COPD is associated with hyperinflation and contributes to hypercapnia, dyspnea, and exercise intolerance in these patients.

Gosselink *et al.*, Eur Respir J, 37 (2011); 416-425

2 REHABILITATIVE STUDIES

CAN EXERCISE TRAINING IN THE CR/PR SETTING IMPROVE INSPIRATORY MUSCLE FUNCTION?

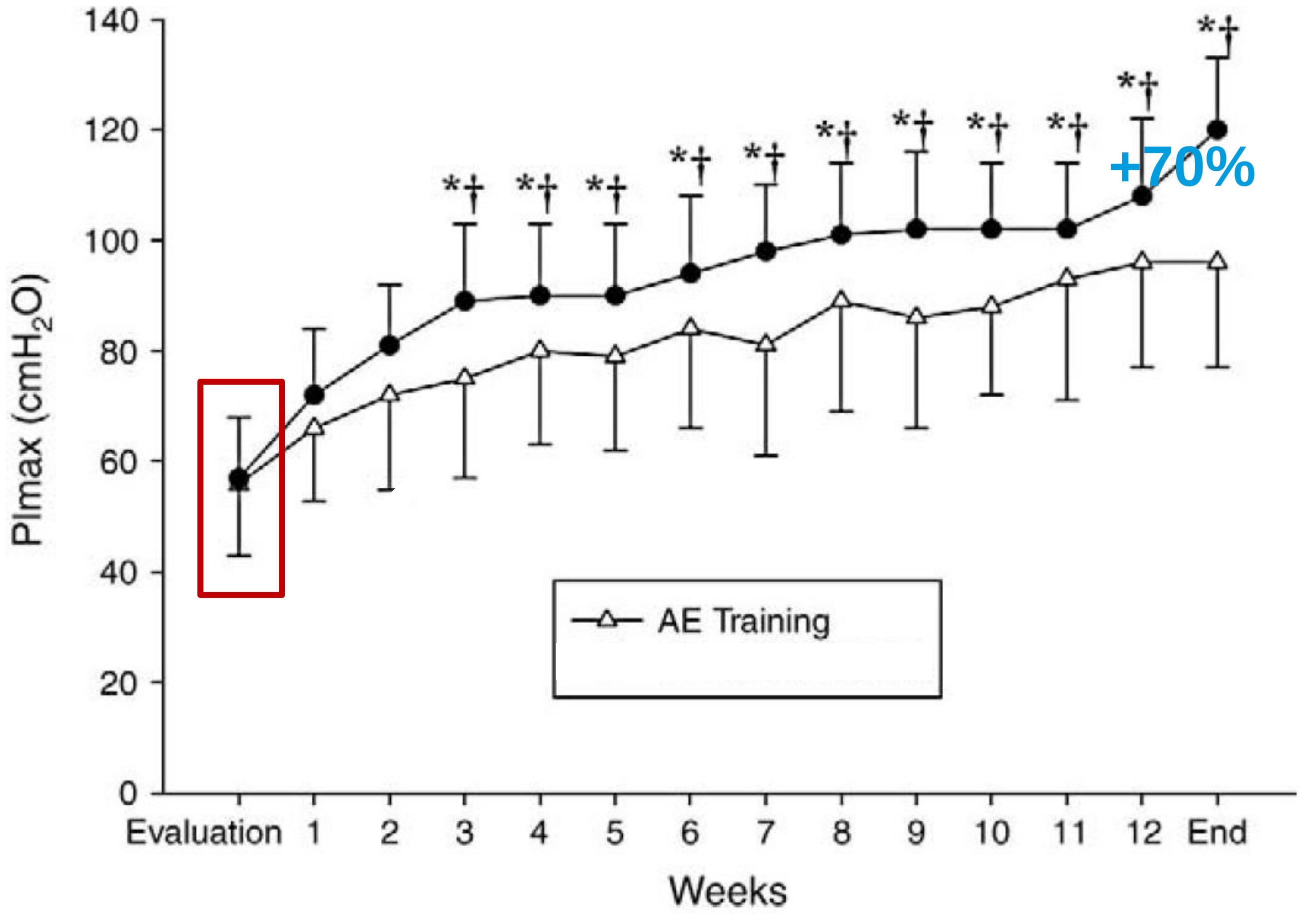
AEROBIC TRAINING

AEROBIC EXERCISE IN *HFREF*

Supervised exercise training

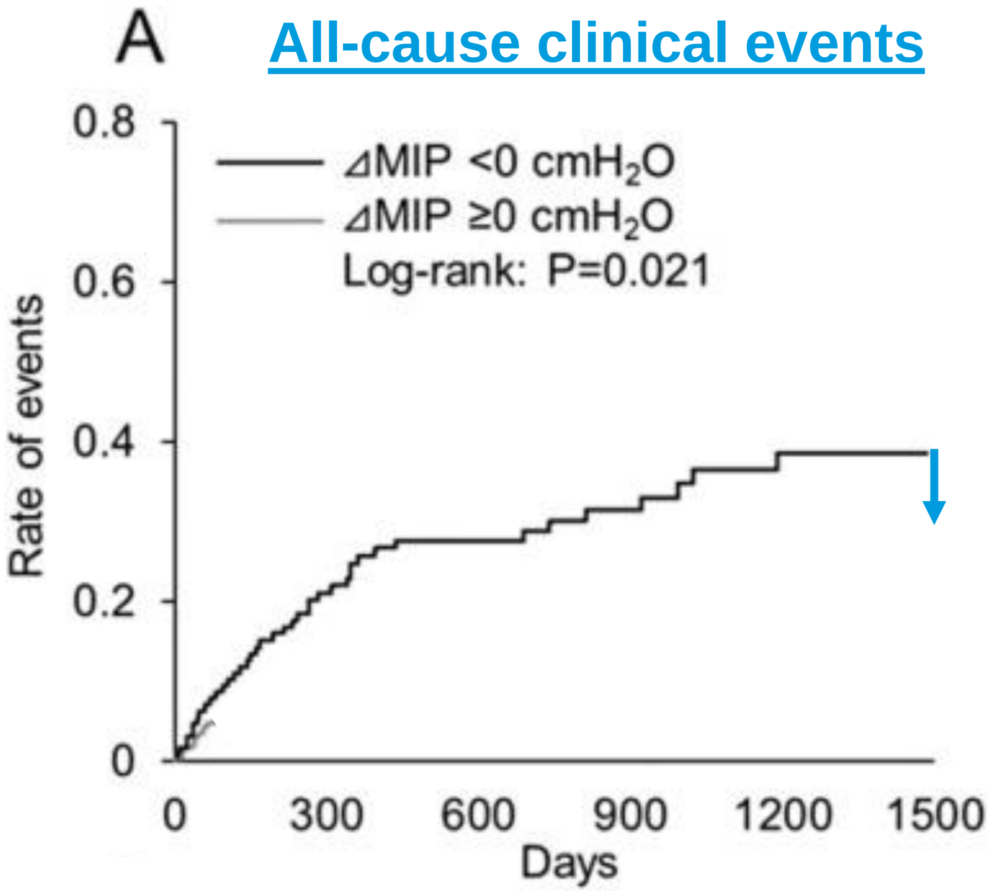
- ➢ 3 times per week for 12 weeks
- ➢ Target intensity was heart rate at first ventilatory threshold
- ➢ Duration was 20 min and progressed to 45 min

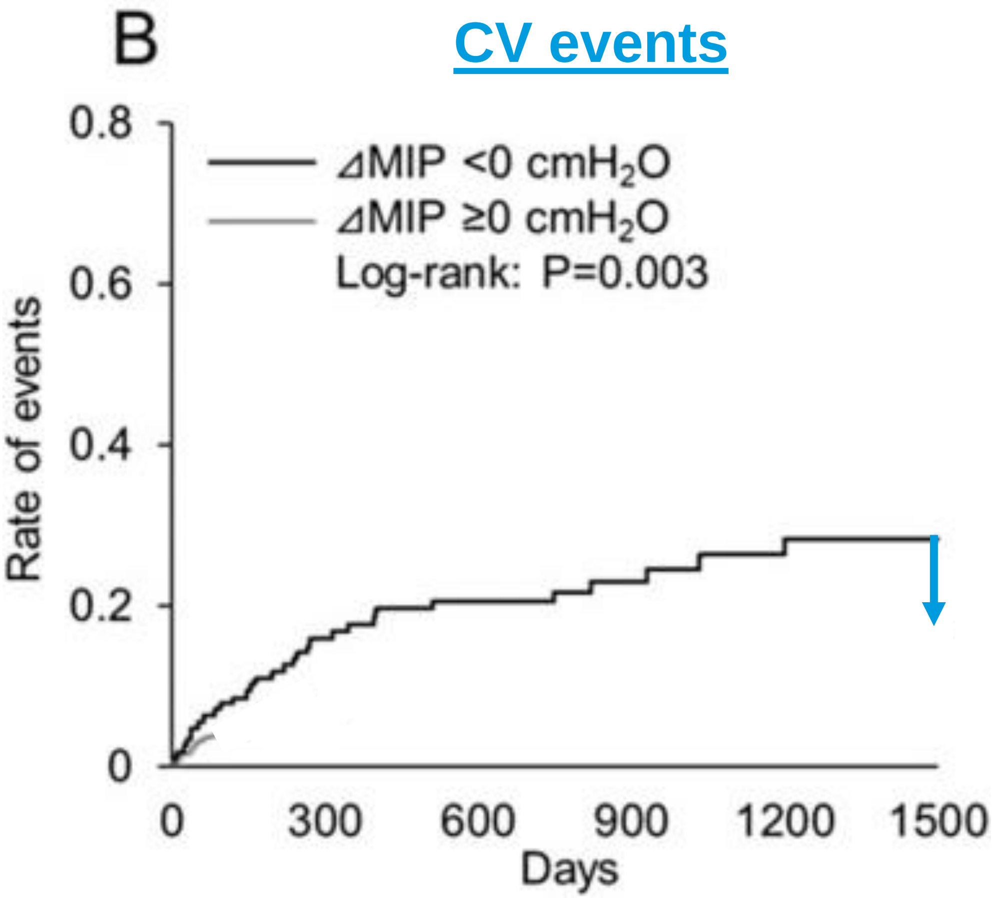
Other studies have reported a smaller MIP increase (~15%) with baseline MIP likely significantly contributing to the degree of MIP improvement



Winkelmann *et al.*, Am Heart J, 158 (2009); 768

AEROBIC TRAINING





Any CR-induced increase in MIP is associated with lower rates of all-cause and CV events in HFrEF

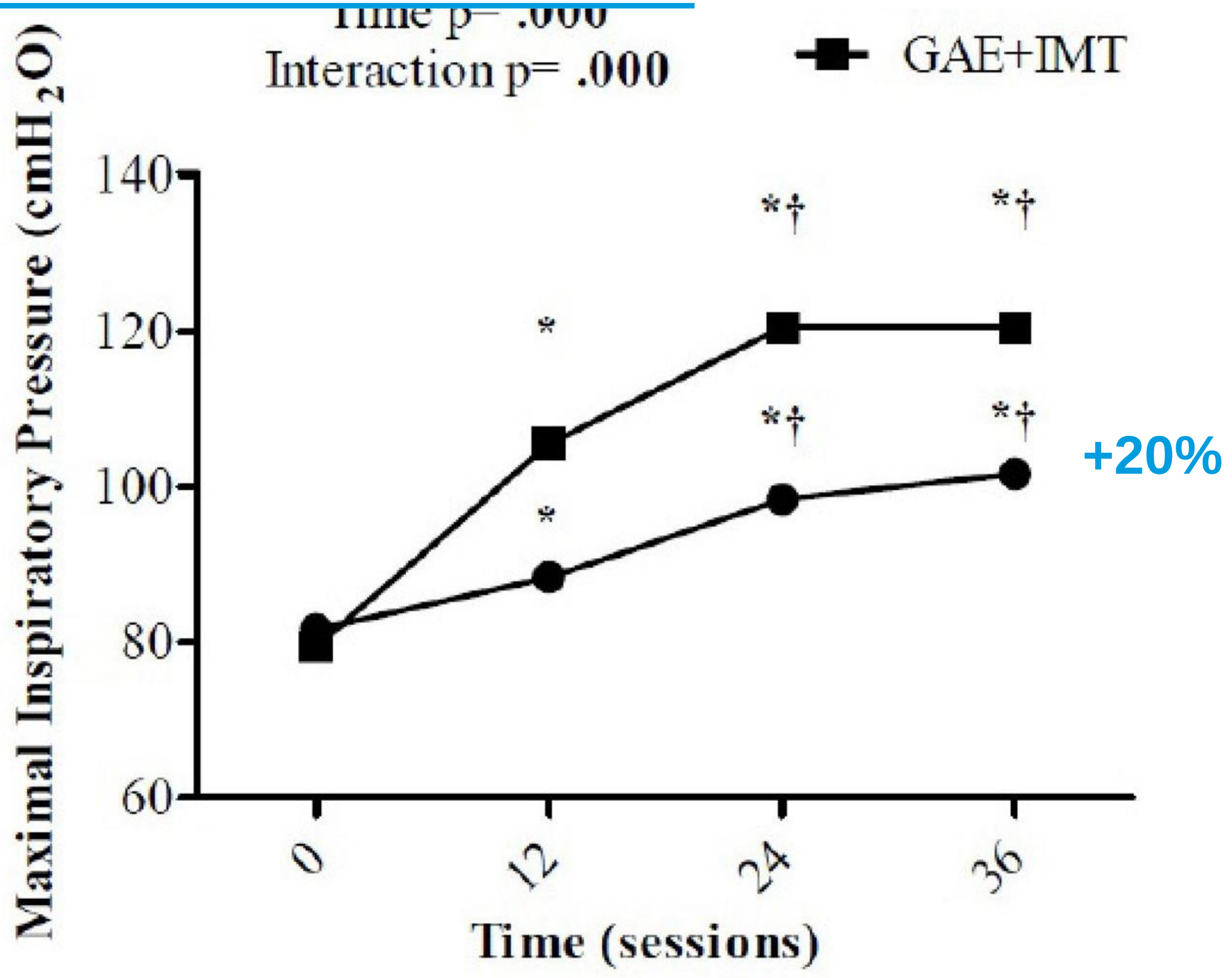
Hamazaki *et al.*, J Clin Medicine, 9 (2020); 952

AEROBIC TRAINING

AEROBIC EXERCISE *FOLLOWING CABG SURGERY*

Supervised exercise training

- 3 times per week for 12 weeks
- Target intensity was 50% to 80% heart rate reserve (progressive increase)
- Duration was 40 min



Other studies have reported no MIP improvement in response to CR following CABG surgery, but the patients in these studies have had higher MIP values at CR entry

Miozzo *et al.*, Braz J Cardiovasc Surg, 33 (2018); 376-83

AEROBIC TRAINING

AEROBIC EXERCISE *FOLLOWING CABG SURGERY*

Taken together, these findings provide evidence that exercise training in the CR setting elicits improvements in MIP in HFrEF and following CABG with those patients exhibiting inspiratory muscle weakness likely exhibiting the greatest increases in inspiratory muscle function.

Miozzo *et al.*, Braz J Cardiovasc Surg, 33 (2018); 376-83

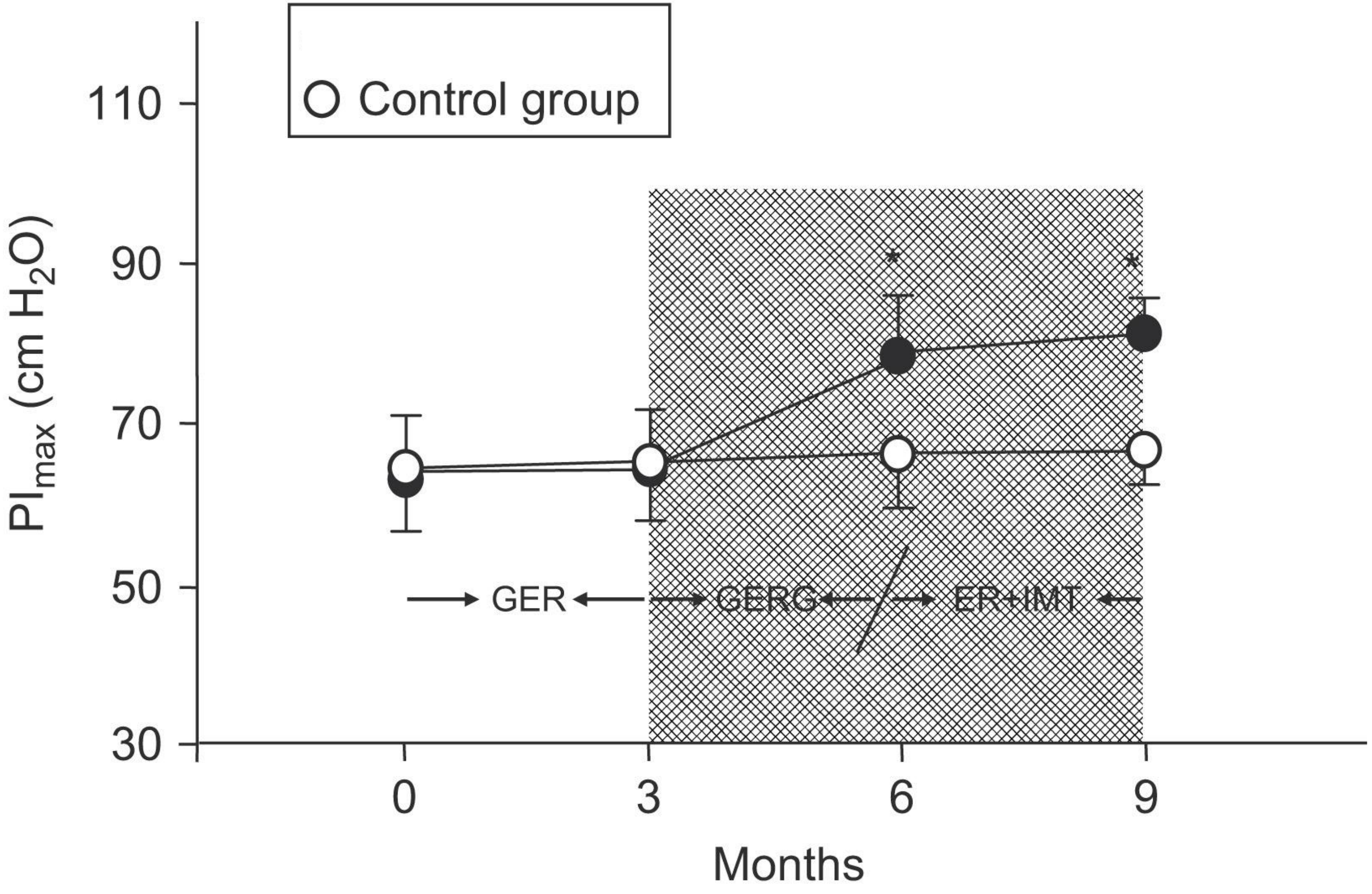
AEROBIC TRAINING

AEROBIC EXERCISE IN *COPD*

Supervised PR program

- 3 times per week for 12 weeks
- General exercise reconditioning program
- Duration was 1.5 hours including endurance exercise and strength training

These findings are consistent with other studies finding minimal increases in MIP with PR in patients with COPD



Magadle *et al.*, Respir Med, 101 (2007); 1500-1505

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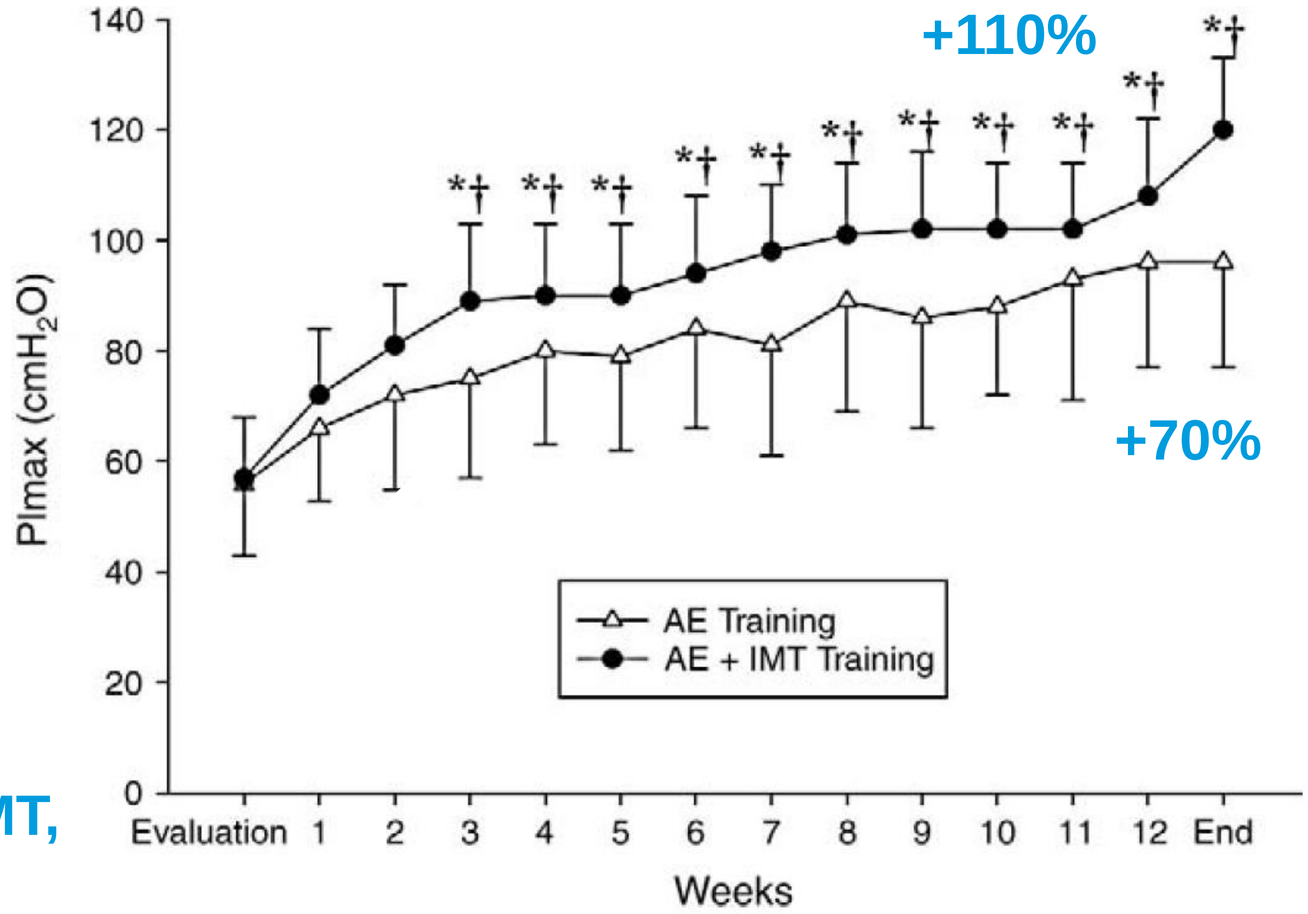
EFFECT OF EXERCISE TRAINING & INSPIRATORY MUSCLE TRAINING (IMT) ON INSPIRATORY MUSCLE FUNCTION AND EXERCISE CAPACITY

AEROBIC/INSPIRATORY MUSCLE TRAINING

AEROBIC EXERCISE VS. AEROBIC EXERCISE PLUS IMT IN *HFREF*

Inspiratory muscle training

- 7 days per week for 12 weeks (1 session supervised and 6 sessions at home)
- 30% of MIP
- Duration was 30 min per session

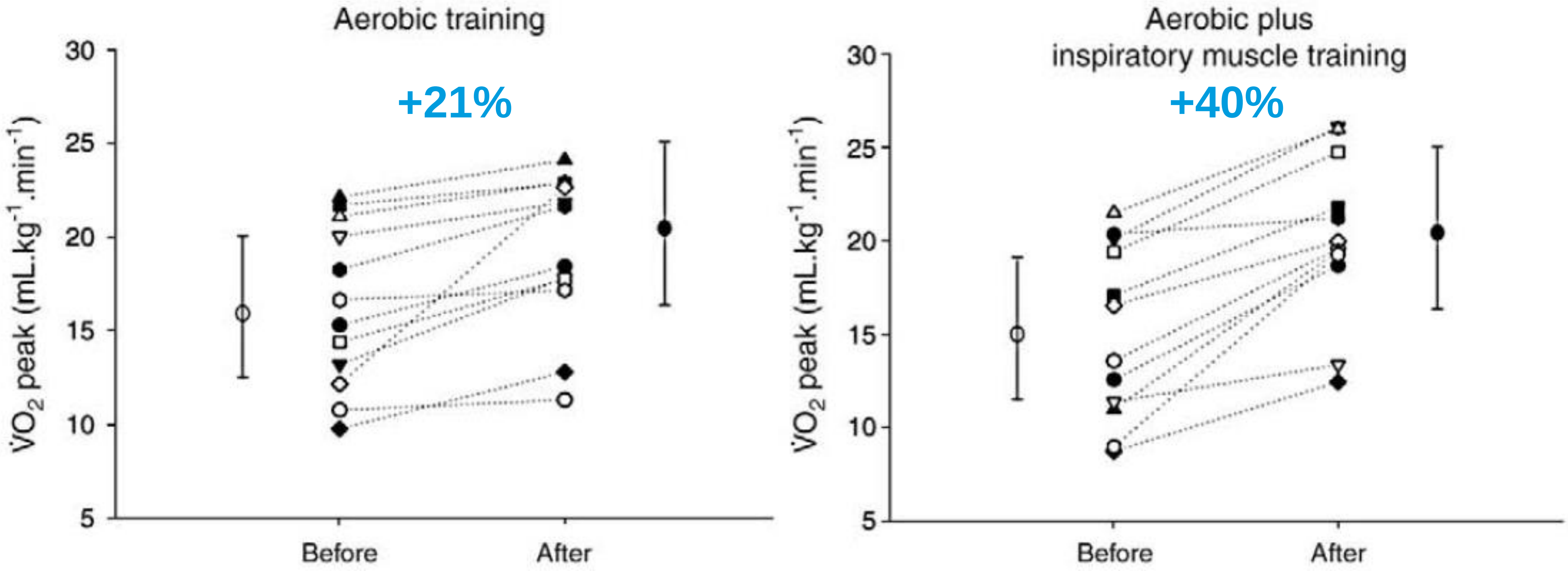


Other studies in HFrEF without inspiratory muscle weakness have found no additional benefit in inspiratory muscle strength with IMT, but these patients did exhibit greater improvements in quality of life and dyspnea than exercise training alone.

Winkelmann *et al.*, Am Heart J, 158 (2009); 768

AEROBIC/INSPIRATORY MUSCLE TRAINING

AEROBIC EXERCISE VS. AEROBIC EXERCISE PLUS IMT IN *HFREF*



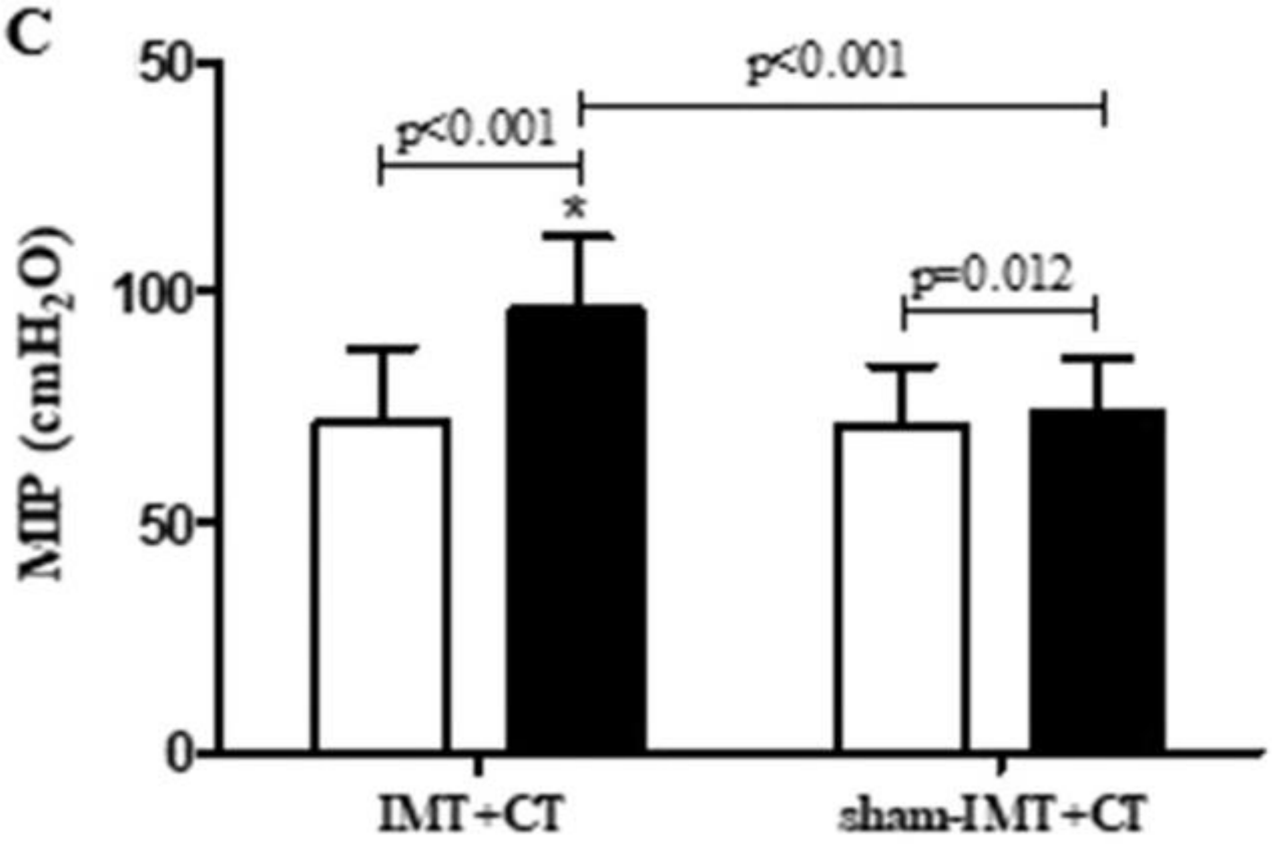
Winkelmann *et al.*, Am Heart J, 158 (2009); 768

AEROBIC/INSPIRATORY MUSCLE TRAINING

AEROBIC EXERCISE VS. AEROBIC EXERCISE PLUS IMT *FOLLOWING CABG SURGERY*

Inspiratory muscle training

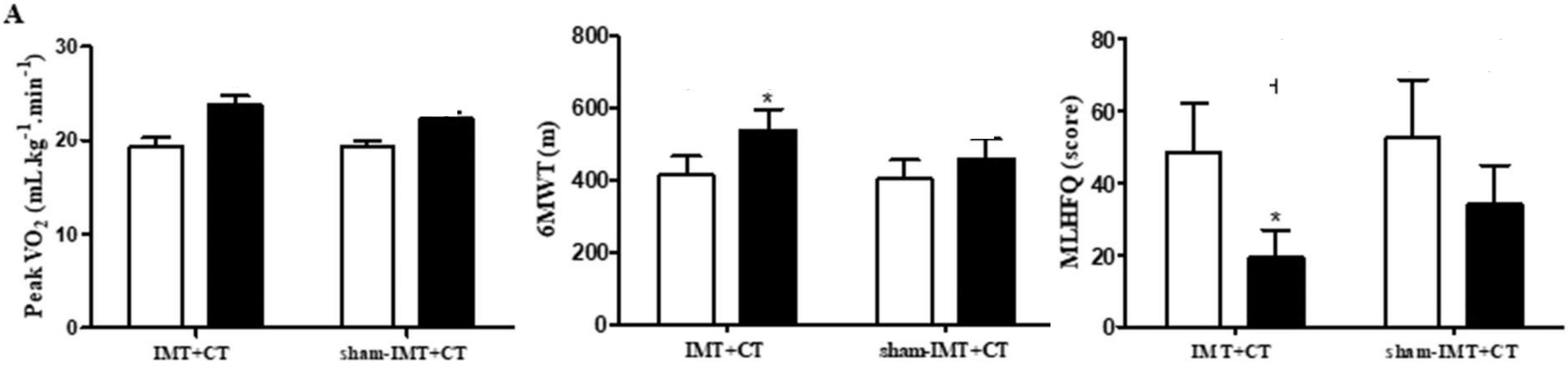
- 2 days per week for 12 weeks
- 50% to 80% of MIP (progressive increase from week 1 to week 8)
- 5 sets of 10 repetitions with 1 min of rest between each set



Santos *et al.*, Int J Cardiol, 279 (2019); 40-46

AEROBIC/INSPIRATORY MUSCLE TRAINING

AEROBIC EXERCISE VS. AEROBIC EXERCISE PLUS IMT *FOLLOWING CABG SURGERY*



Aerobic training in the CR setting combined with IMT resulted in greater improvements in VO_2peak, 6-minute walk, and quality of life following CABG surgery.

Santos *et al.*, Int J Cardiol, 279 (2019); 40-46

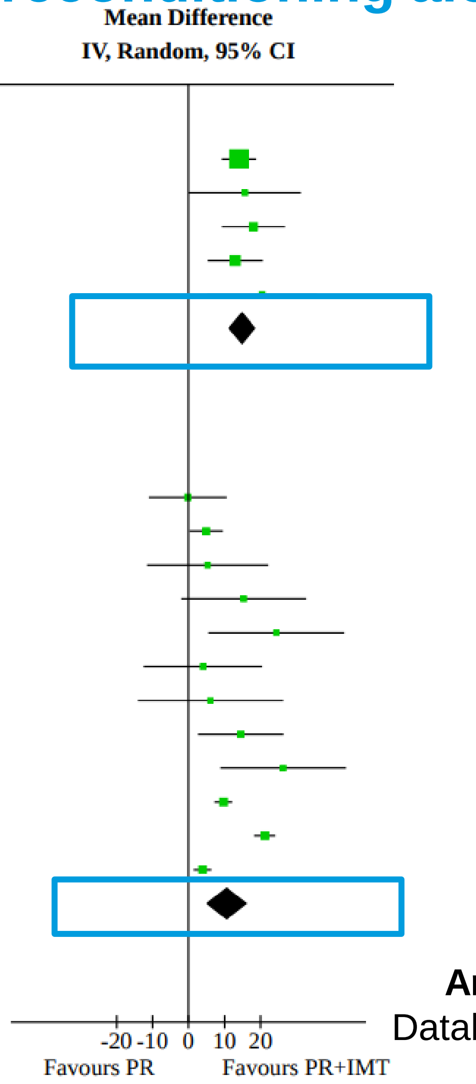
AEROBIC/INSPIRATORY MUSCLE TRAINING

AEROBIC EXERCISE VS. AEROBIC EXERCISE PLUS IMT IN *COPD*

Effect of exercise reconditioning plus IMT vs. exercise reconditioning alone on MIP

	PR+IMT			PR				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
1.14.1 With respiratory muscle weakness								
Charususin 2018	75	19	89	61	13	85	52.7%	14.00 [9.18 , 18.82]
Dekhuijzen 1991	81.2	27.53	20	65.56	22.5	20	5.0%	15.64 [0.06 , 31.22]
Dellweg 2017	55	11	15	37	13	14	15.8%	18.00 [9.20 , 26.80]
Weiner 1992	57.8	10	12	44.8	9	12	21.1%	13.00 [5.39 , 20.61]
Weiner 2000	77.5	17.5	11	57.07	11.4	4	5.3%	20.43 [5.21 , 35.65]
Subtotal (95% CI)			**147**			**135**	**100.0%**	**14.84 [11.35 , 18.34]**
Heterogeneity: Tau² = 0.00; Chi² = 1.37, df = 4 (P = 0.85); I² = 0%								
Test for overall effect: Z = 8.32 (P < 0.00001)								
1.14.2 Without respiratory muscle weakness								
Beaumont 2015	85.38	15.75	16	85.61	16.3	18	8.7%	-0.23 [-11.01 , 10.55]
Beaumont 2018	14.8	14.9	74	9.9	13.8	75	12.2%	4.90 [0.29 , 9.51]
De Farias 2019 (1)	90	18.5	12	84.7	15	5	5.8%	5.30 [-11.51 , 22.11]
De Farias 2019 (2)	100	17.4	9	84.7	15	5	5.5%	15.30 [-2.08 , 32.68]
Fanfa Bordin 2020	95.12	20.5	12	70.7	24	10	5.0%	24.42 [5.56 , 43.28]
Larson 1999	90	16	14	86	27	14	5.9%	4.00 [-12.44 , 20.44]
Mador 2005	76.3	32.53	15	70.2	22.44	14	4.6%	6.10 [-14.13 , 26.33]
Magadle 2007	81.2	16	14	66.7	15.5	13	8.0%	14.50 [2.62 , 26.38]
Paneroni 2018	107.6	22.9	12	81.3	18.9	10	5.5%	26.30 [8.83 , 43.77]
Schultz 2018	18.66	16.11	300	8.97	14.89	302	13.0%	9.69 [7.21 , 12.17]
Tounsi 2021	22.9	5.8	16	1.7	1.6	16	12.9%	21.20 [18.25 , 24.15]
Wang 2017	5.2	4.7	28	1.3	4.7	27	13.0%	3.90 [1.42 , 6.38]
Subtotal (95% CI)			**522**			**509**	**100.0%**	**10.57 [5.23 , 15.91]**
Heterogeneity: Tau² = 55.50; Chi² = 94.26, df = 11 (P < 0.00001); I² = 88%								
Test for overall effect: Z = 3.88 (P = 0.0001)								

Test for subgroup differences: Chi² = 1.72, df = 1 (P = 0.19), I² = 41.8%

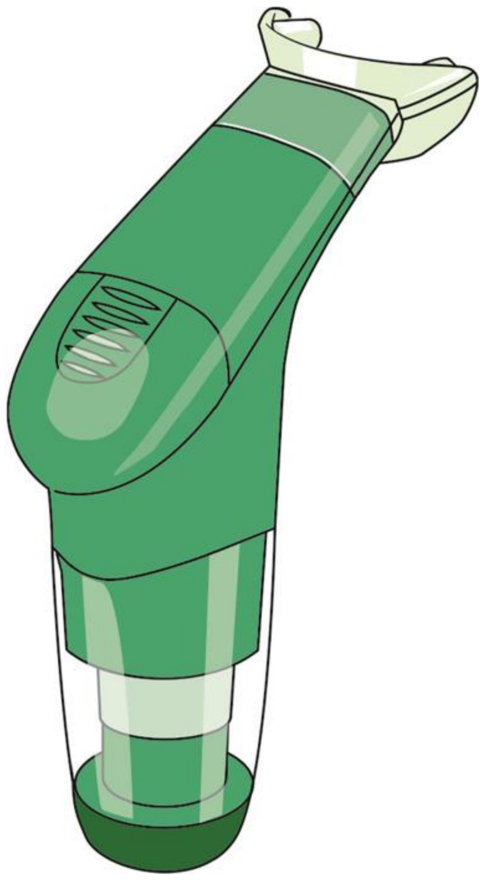


Ammous *et al.*, Cochrane Database Syst Rev, 1 (2023); CD013778

3 PRACTICAL GUIDANCE

INSPIRATORY MUSCLE TRAINING

PRACTICAL GUIDANCE



Adjunct therapy

Inspiratory muscle function, breathlessness, exercise capacity (?)

Three primary modalities

Hyperpnea, ‘fixed’ resistive loading, pressure threshold loading**

Consider baseline MIP

Intervention most effective in those with existing inspiratory muscle weakness (MIP <60 cmH_2O)

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OPTIMAL IMT PRESCRIPTION?

‘Standard’

- 2 × 30 dynamic efforts
- 6-to-7 days per week
- 4-to-10+ weeks
- ~50% of MIP
- Progression
    - Periodically increase load such that completion of 30 breaths approximates limit of inspiratory muscle tolerance

‘High-intensity’

- 2-min loaded inspirations, 1-min recovery
- Repeat 7 times
- 3-to-5 days per week
- ~8 weeks
- Start ‘low’ (~20-30% MIP)
- Progress to ~70% by 3rd or 4th session; further increase load such that final 2 min of session ‘only just’ completed

INSPIRATORY MUSCLE TRAINING

PRACTICAL GUIDANCE

TABLE 1 Benefits and evidence levels of pulmonary rehabilitation outcomes in chronic obstructive pulmonary disease (COPD)

Benefits	Evidence
Improves exercise capacity	A
Reduces the perceived intensity of breathlessness	A
Improves health-related quality of life	A
Reduces the number of hospitalisations and hospital days	A
Reduces anxiety and depression associated with COPD	A
Strength and endurance training of the upper limbs improves arm function	B
Benefits extend well beyond the immediate period of training	B
Improves survival	B
Respiratory muscle training can be beneficial, especially when combined with general exercise training	C

Category A: randomised controlled trials, rich body of data; Category B: randomised controlled trials, limited body of data; Category C: nonrandomised trials or observational studies. Reproduced from [3] with permission from the publisher.

Consider baseline MIP

Intervention (ExT and/or IMT) most effective in those with existing inspiratory muscle weakness (MIP <60 cmH_2O)

INTERIM SUMMARY (PART II)

- Inspiratory muscle weakness is prevalent in heart failure and COPD.
- The prevalence of inspiratory muscle weakness in patients with other indications to CR (e.g., stable angina) is needed.
- Exercise-based CR and PR with/without IMT may improve inspiratory muscle function, physiological responses, and clinical outcomes.
- Evidence suggests that patients with inspiratory muscle weakness may exhibit the most benefit from exercise-based CR and PR with/without IMT.

MAYO CLINIC

CASE PRESENTATION: DIAPHRAGM DYSFUNCTION AFTER AORTIC VALVE REPLACEMENT

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PHASE II CR FOLLOWING AVR: CASE PATIENT

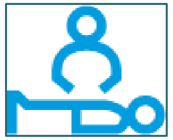
54-YEAR-OLD MALE

History

- Hypertension
- Hyperlipidemia
- Sleep apnea
- CA calcification
- Bicuspid aortic valve, severe stenosis

Medications

- Atorvastatin
- Metoprolol Succinate
- Warfarin
- Amlodipine
- Lisinopril
- Chlorthalidone
- Famotidine



Procedure

Mechanical aortic valve replacement via right mini thoracotomy

Phase II CR

25 total sessions over 15 weeks with 5 week ‘break’ due to work & family commitments

PHASE II CR FOLLOWING AVR: CASE PATIENT

54-YEAR-OLD MALE

	Rest	6MWT
Weight, lbs	288	
BMI, kg/m^2	35.1	
Heart rate, bpm	75	90
BP, mmHg	156/64	198/84
SpO_2, %	97	95
RPE		9
Distance, ft		1,402
Speed, mph		2.6
METS		3
ECG	NSR, no ectopy	NSR, no ectopy

CLINICAL COURSE

- Complaints of dyspnea after surgery, thought to be related to post-op deconditioning
- Pt was able to complete 30 min of seated aerobic exercise during his rehab sessions with minimal complaints of dyspnea
- Dyspnea worsened during resistance training
- Coached patient in proper breathing technique during resistance training without any symptom improvement

PHASE II CR FOLLOWING AVR: CASE PATIENT
54-YEAR-OLD MALE

- Patient was absent from rehab for 5 weeks due to family/work commitments
- Returned with persistent/worsening dyspnea, especially during resistance exercise prompted review of medical history with emphasis on the patients’ pulmonary history
- Multifactorial breathlessness in setting of obesity, weight gain, post-operative deconditioning
- Weight gain after CR ‘break’ (296 lbs, +8 lbs)

PHASE II CR FOLLOWING AVR: CASE PATIENT

54-YEAR-OLD MALE

Iatrogenic right hemidiaphragm paralysis & elevation

Injury to the phrenic nerve during cardiac surgery

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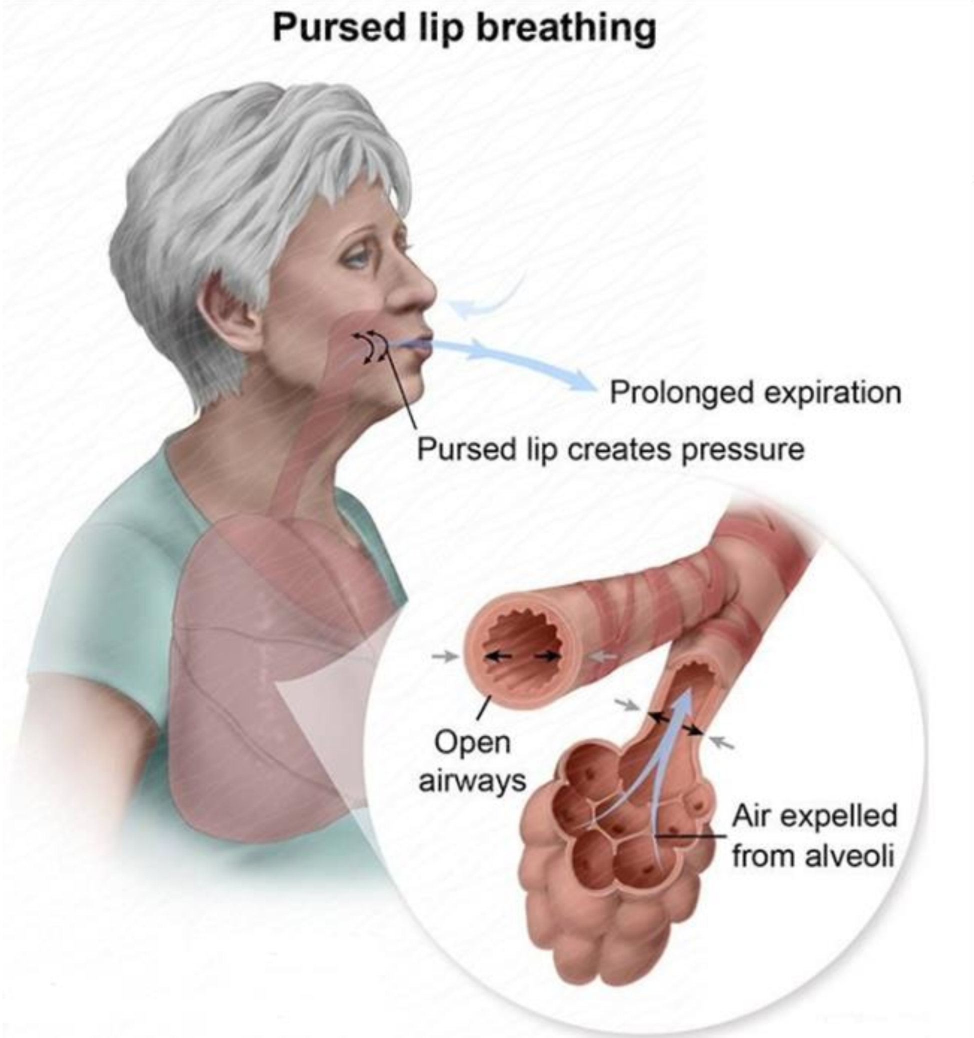
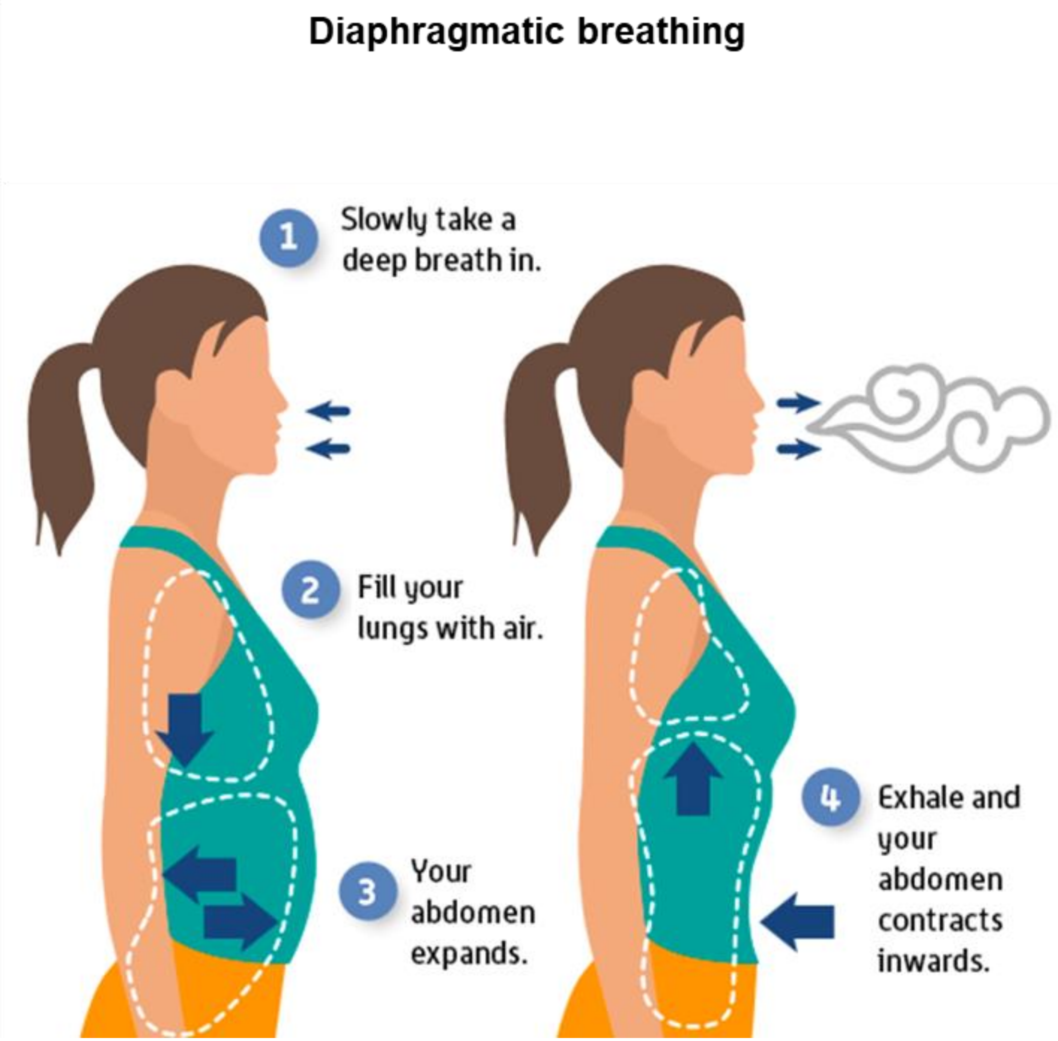
HOW DID WE MANAGE THE PATIENT IN CR?

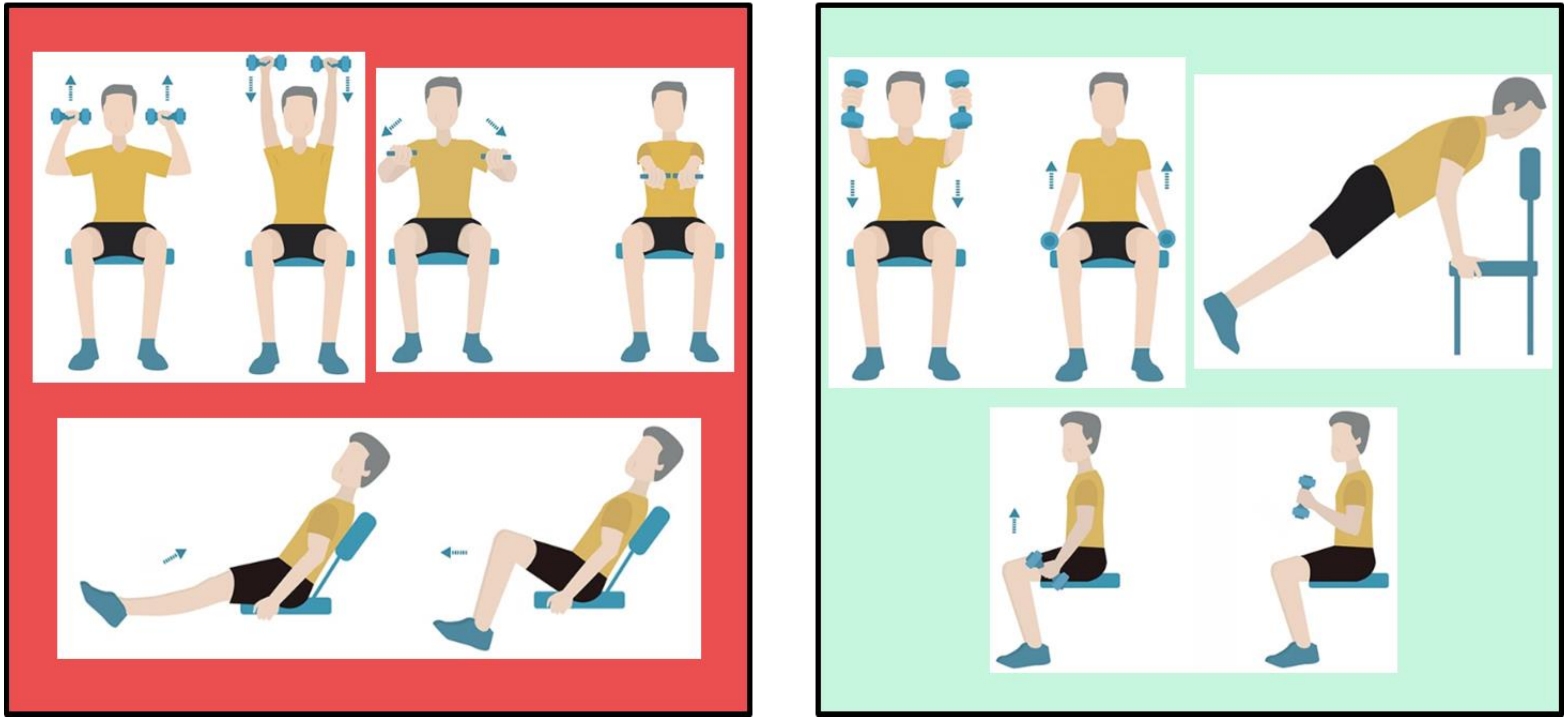
PHASE II CR FOLLOWING AVR: CASE PATIENT
54-YEAR-OLD MALE





PHASE II CR FOLLOWING AVR: CASE PATIENT
54-YEAR-OLD MALE

Modification of resistance exercise training plan.



PHASE II CR FOLLOWING AVR: CASE PATIENT

54-YEAR-OLD MALE

23 total sessions over 15 weeks	Before CR (rest)	After CR (rest)	Δ
Weight, lbs	288	292	+4
BMI, kg/m^2	35.1	35.5	+0.4
Heart rate, bpm	75	82	
BP, mmHg	156/64	122/60	**−34/4**
SpO_2, %	97	96	
ECG	NSR, no ectopy	NSR, no ectopy	

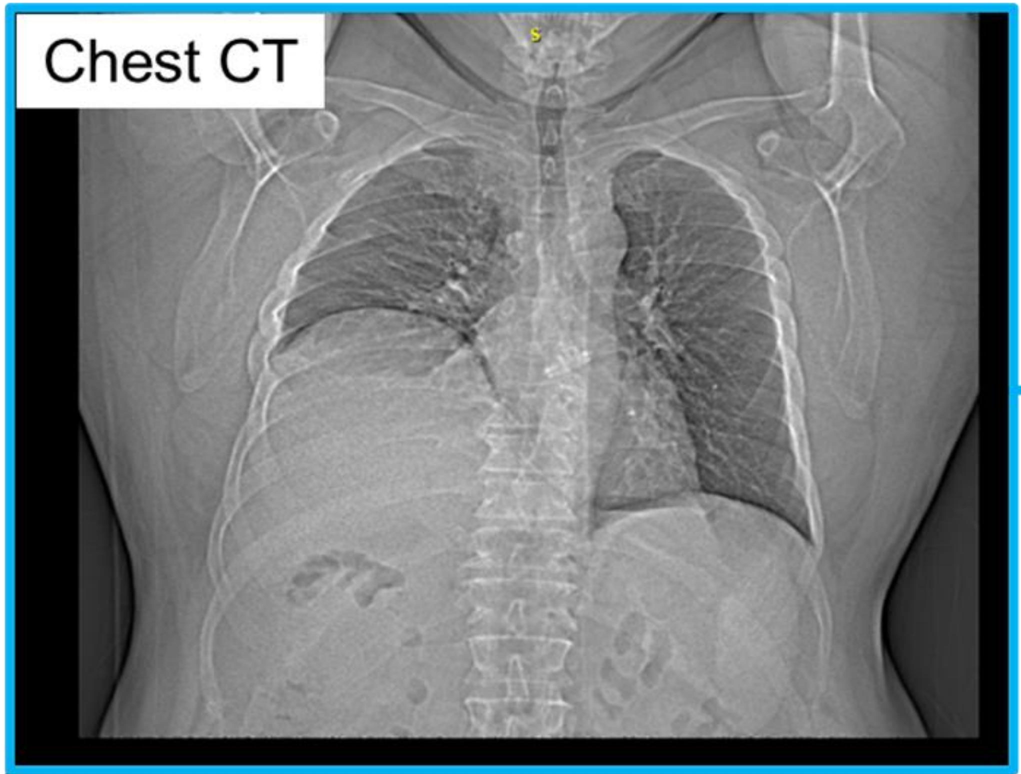
PHASE II CR FOLLOWING AVR: CASE PATIENT

54-YEAR-OLD MALE

23 total sessions over 15 weeks	Before CR (6MWT)	After CR (6MWT)	Δ
Heart rate, bpm	90	109	
BP, mmHg	198/84	148/66	
SpO_2, %	95	98	
RPE	9	15	
Distance, ft	1,402	1,620	**+218**
Speed, mph	2.6	3.1	**+0.5**
METS	3	3.3	**+0.3**
ECG	NSR, no ectopy	NSR, no ectopy	

PHASE II CR FOLLOWING AVR: CASE PATIENT

54-YEAR-OLD MALE



Iatrogenic right hemidiaphragm paralysis and elevation

Adhesions between right hemidiaphragm & lower lobe freed; right hemidiaphragm lowered 2 rib spaces

QUESTIONS & ANSWERS