



# 호흡재활에 사용되는 다양한 Device

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# Contents

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Devices for Assessment

Devices for Airway clearance therapy

Devices for Muscle training

# Assessment of ventilation

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ABGA

Non-invasive method of serial measurement

SaO<sub>2</sub> (Oxyhemoglobin saturation) by Pulse Oxymeter

EtCO<sub>2</sub> (End-tidal CO<sub>2</sub> ) by Capnometer/Capnography

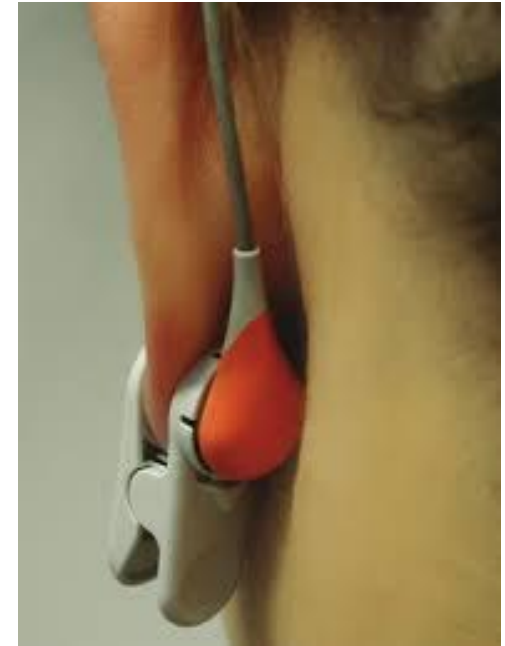
TcCO<sub>2</sub> (Transcutaneous CO<sub>2</sub> ) by transcutaneous blood gas monitoring device



SaO<sub>2</sub> (Oxyhemoglobin saturation)  
by Pulse Oxymeter



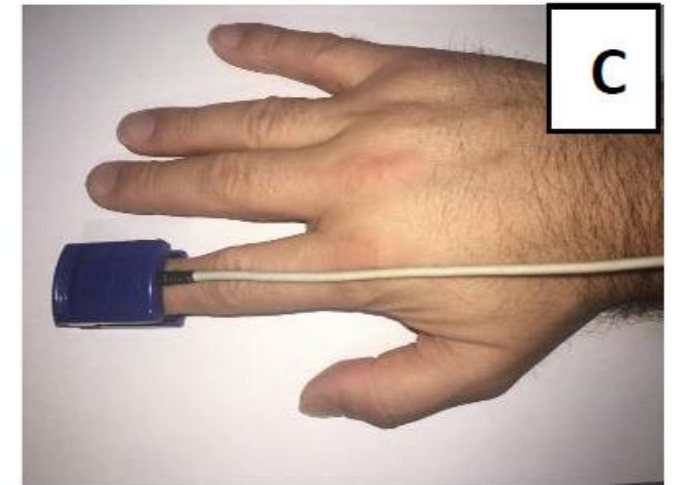
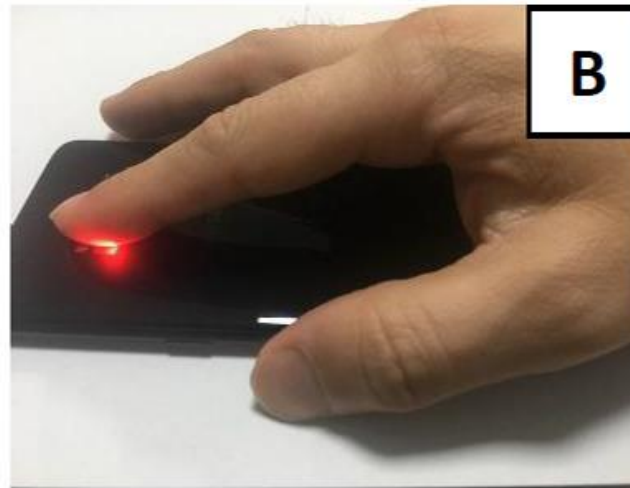
EtCO<sub>2</sub> (End-tidal CO<sub>2</sub>)  
by Capnometer/Capnography



TcCO<sub>2</sub> (Transcutaneous CO<sub>2</sub>)  
by transcutaneous blood gas monitoring

# Reliability of smartphone measurements of vital parameters: A prospective study using a reference method

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# Reliability of smartphone measurements of vital parameters: A prospective study using a reference method

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	<b>SaO<sub>2</sub> calculated by VSM</b>	<b>SaO<sub>2</sub> calculated by ABG device</b>	<b>SaO<sub>2</sub> calculated by smartphone</b>
<b>Mean</b>	95.06	94.02	94.39
<b>Median</b>	96.0	95.0	95.00
<b>Standard deviation</b>	3.508	3.738	3.487
<b>Standard error of the mean</b>	0.350	0.373	0.348

# Reliability of smartphone measurements of vital parameters: A prospective study using a reference method

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	VSM SaO <sub>2</sub> -ABG SaO <sub>2</sub>	SP SaO <sub>2</sub> -ABG SaO <sub>2</sub>
<b>Regression equation</b>	$y = -4.103448 + 1.034483x$	$y = 0.0542 + -0.006171x$
<b>Intercept (95% CI)</b>	-7.2533 (-14.1041 to -0.4024)	-0.08542 (-4.9254 to 4.7545)
<b>Slope (95% CI)</b>	0.0657 (-0.0006 to 0.1381)	-0.00617 (-0.0572 to 0.04489)
<b>Correlation coefficient (95% CI)</b>	0.936 (95% CI=0.907 to 0.957)	0.968 (95% CI=0.952 to 0.978)
<b>Significance level of correlation coefficient</b>	P<0.0001	P<0.0001

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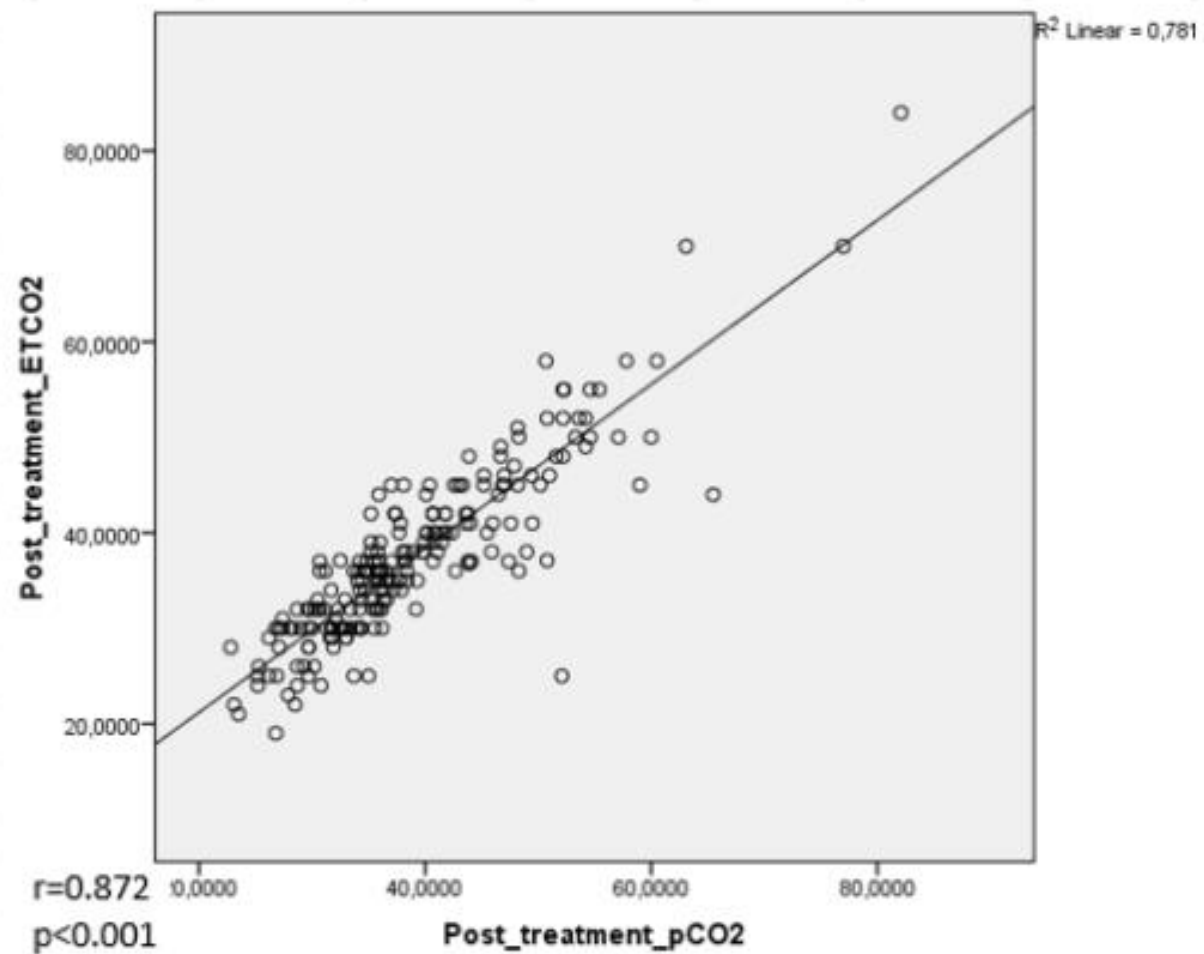
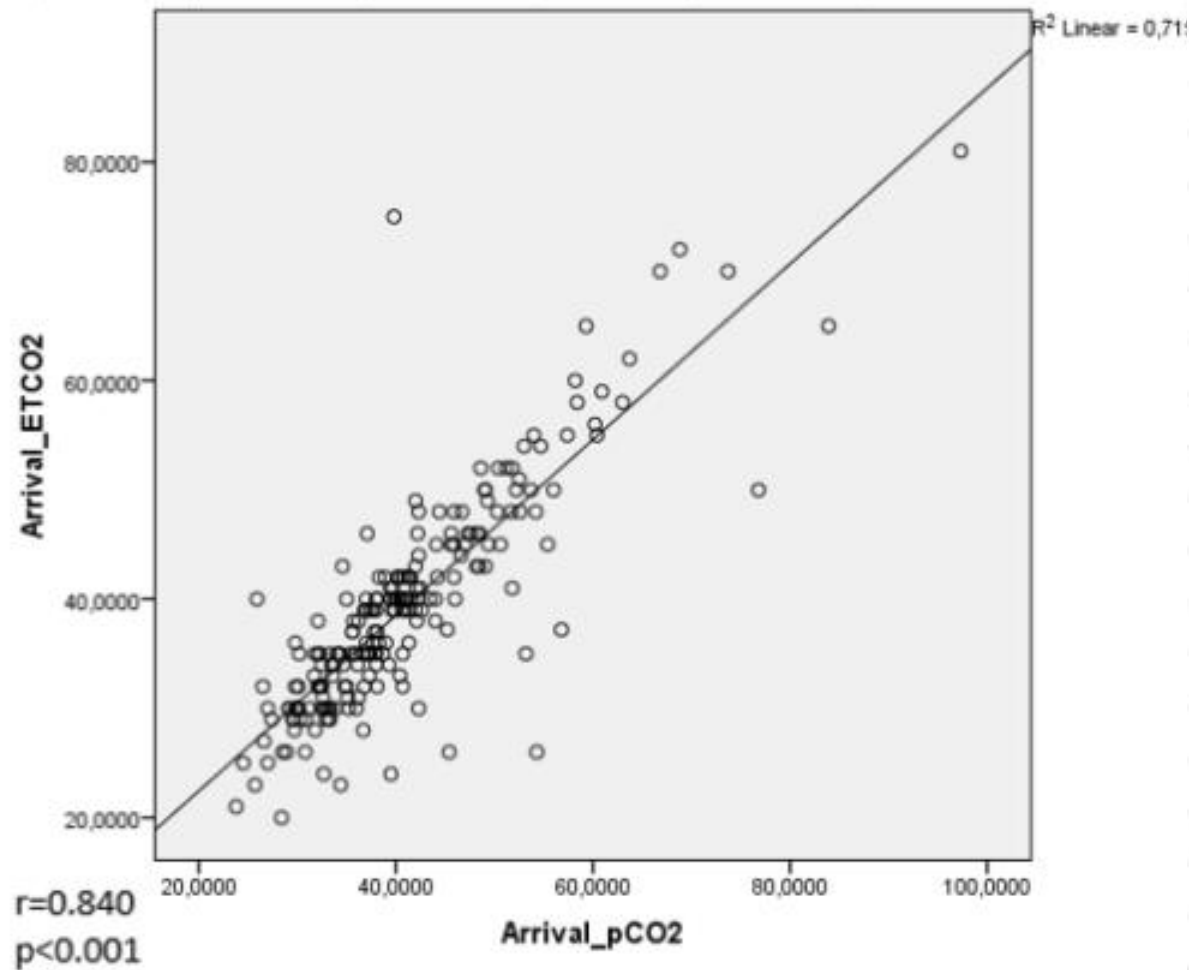
**Table 1.** Advantages and disadvantages of various P<sub>CO<sub>2</sub></sub> monitoring techniques

Criterion	ABG	CBG	VBG	Capnography/ Capnometry	Ptc <sub>CO<sub>2</sub></sub>
“Gold standard”	+	-	-	-	-
Accurate	+	+	-	-	-
Continuous	-	-	-	+	+
Noninvasive	-	-	-	+	+
Painless	-	-	-	+	+
Without puncture damage	-	-	-	+	+
Without blood loss	-	-	-	+	+
Rapid results/no delay	+	-	+	+	-
Additional parameters*	+	+	+	-	-
Nonskilled staff	-	+	+	+	+
Standard venous blood sample	-	-	+	-	-
No technical drift	+	+	+	+	-
Valid with perfusion-ventilation mismatch	+	+	+	-	+
Independent from leakage	+	+	+	-	+
No sleep disturbance	-	-	-	+	+
Independent from dermal perfusion	+	-	+	+	-
No artificial airway necessary	+	+	+	-	+

**Table 1.** Advantages and disadvantages of various P<sub>CO<sub>2</sub></sub> monitoring techniques

Criterion	ABG	CBG	VBG	Capnography/ Capnometry	Ptc <sub>CO<sub>2</sub></sub>
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Noninvasive	-	-	-	+	+
Painless	-	-	-	+	+
Without puncture damage	-	-	-	+	+
Without blood loss	-	-	-	+	+
Rapid results/no delay	+	-	+	+	-
Additional parameters*	+	+	+	-	-
Nonskilled staff	-	+	+	+	+
Standard venous blood sample	-	-	+	-	-
No technical drift	+	+	+	+	-
Valid with perfusion-ventilation mismatch	+	+	+	-	+
Independent from leakage	+	+	+	-	+
No sleep disturbance	-	-	-	+	+
Independent from dermal perfusion	+	-	+	+	-
No artificial airway necessary	+	+	+	-	+

# Correlation of the end-tidal CO2 value with arterial blood gas parameters



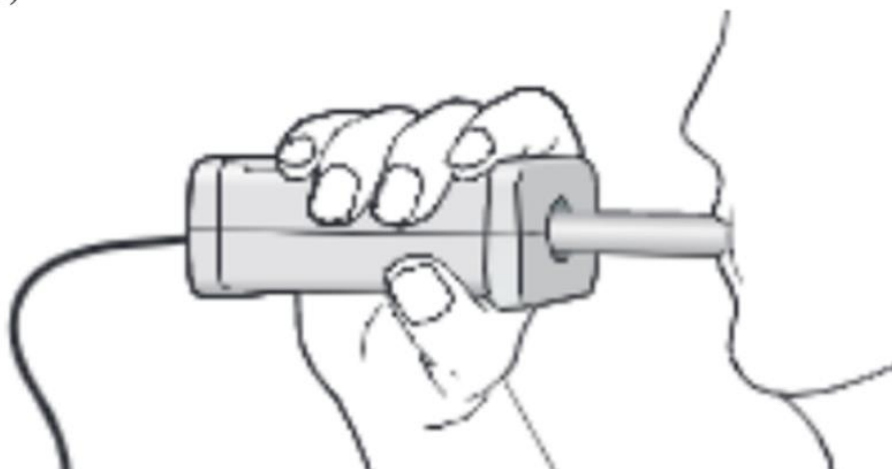
Clinical Application	ABG	CBG	VBG	Capnography/ Capnometry	PtcCO <sub>2</sub>
ICU setting	+	-	-	+	-
Emergency department	+	-	+	-	-
Acute respiratory failure	+	-	-	-	-
Chronic respiratory failure	+	+	-	-	+
Invasive mechanical ventilation	+	+	-	-	-
Noninvasive mechanical ventilation	+	+	-	-	+
Screening for nocturnal alveolar hypoventilation	-	+	-	-	+
General anesthesia	+	-	-	+	-
Sedation in patients at risk for hypoventilation	+	-	-	-	+
Resuscitation	+	-	-	+	-
Screening for hypercapnia	+	+	+	-	+
Confirmation and monitoring of tube placement	-	-	-	+	-

# Correlation of the end-tidal CO2 value with arterial blood gas parameters

(A)

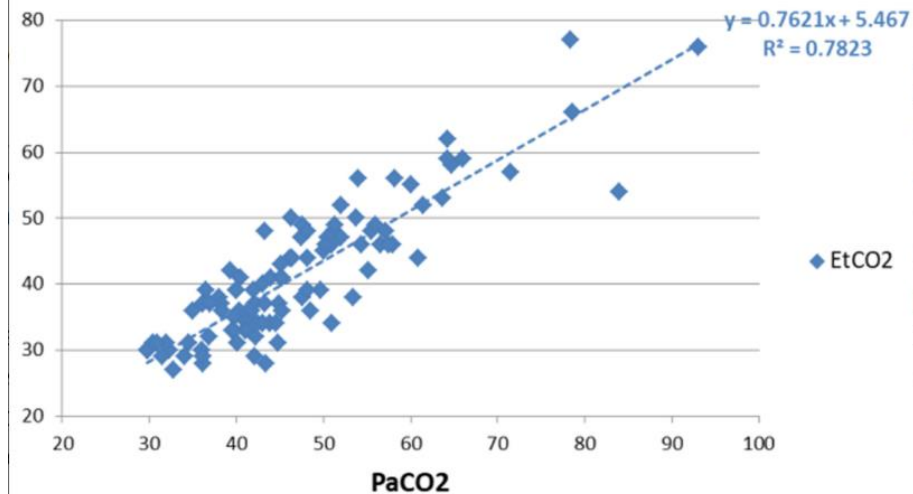


(B)



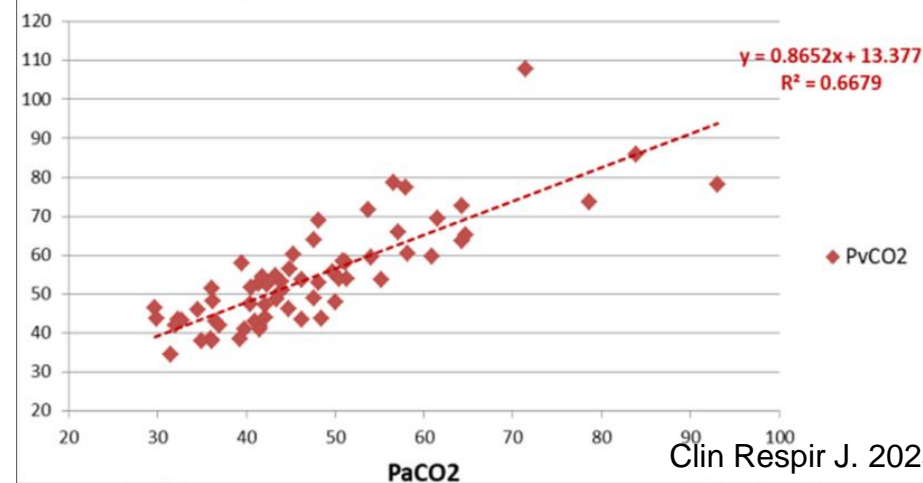
(A)

### Comparison between PaCO2 and EtCO2

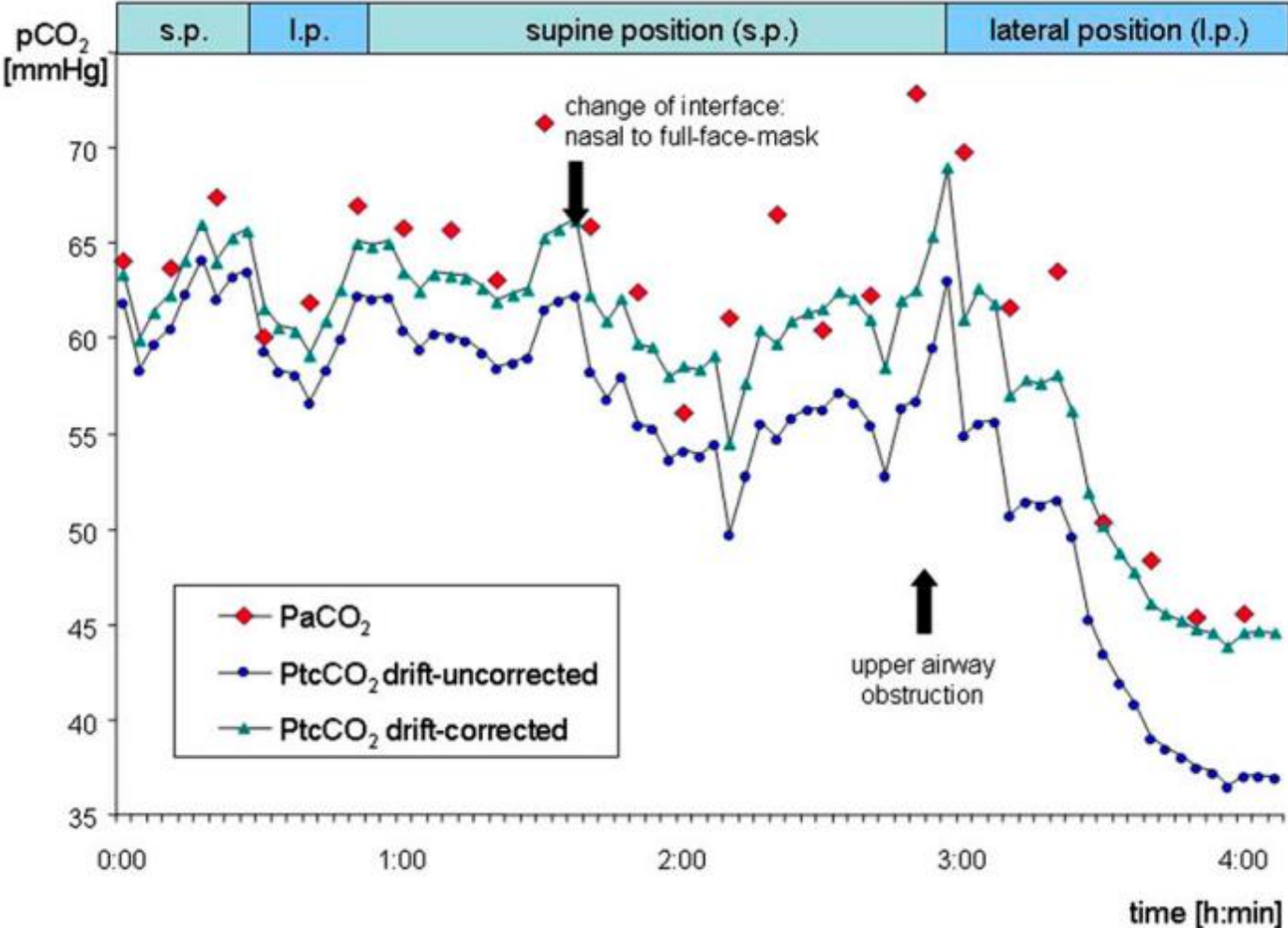


(B)

### Comparison between PaCO2 and PvCO2



# PaCO<sub>2</sub> and PtcCO<sub>2</sub> levels during NIV in a patient with COPD



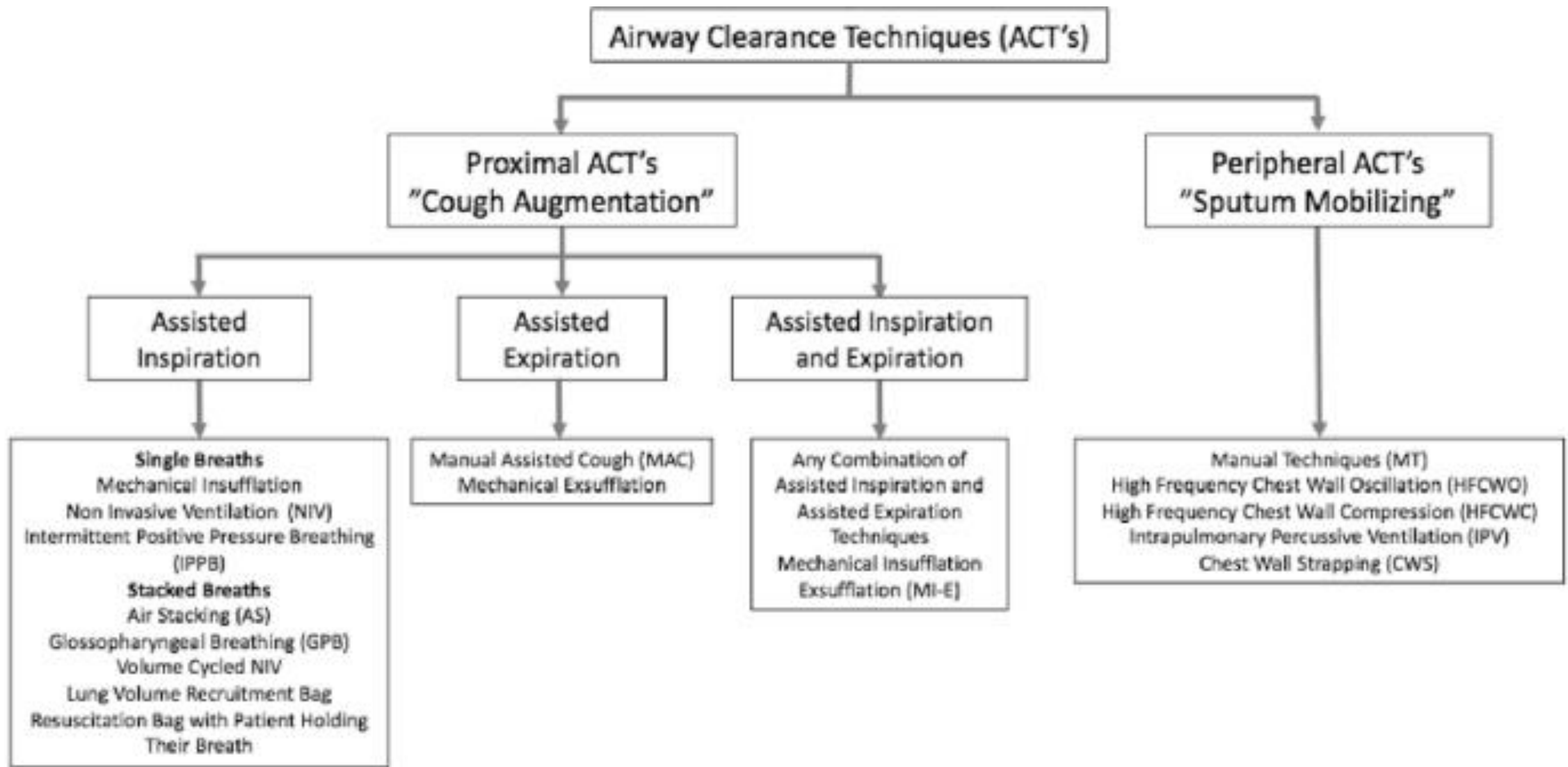
# Contents

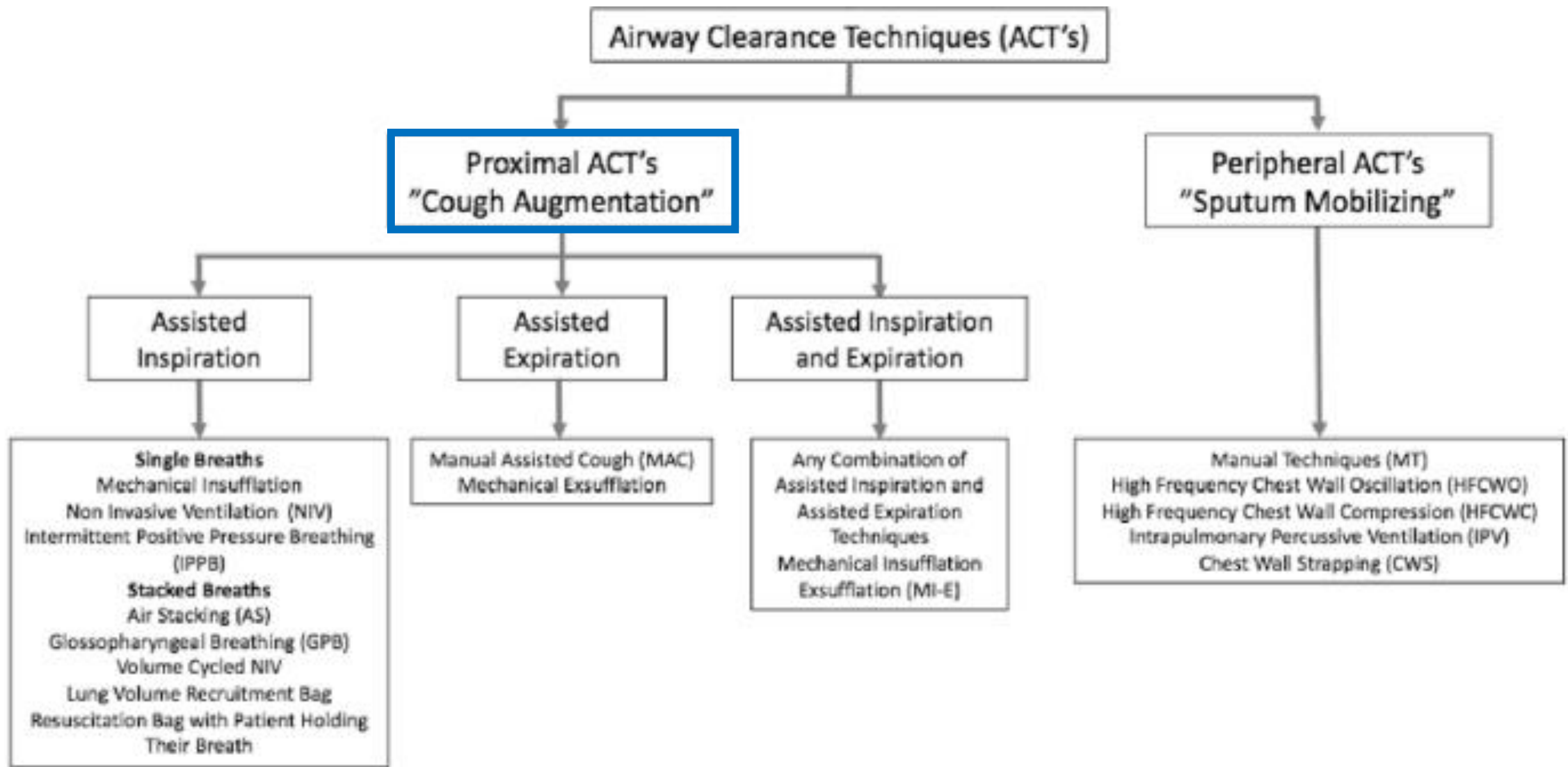
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Devices for Assessment

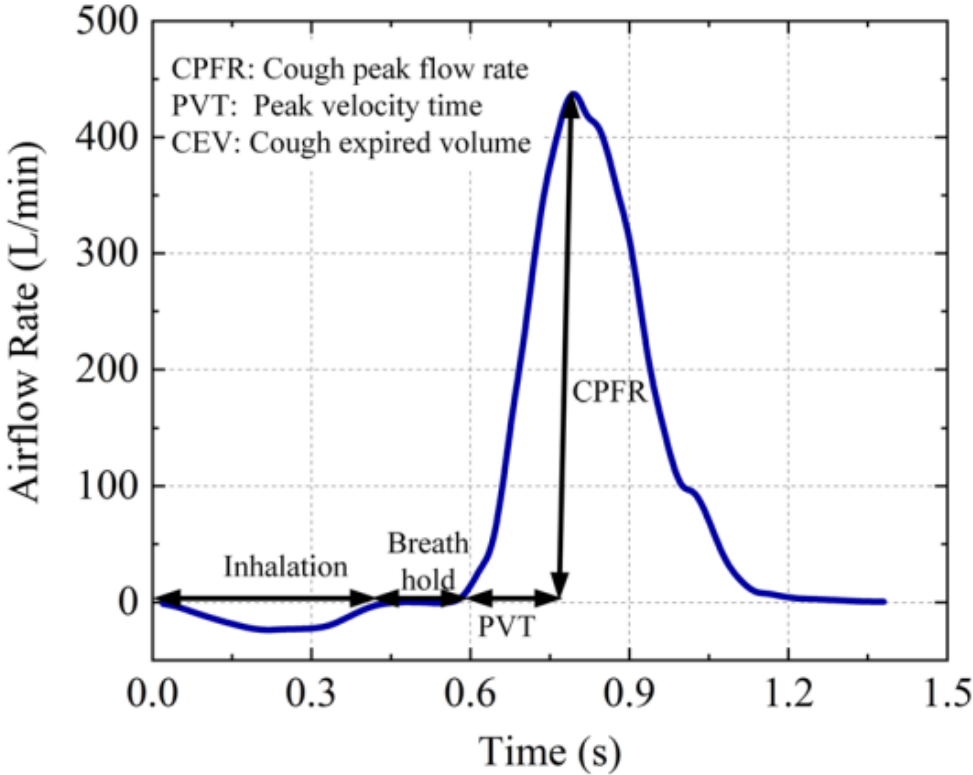
**Devices for Airway clearance therapy**

Devices for Respiratory muscle training

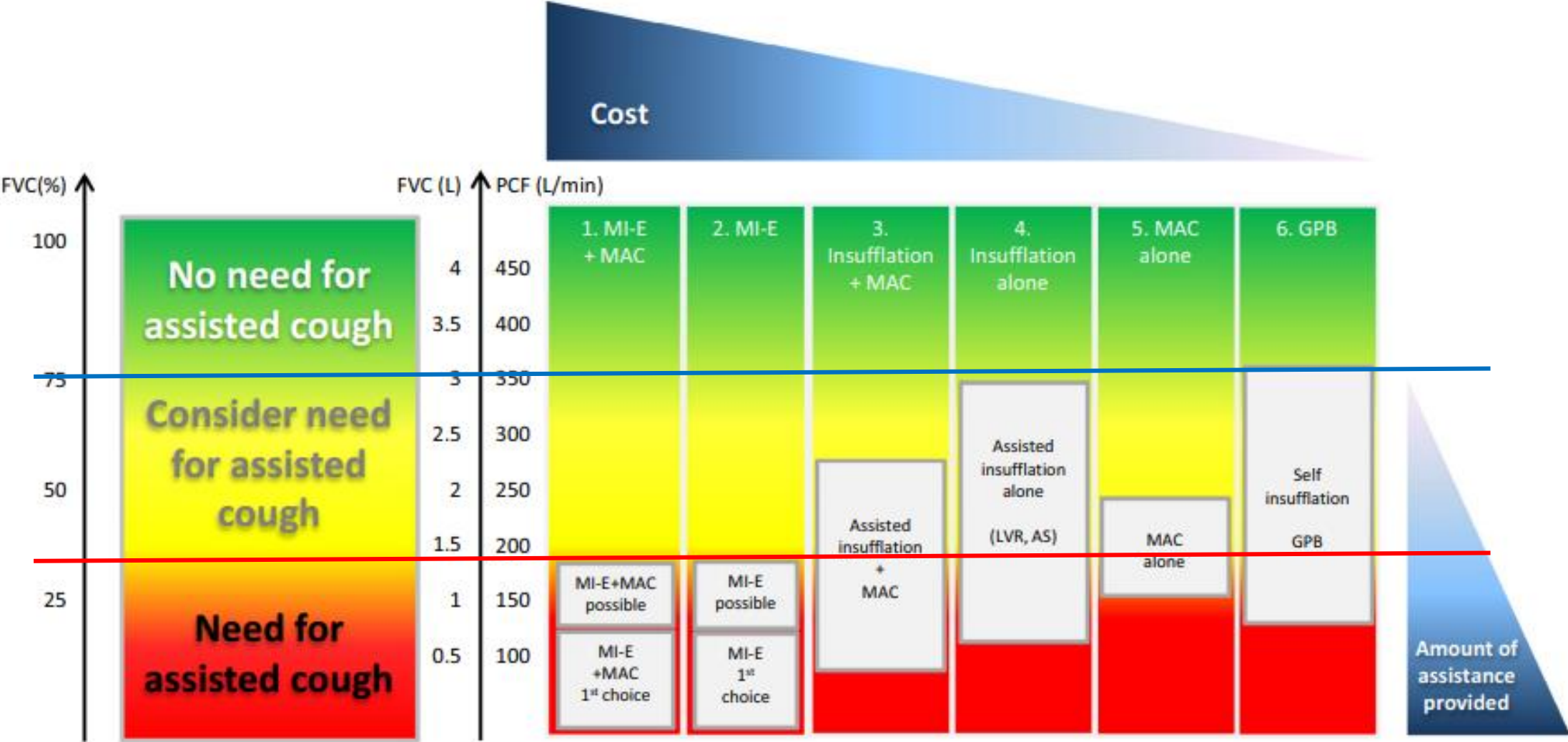




# Peak Cough Flow



# FVC and Peak Cough Flow



# FVC and Peak Cough Flow



FVC(%)  
10

Q2-4

처방전 발급 기준은 어떻게 되나요?

A) 아래 ①과 ② 기준을 충족하여야만 처방전 발급이 가능합니다.

- ① 건강보험 기침유발기 급여대상자에 등록된 사람으로서 인공 호흡기 사용자이고, 해당 상병 및 호흡기 질환 병력 확인, 호흡기능 검사에서 최고호기유량 측정 결과 최대기침유량이 250L/min이하 이어야 합니다.



# Mechanical Insufflator-Exsufflator (MIE, cough machine)

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# Mechanical Insufflator-Exsufflator (MIE, cough machine)



# Mechanical Insufflator-Exsufflator (MIE, cough machine)

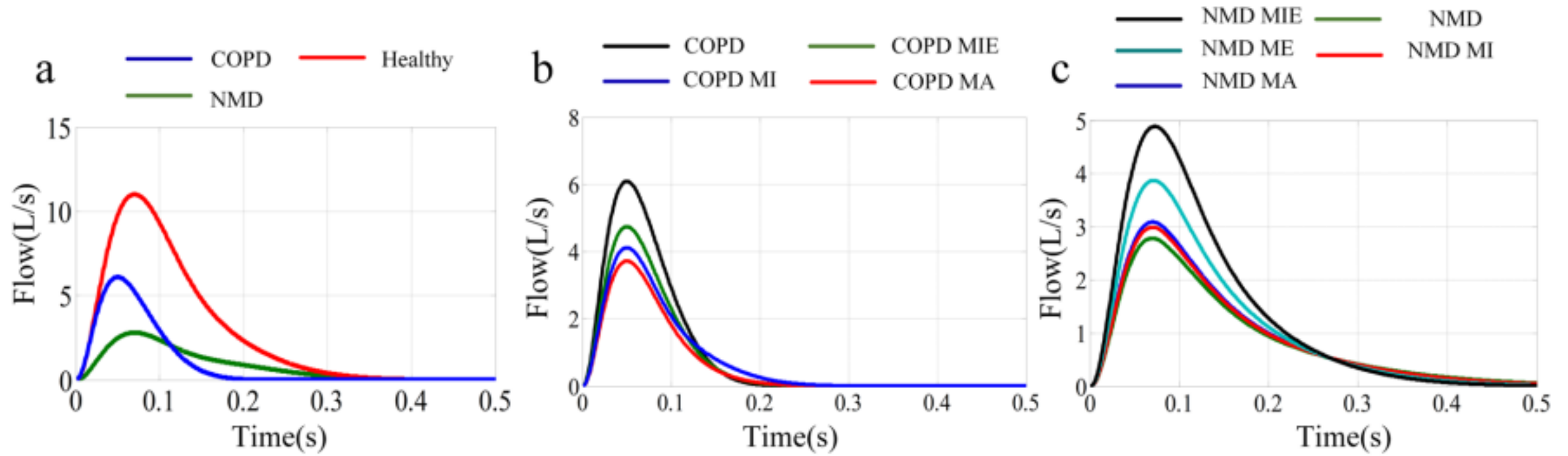
## 기침유발기 임대료

구분	월 기준금액	의료보험 적용시
기침유발기	160,000원	16,000원
소모품 1세트 (튜브 + 마스크)	(기침유발기 임대료 포함)	



*Table 2 Peak cough expiratory flow rate (PCEF), cough expiratory volume (CEV), and peak value time (PVT) in subjects during the various assisted cough techniques*

	Normal subjects (n=9)	COPD (n=8)	Neuromuscular weakness	
			Without scoliosis (n=8)	With scoliosis (n=4)
<b>Baseline</b>				
PCEF (l/min)	668 (310–700)	370 (267–483)	104 (43–188)	288 (175–367)
CEV (l)	2.4 (1.31–4.91)	1.02 (0.4–2.51)	0.5 (0.3–0.8)	0.9 (0.50–1.1)
PVT (ms)	35 (30–45)	32 (25–40)	80 (40–220)	44 (40–50)
<b>Manually assisted cough</b>				
PCEF (l/min)	624 (326–700)	226 (120–315)*	185 (93–355)*	193 (185–287)
CEV (l)	2.91 (1.31–5.31)	0.8 (0.20–1.51)	0.7 (0.31–1.07)	0.5 (0.41–1.01)
PVT (ms)	50 (40–85)**	45 (30–60)*	118 (35–360)*	50 (35–55)
<b>Mechanical insufflation</b>				
PCEF (l/min)	676 (494–695)	288 (218–370)	156 (61–247)	231 (148–597)
CEV (l)	2.2 (0.8–5.91)	0.45 (0.2–0.91)*	0.6 (0.3–1.61)	0.7 (0.3–1.3)
PVT (ms)	35 (30–40)	33 (30–40)	85 (20–420)	45 (30–60)
<b>In combination</b>				
PCEF (l/min)	624 (288–695)	245 (218–370)*	248 (110–343)*	362 (218–440)
CEV (l)	2.2 (0.7–5.41)	0.8 (0.3–1.00)	0.6 (0.40–2.19)	0.6 (0.4–1.01)
PVT (ms)	55 (40–100)	40 (35–50)	75 (20–420)	50 (45–120)



CE (%)	UA	MA	MI	ME	MIE
Healthy	56	—	—	—	—
COPD	12	7.54	8.45	—	9.72
NMD	0.16	0.59	0.64	2.65	9.82

**Table 1.** Cough efficiency (CE).

# **Types of Airway Clearance Modalities**

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## **Breathing techniques**

Active Cycle of Breathing (ACBT)

Autogenic Drainage

## **Manual techniques**

Postural drainage

Clapping, Percussion, and Vibration

## **Mechanical devices**

Positive Expiratory Pressure (PEP)

Oscillatory Positive Expiratory Pressure (OPEP)

High frequency chest wall compression

Intrapulmonary Percussive Ventilation (IPPV)

Mechanical Insufflation-Exsufflator (MIE, cough machine)

# Types of Airway Clearance Modalities

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## Breathing techniques

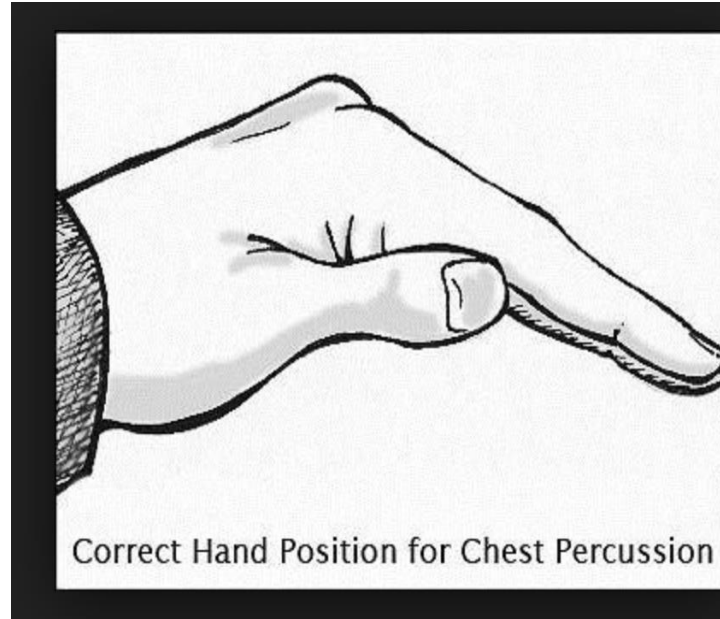
Active Cycle of Breathing (ACBT)  
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# Types of Airway Clearance Modalities

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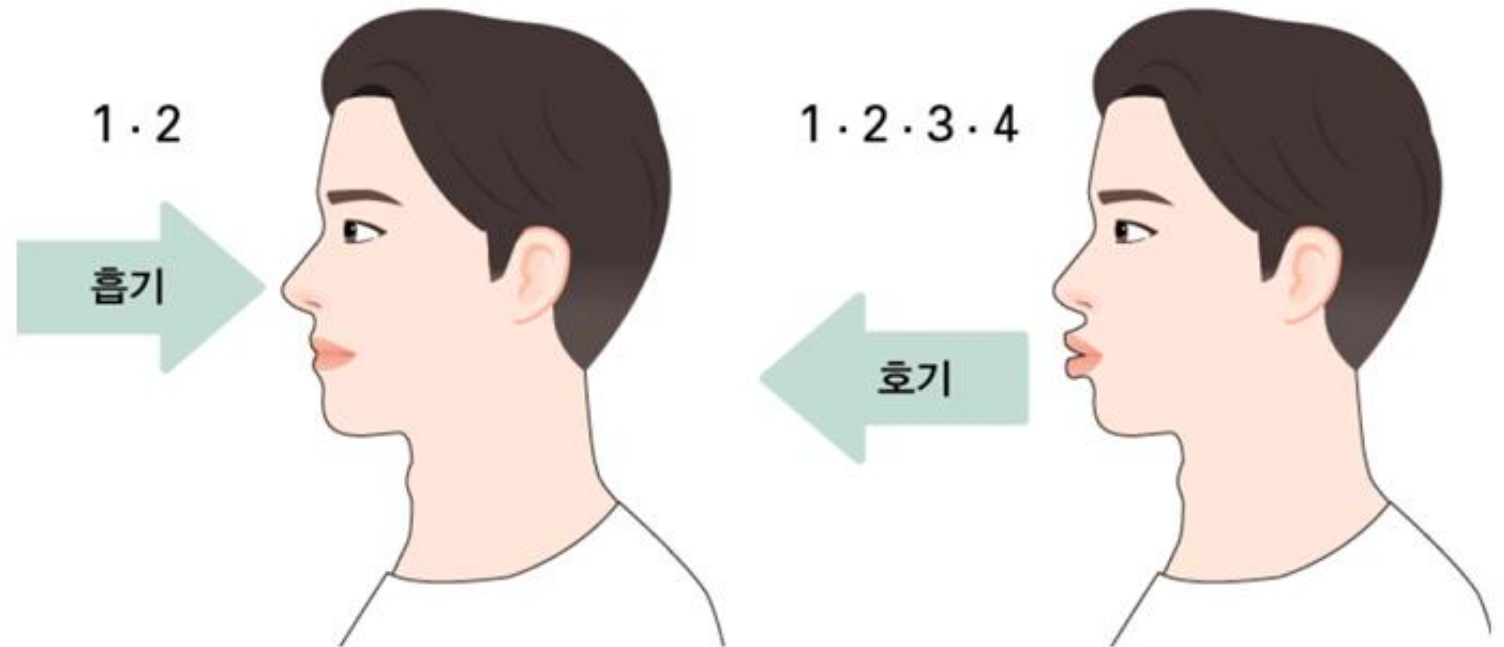
Mechanical Insufflation-Exsufflator (MIE, cough machine)

# Positive Expiratory Pressure (PEP)

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# Positive Expiratory Pressure (PEP)



**Pursed lip breathing**

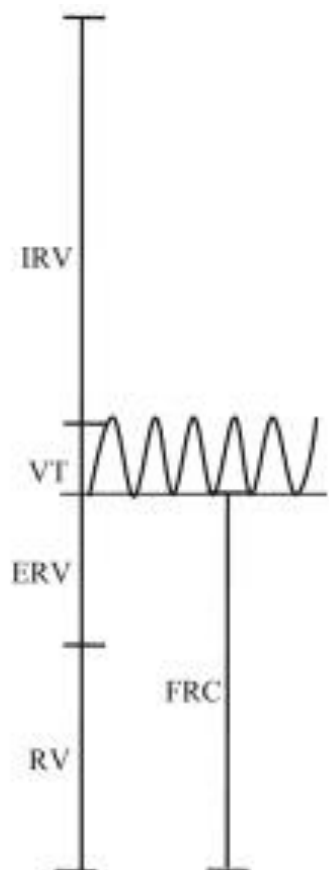
# Effects of Imposed Pursed-Lips Breathing on **Respiratory Mechanics** and **Dyspnea** at **Rest** and During Exercise in COPD

Table 2—Ventilatory Parameters in Eight Patients With COPD During Resting Breathing

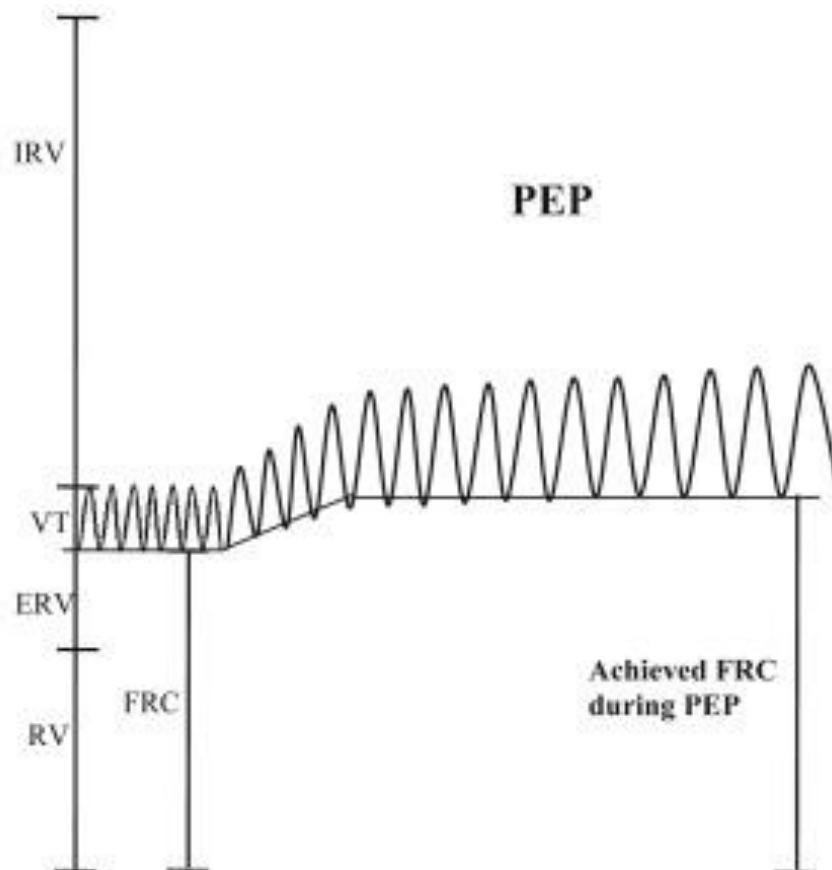
Subject	Control Breathing							PLB						
	T <sub>I</sub> , s	T <sub>TOT</sub> , s	V <sub>T</sub> , L	f <sub>B</sub> , breaths/min	Ṡ <sub>E</sub> , L/min	V <sub>T</sub> /T <sub>I</sub> , L/s	EELV, L	T <sub>I</sub> , s	T <sub>TOT</sub> , s	V <sub>T</sub> , L	f <sub>B</sub> , breaths/min	Ṡ <sub>E</sub> , L/min	V <sub>T</sub> /T <sub>I</sub> , L/s	EELV, L
1	1.16	2.98	0.63	20.13	12.68	0.54	5.85	2.56	9.02	1.41	6.65	9.38	0.55	5.45
2	1.39	4.02	0.86	14.93	12.84	0.60	6.36	1.93	5.84	1.33	10.27	13.66	0.70	6.34
3	4.13	9.74	1.21	6.16	7.45	0.30	5.01	4.28	11.55	1.49	5.19	7.74	0.35	5.35
4	1.02	2.57	0.38	23.35	8.87	0.38	3.51	0.93	2.09	0.86	28.71	24.69	0.94	3.76
5	0.97	2.56	0.84	23.44	19.69	0.86	3.35	0.89	2.48	0.99	24.19	23.95	1.12	3.19
6	3.30	7.07	1.24	8.49	10.52	0.39	4.38	3.30	9.77	2.00	6.14	12.28	0.62	4.30
7	1.12	2.76	0.69	21.74	15.00	0.61	7.98	1.98	4.97	1.27	12.07	15.33	0.64	7.64
8	1.22	3.12	0.76	19.23	14.16	0.63	4.49	1.09	3.37	0.80	17.80	14.24	0.74	4.42
Mean ± SD	1.79 ± 1.22	4.35 ± 2.64	0.83 ± 0.29	17.18 ± 6.69	12.71 ± 3.87	0.54 ± 0.18	5.12 ± 1.56	2.12 ± 1.21	6.14 ± 3.58*	1.27 ± 0.39*	13.88 ± 8.83	15.16 ± 6.19	0.71 ± 0.24	5.06 ± 1.45

\*p < 0.05 vs rest control breathing.

# PEP and Lung volume

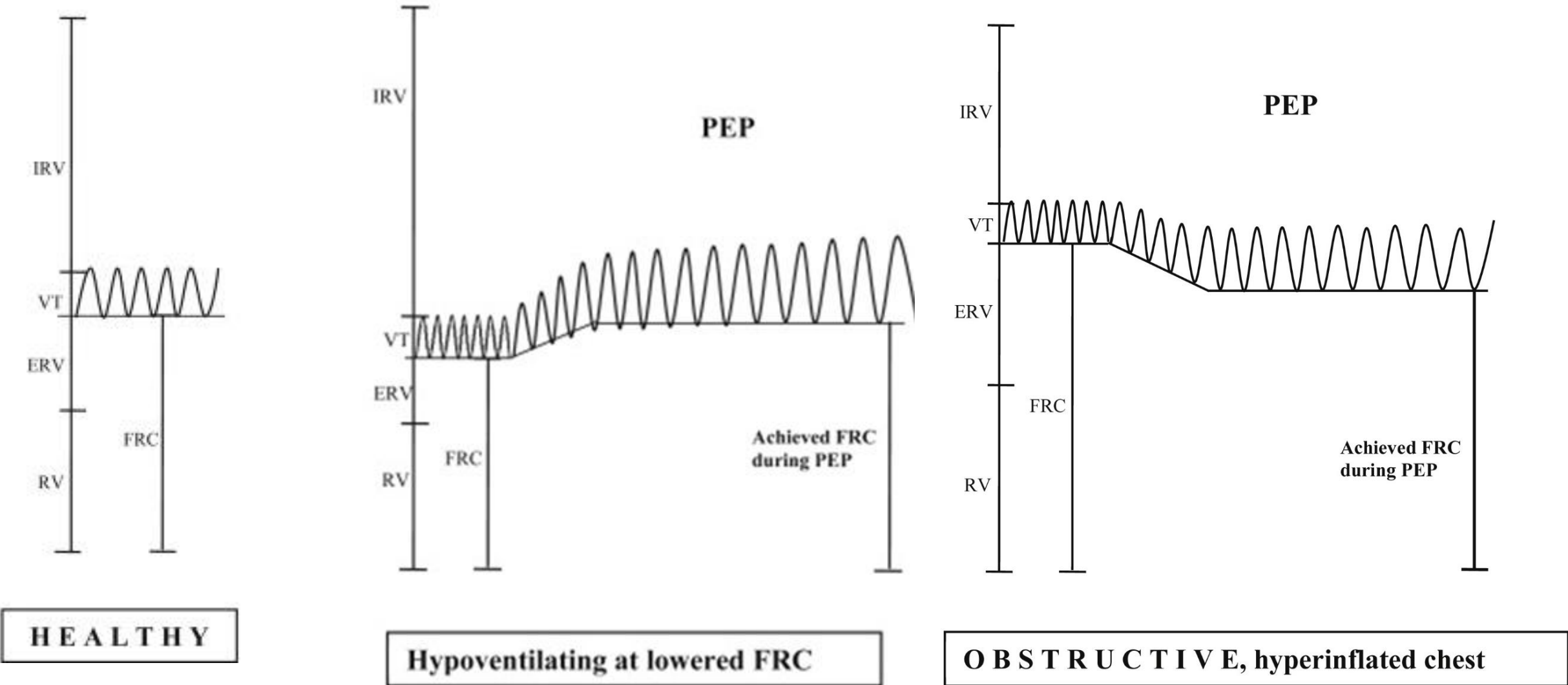


**HEALTHY**



**Hypoventilating at lowered FRC**

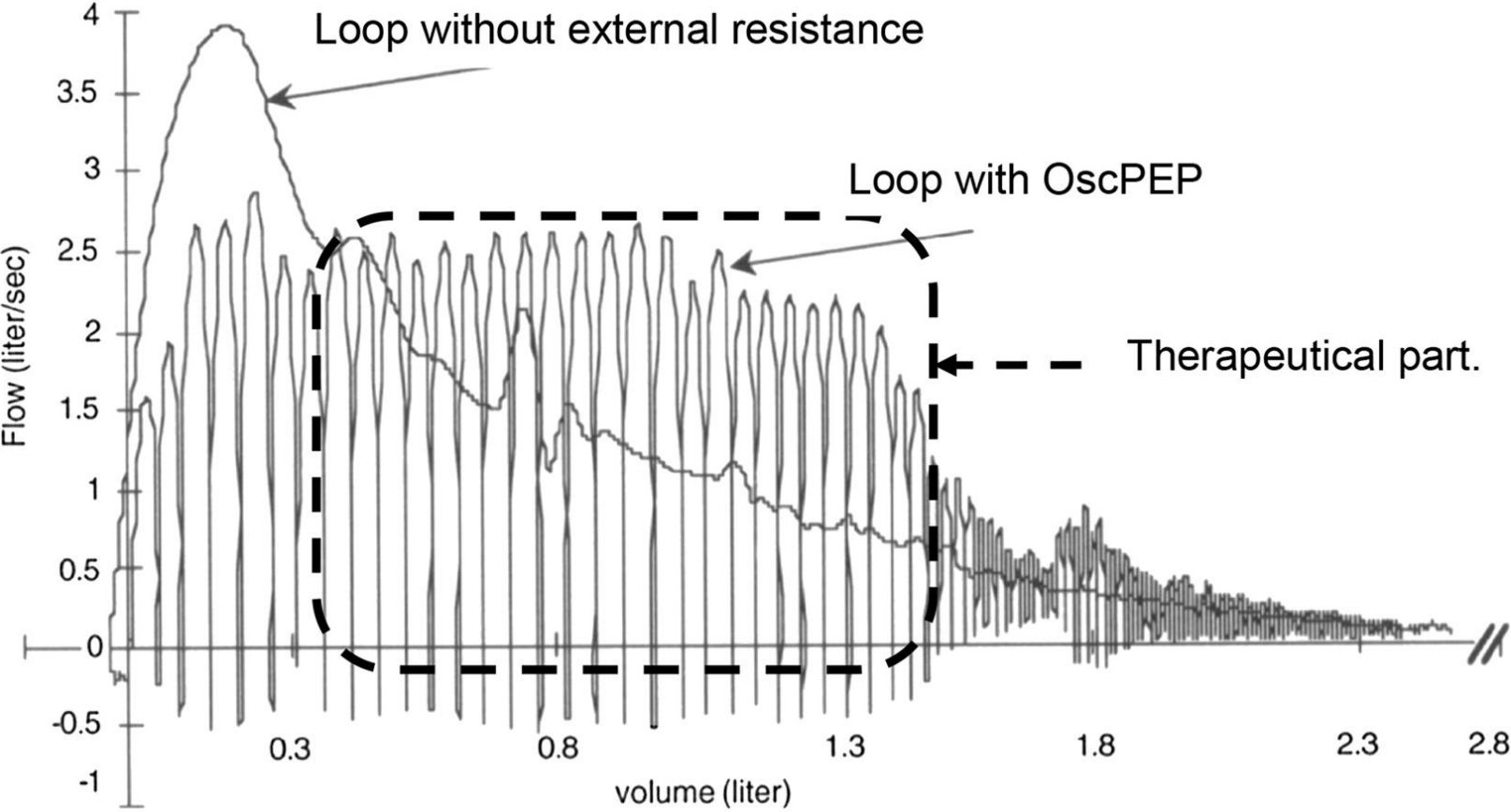
# PEP and Lung volume



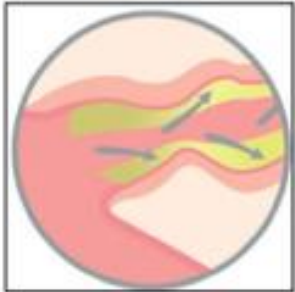
# **Oscillatory Positive Expiratory Pressure (OPEP)**

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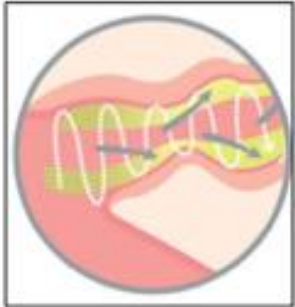
# Oscillatory Positive Expiratory Pressure (OPEP)



Airway with a mucus plug

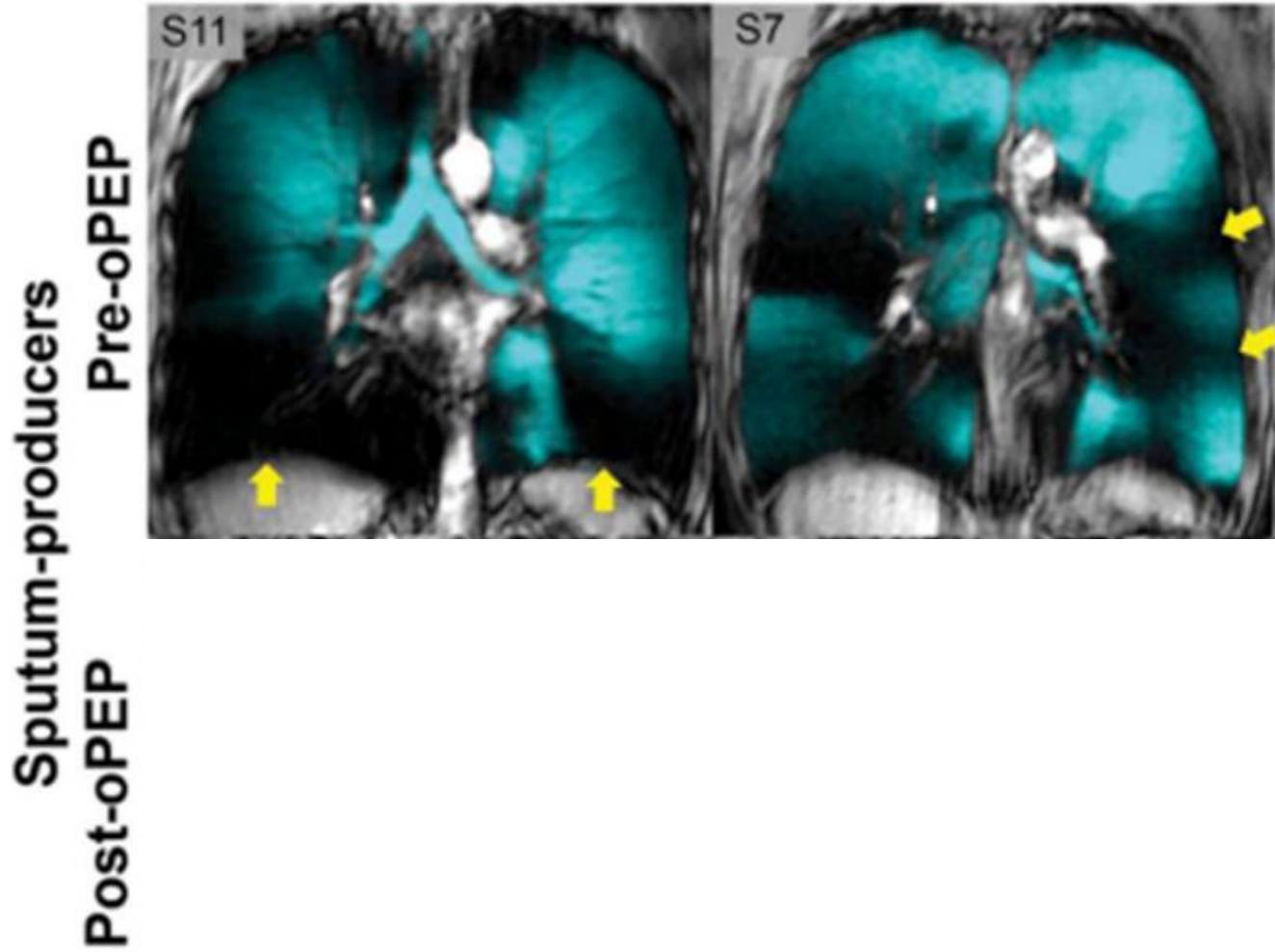


Resistance holds the airways open



Pulses help thin and loosen mucus while the airways are held open

# OPEP and fMRI ventilation



Name	Manufacturer	Type	Mechanism	Settings	Range
TheraPEP	Smiths Medical, Minneapolis, MN	PEP	Flow resistor	1–6	13 cm H <sub>2</sub> O
Resistex	Mercury Medical, Clearwater, FL	PEP	Flow resistor	1–4	5–20 cm H <sub>2</sub> O
Threshold PEP	Phillips Respironics, Chichester, UK	PEP	Threshold resistor	Twist 5–20 cm H <sub>2</sub> O	5–20 cm H <sub>2</sub> O
AccuPEP	Sarnova, Dublin, Ohio	PEP	Threshold resistor	1–4	5–20 cm H <sub>2</sub> O
AccuPAP	Sarnova, Dublin, Ohio	PEP	Threshold resistor with external flow	1–4	5–20 cm H <sub>2</sub> O
EzPAP	Smiths Medical, Minneapolis, MN	PEP	Threshold resistor with external flow	NA	5–20 cm H <sub>2</sub> O
Versa PAP	Monaghan Medical, Plattsburgh, NY	PEP	Threshold resistor with external flow	NA	5–20 cm H <sub>2</sub> O
Oxyjet	D R Burton Healthcare, Farmville, NC	PEP	Threshold resistor with external flow	NA	5–20 cm H <sub>2</sub> O
Acapella DH	Smiths Medical, Minneapolis, MN	OPEP	Intermittent occlusion	1–5	5–20 cm H <sub>2</sub> O
Acapella DM	Smiths Medical, Minneapolis, MN	OPEP	Intermittent occlusion	1–5	5–20 cm H <sub>2</sub> O
Acapella Choice	Smiths Medical, Minneapolis, MN	OPEP	Intermittent occlusion	1–5	5–20 cm H <sub>2</sub> O
VibraPEP	Sarnova, Dublin, Ohio	OPEP	Intermittent occlusion	1–5	5–20 cm H <sub>2</sub> O
Aerobika	Monaghan Medical, Plattsburgh, NY	OPEP	Intermittent occlusion	1–5	5–20 cm H <sub>2</sub> O
vPEP	D R Burton Healthcare, Farmville, NC	OPEP	Intermittent occlusion	Dial	5–20 cm H <sub>2</sub> O
ShurClear	Mercury Medical, Clearwater, FL	OPEP	Intermittent occlusion	Angle	6–20 Hz
PocketPEP	D R Burton Healthcare, Farmville, NC	OPEP	Intermittent occlusion	Flip	5–20 cm H <sub>2</sub> O

PEP = positive expiratory pressure

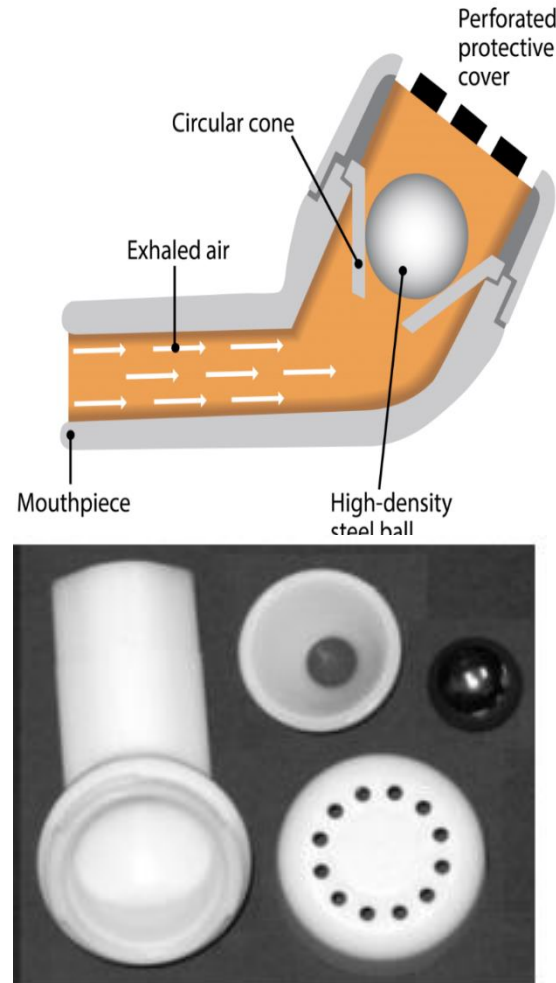
NA = not applicable

OPEP = oscillatory positive expiratory pressure

# Oscillatory Positive Expiratory Pressure (OPEP)



**Flutter Valve**

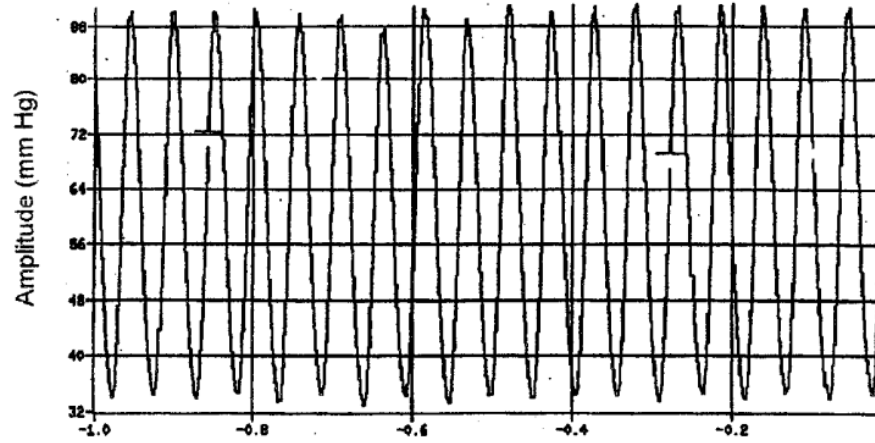


# Performance Comparison of Two Oscillating Positive Expiratory Pressure Devices: Acapella Versus Flutter

Teresa A Volsko RRT FAARC, Juliann M DiFiore, and Robert L Chatburn RRT FAARC

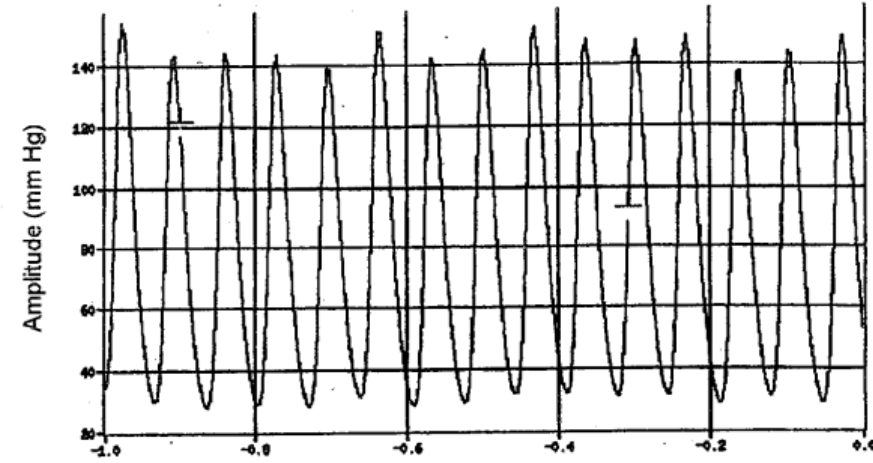
**Flutter**

Flow = 10 L/min  
Frequency = 19 Hz  
Amplitude = 55 mm Hg



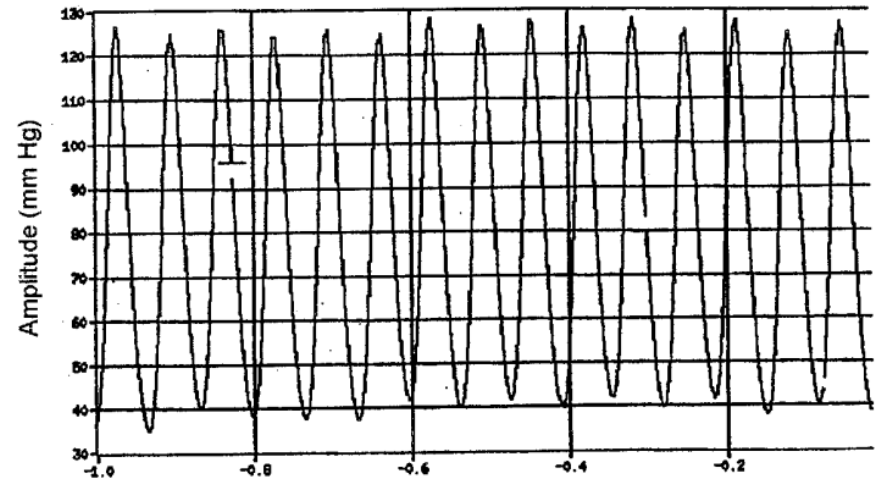
**Flutter**

Flow = 25 L/min  
Frequency = 15 Hz  
Amplitude = 115 mm Hg



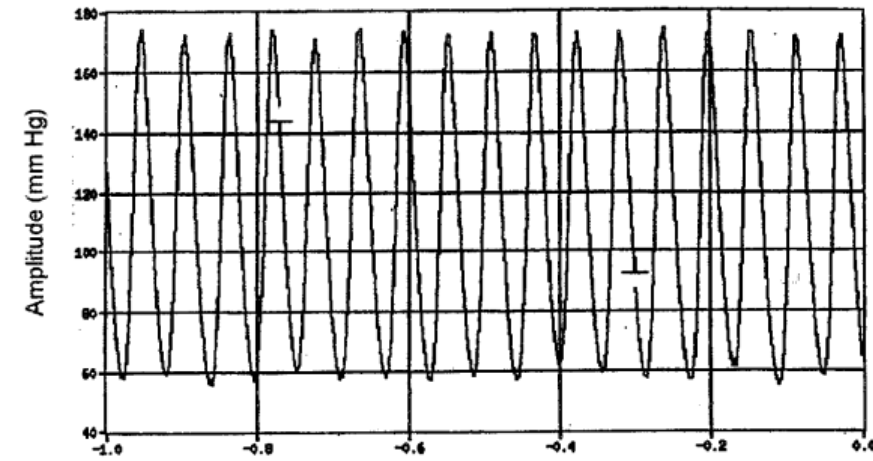
**Acapella (blue)**

Flow = 10 L/min  
Frequency = 15 Hz  
Amplitude = 85 mm Hg

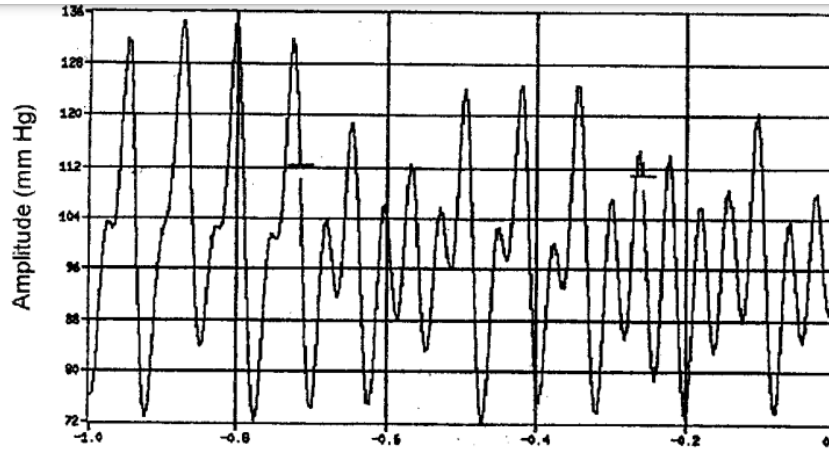


**Acapella (green)**

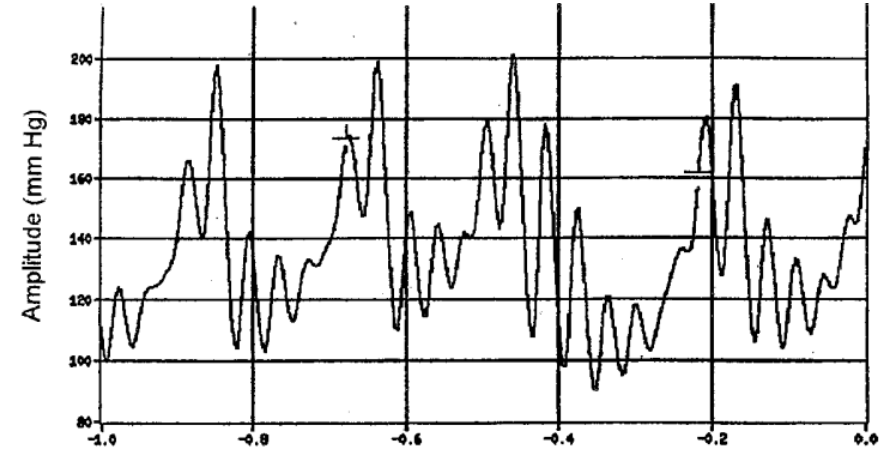
Flow = 25 L/min  
Frequency = 17 Hz  
Amplitude = 120 mm Hg



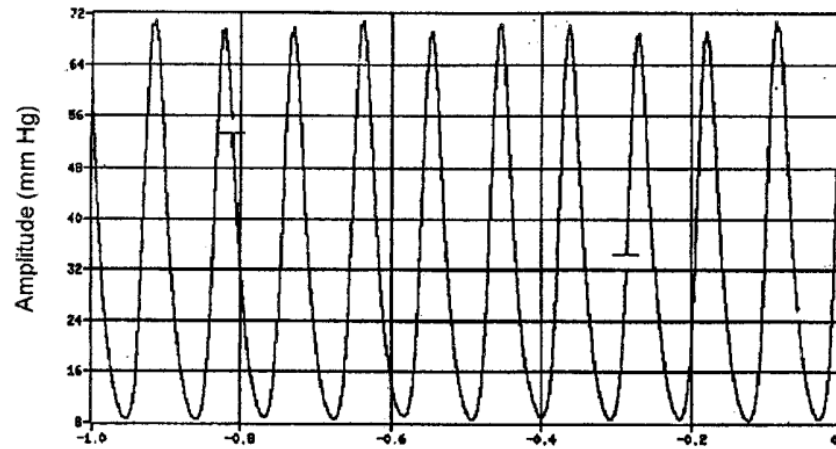
**Flutter**  
Flow = 5 L/min  
Frequency = 20 Hz  
Amplitude = 35 mm Hg



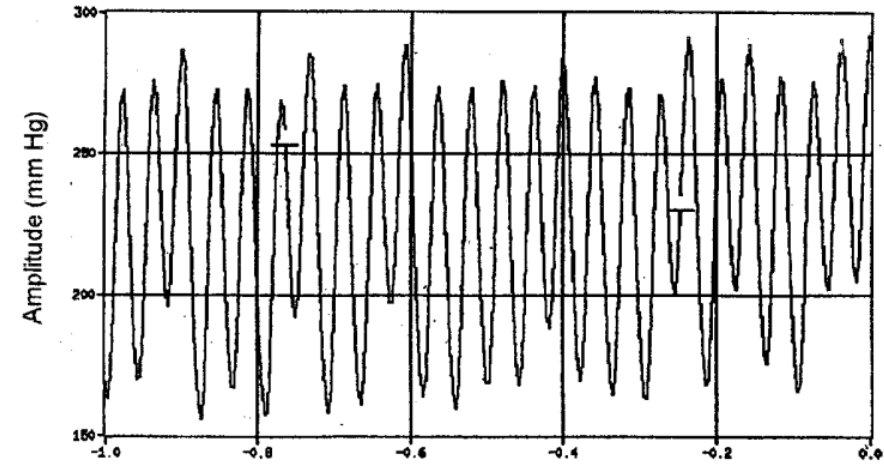
**Flutter**  
Flow = 30 L/min  
Frequency = 20–30 Hz  
Amplitude = 20–100 mm Hg



**Acapella (green)**  
Flow = 5 L/min  
Frequency = 10 Hz  
Amplitude = 60 mm Hg








**Acapella (blue)**  
Flow = 30 L/min  
Frequency = 25 Hz  
Amplitude = 100 mm Hg

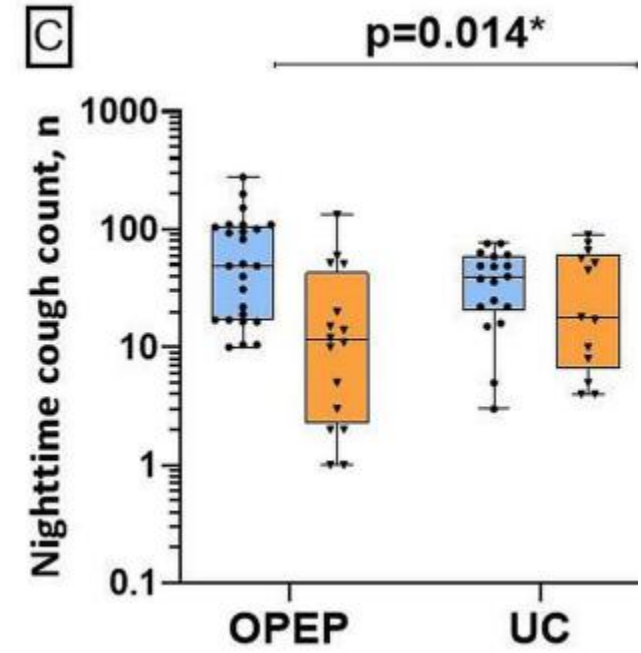
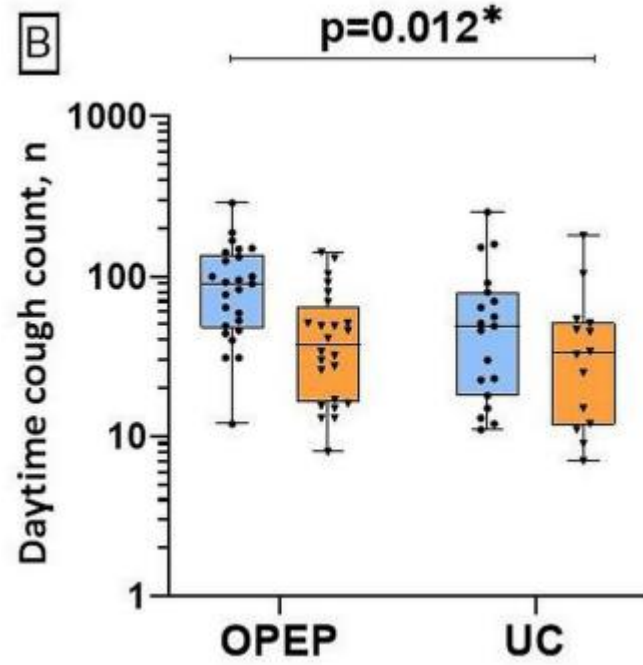
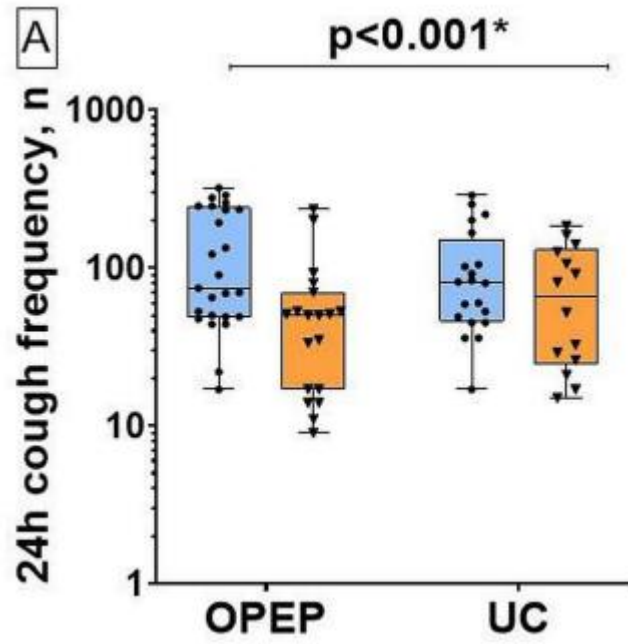


Original research

# Oscillatory positive expiratory pressure therapy in COPD (O-COPD): a randomised controlled trial

Saeed M Alghamdi <sup>1,2</sup> Abdullah S Alsulayyim <sup>2,3</sup> Ali M Alasmari,<sup>2,4</sup>  
Keir E J Philip <sup>2</sup> Sara C Buttery,<sup>2</sup> Winston A S Banya,<sup>2</sup> Michael I Polkey <sup>2</sup>,  
Surinder S Biring,<sup>5</sup> Nicholas S Hopkinson <sup>2</sup>





**Table 2** Impact of treatment on primary and secondary endpoints

Primary secondary endpoints	Intention to treat analysis (imputed data)							
	OPEP (n=61) mean±SD			UC (n=61) mean±SD			Between groups	
	Pre	Post	Change (95% CI)	Pre	Post	Change (95% CI)	MD (95% CI)	P value
LCQ total score	11.09±4.01	12.63±4.28	1.54 (0.33 to 2.18)	11.06±3.93	11.57±3.97	0.51 (0.34 to 1.89)	1.03 (0.71 to 2.10)	0.03
Physical	4.51±1.54	4.99±1.91	0.48 (−0.40 to 0.75)	4.36±1.53	4.66±1.51	0.30 (−0.20 to 0.77)	0.18 (−0.01 to 0.80)	0.06
Psychological	4.01±1.66	4.72±1.74	0.74 (0.3 to 1.02)	4.26±1.61	4.49±1.64	0.23 (−0.05 to 0.75)	0.51 (0.06 to 0.90)	0.02
Social	2.55±1.16	2.85±1.09	0.29 (−0.06 to 0.52)	2.43±0.97	2.49±0.98	0.06 (−0.42 to 0.25)	0.23 (−0.08 to 0.44)	0.18
FACIT (fatigue)	27.16±12.65	32.98±12.82	5.82 (0.11 to 9.46)	27.03±12.25	28.17±13.06	1.14 (0.23 to 6.32)	4.68 (1.34 to 8.02)	<0.001
EQ-5D	52.38±23.61	58.29±27.48	5.91 (0.08 to 16.83)	52.57±25.09	54.48±25.31	1.91 (0.99 to 11)	4.00 (0.49 to 19.75)	0.04
Cough-VAS	51.95±24.97	51.60±26.73	−0.32 (−5.81 to 9.72)	54.18±25.56	51.95±26.98	−2.23 (−5.30 to 11.67)	1.91 (−5.53 to 8.30)	0.68
CAT total	31.32±9.03	29.36±10.36	−1.96 (−2.51 to 2.19)	32.62±8.50	30.81±8.88	−1.81(−4.38 to 2.83)	0.15 (−1.93 to 1.63)	0.18
Sputum frequency scale	1.33±0.65	1.84±0.88	0.50 (0.11 to 0.81)	1.41±0.79	1.47±0.77	0.06 (0.02 to 0.22)	0.44 (0.27 to 0.60)	<0.001

# High-frequency airway clearance techniques

---

## Unassisted

Oscillatory Positive Expiratory Pressure (OPEP)

## Assisted

Intrapulmonary percussive ventilation (IPV)

Airway application

High frequency chest wall compression (HFCWC)

External (chest wall)

# High frequency chest wall oscillator



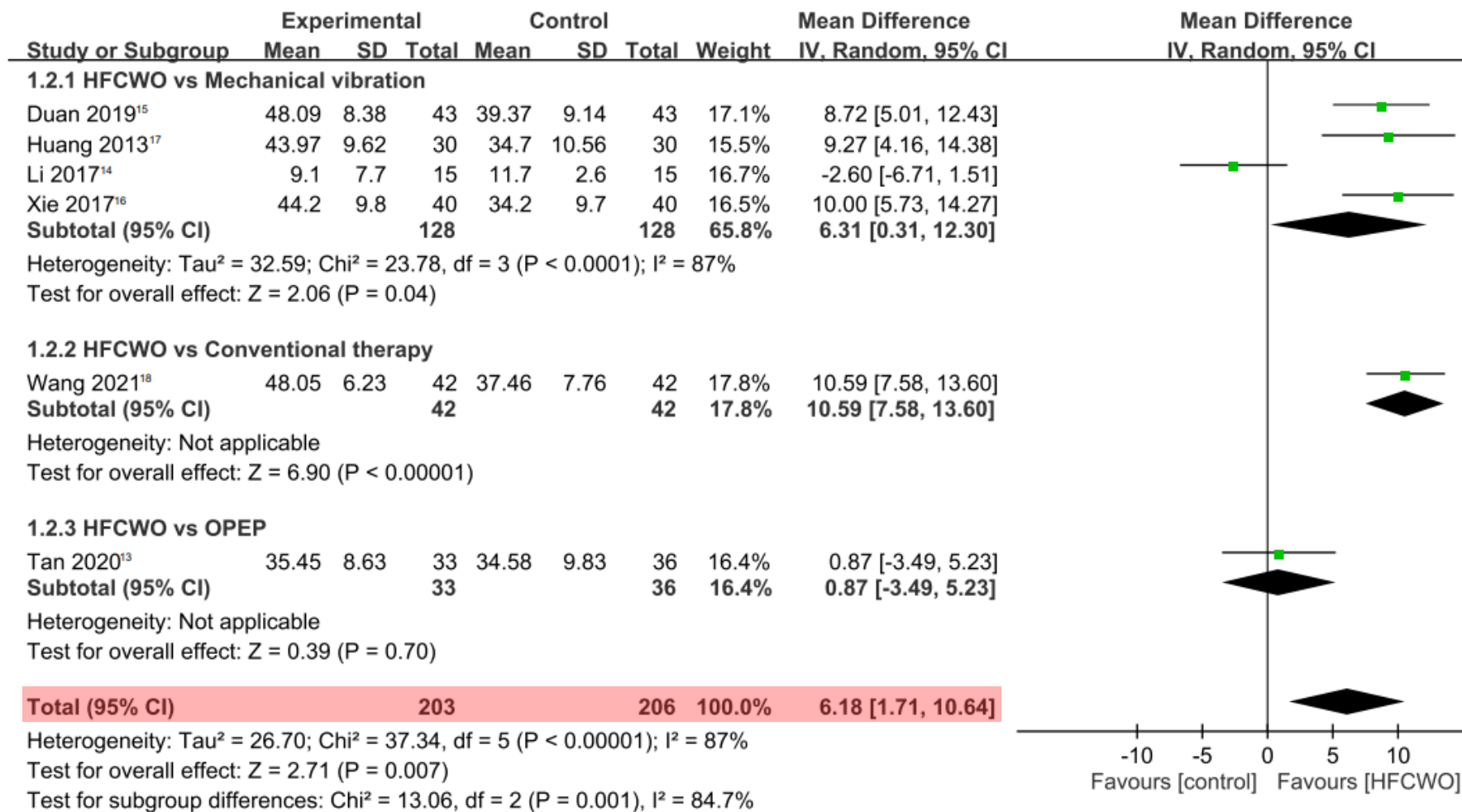
nonstretch inflatable vest



variable air-pulse generator

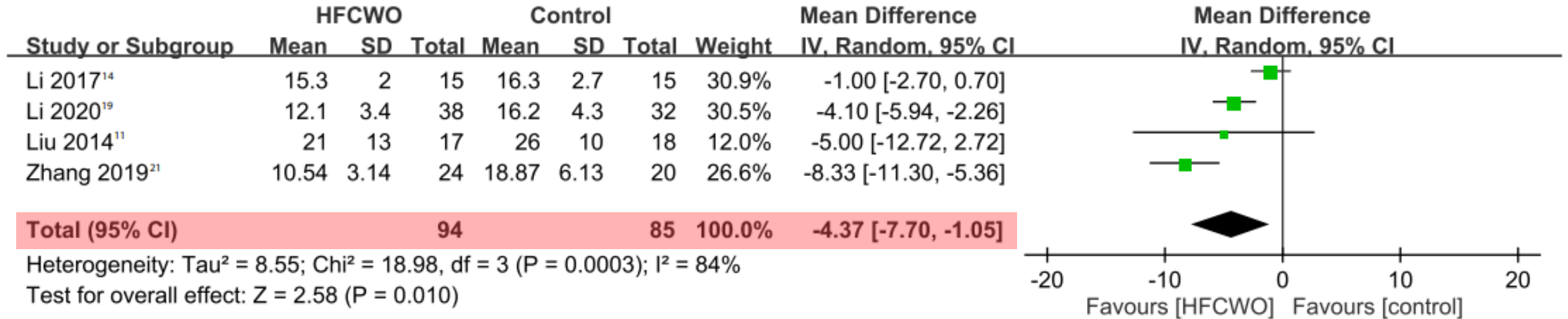


# Sputum expectoration in AECOPD patients



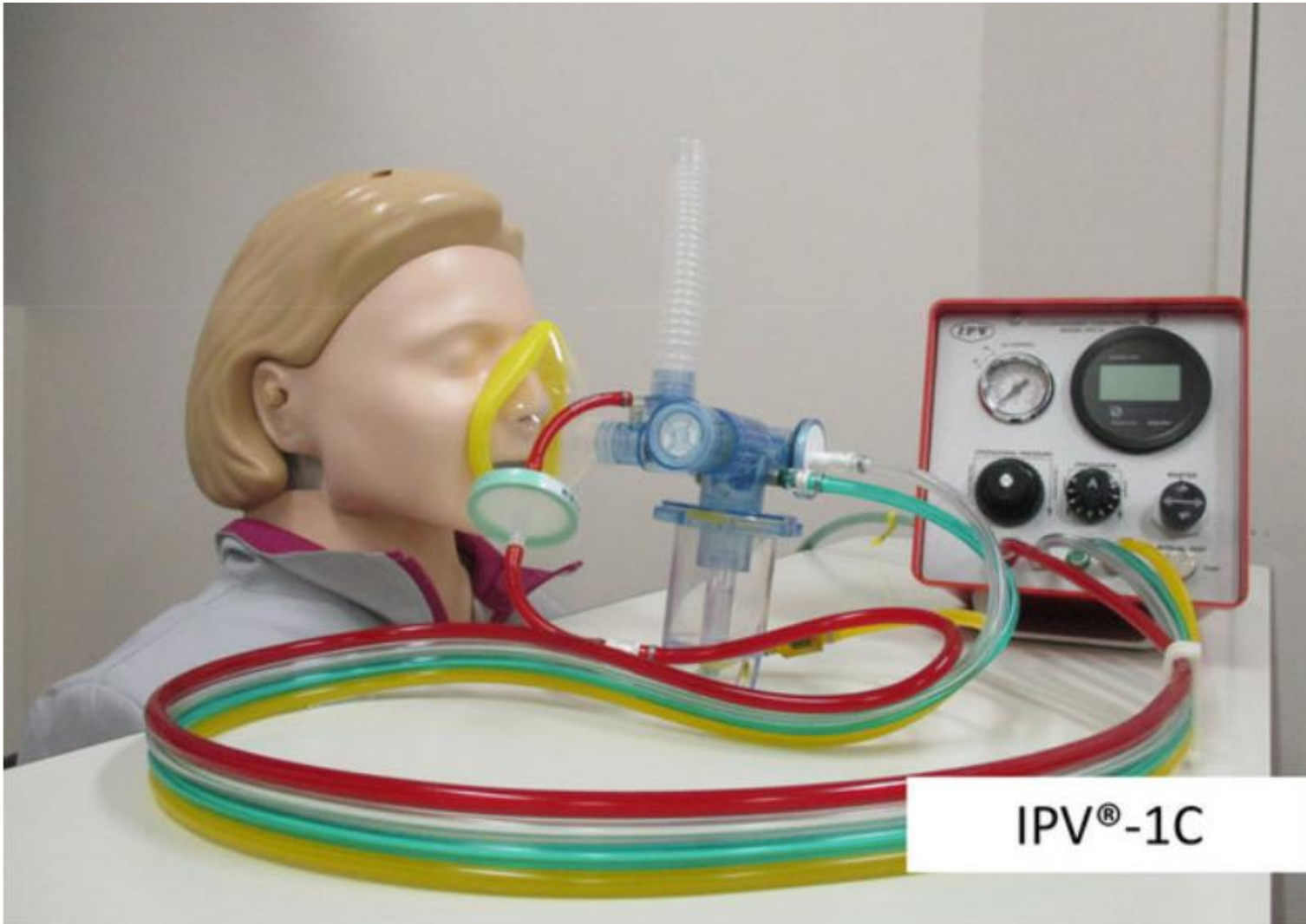
**Figure 4** Forest plot of HFCWO vs mechanical vibration, conventional, and OPEP, outcome: Sputum expectoration (mL).

# Hospital stays in AECOPD patients



**Figure 5** Forest plot of HFCWO versus control group, outcome: Hospital stay (days).

# Intrapulmonary percussive ventilation



# MetaNeb®

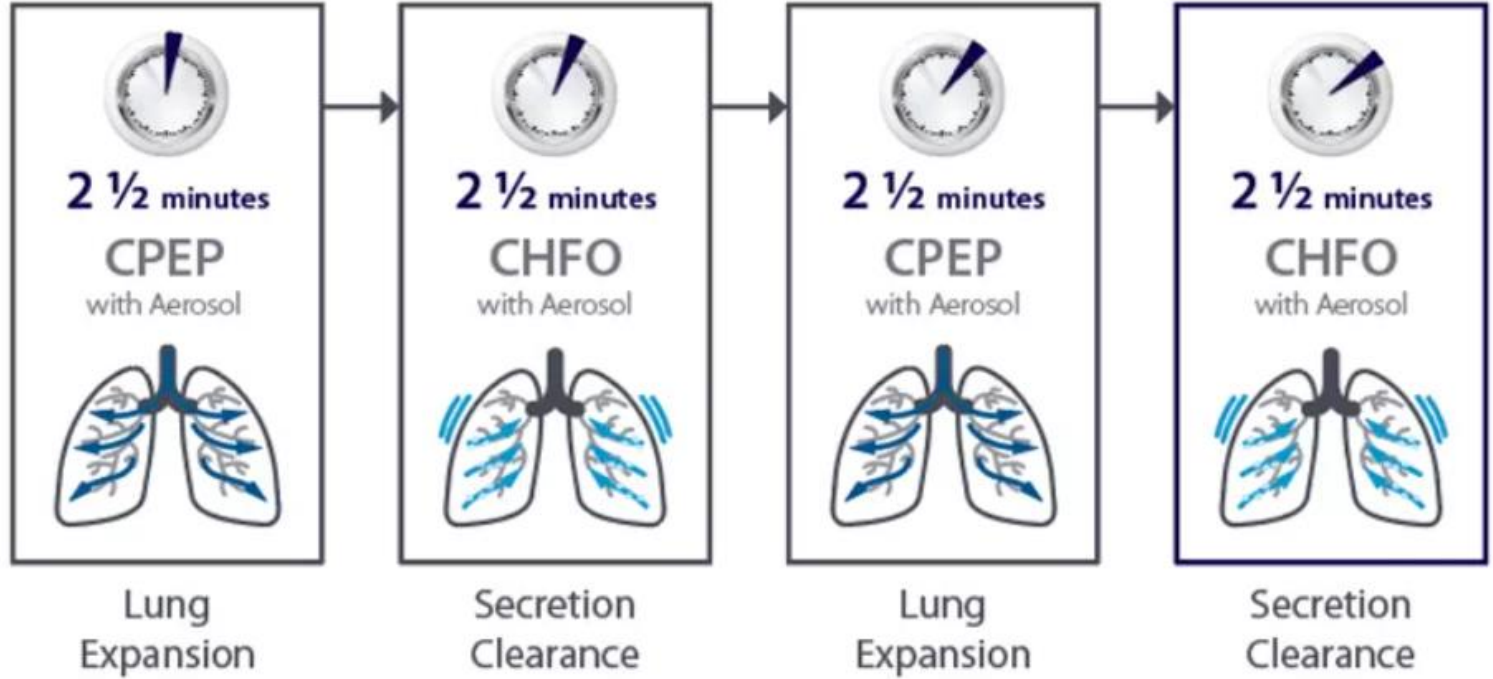


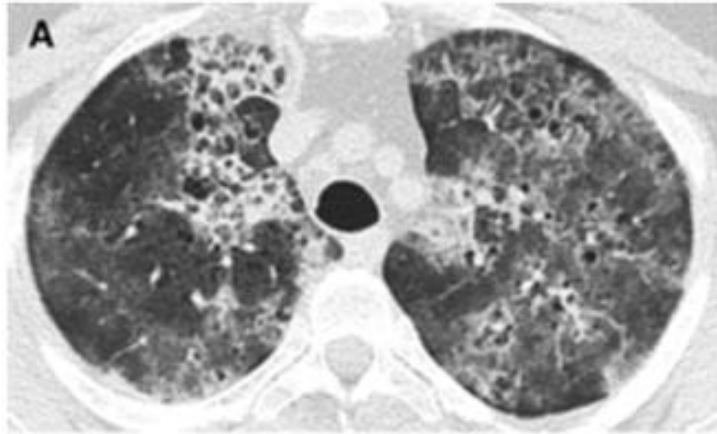
Table 4. Gas exchange values before and after the first application of intrapulmonary percussive ventilation

	Pre		Post		<i>p</i>
pH <sup>a</sup>	7.31	0.03	7.34	0.04	<.01 <sup>b</sup>
Paco <sub>2</sub> , mm Hg <sup>a</sup>	68.1	4.9	60.6	5.8	<.01 <sup>b</sup>
Pao <sub>2</sub> /Fio <sub>2</sub> <sup>a</sup>	226	32	267	24	<.01 <sup>b</sup>
Pa <sub>mean</sub> , mm Hg <sup>a</sup>	89.5	6	83	6	.02 <sup>b</sup>
RR, min <sup>c</sup>	28	27.5–29	24	22–24.5	<.01 <sup>d</sup>
HR, min <sup>c</sup>	93	90–97.5	81	80–85	.02 <sup>d</sup>

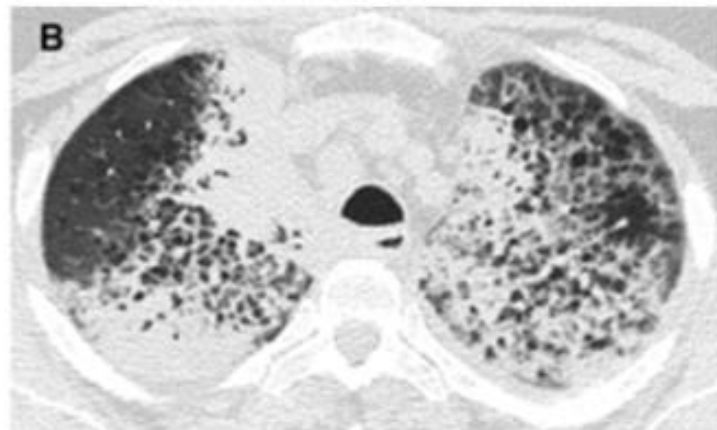
**Table 3.** Characteristics and outcome variables in patients with acute exacerbation of chronic obstructive pulmonary disease

	Phys Group		IPV Group		Control Group		<i>p</i>
Patients requiring intubation <sup>a</sup>	7	35	7	35	21	53	NS <sup>b</sup>
Ventilatory assistance, hrs <sup>c</sup>	89	82–96	61	60–71	87	75–91	<.01 <sup>d</sup>
Length of ICU stay, days <sup>c</sup>	9	7.75–9.5	7	6–8	10	9–11	<.01 <sup>d</sup>
Metabolic complications <sup>a</sup>	4	20	4	20	12	30	NS <sup>e</sup>
Sepsis and pneumonia <sup>a</sup>	4	20	2	10	11	28	NS <sup>e</sup>
Tracheostomy <sup>a</sup>	0	—	0	—	3	8%	NS <sup>e</sup>

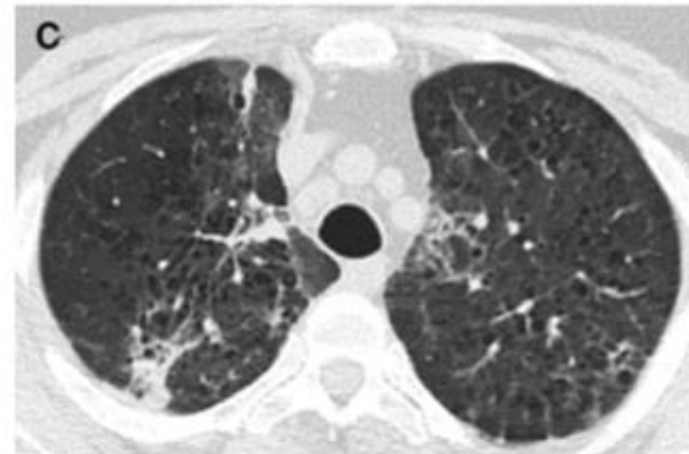
# Pulmonary alveolar proteinosis with respiratory failure treated by IPV



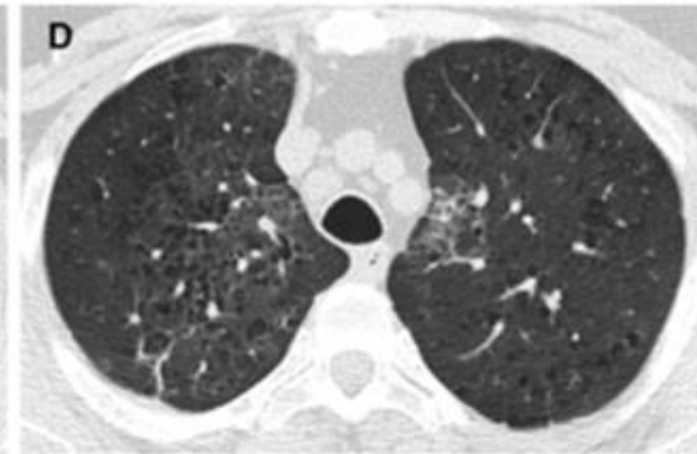
At diagnosis



Before IPV therapy  
(on admission)



One month after  
IPV therapy

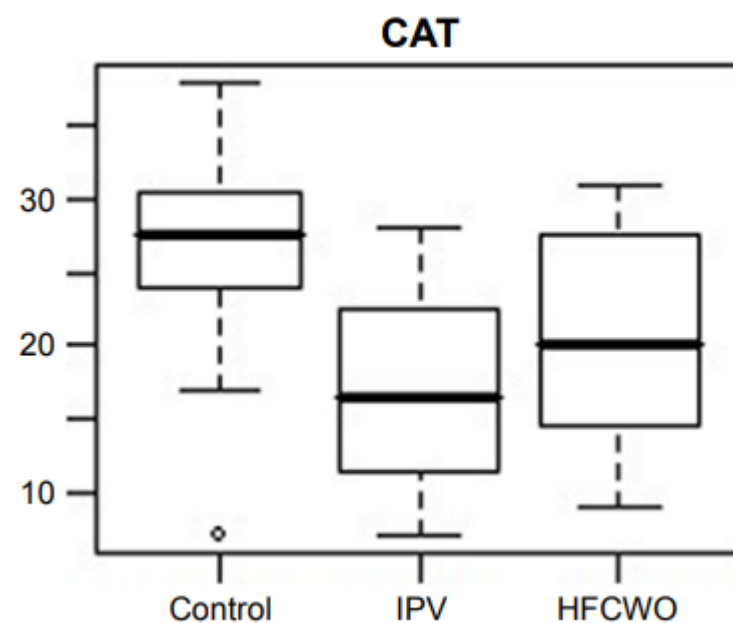
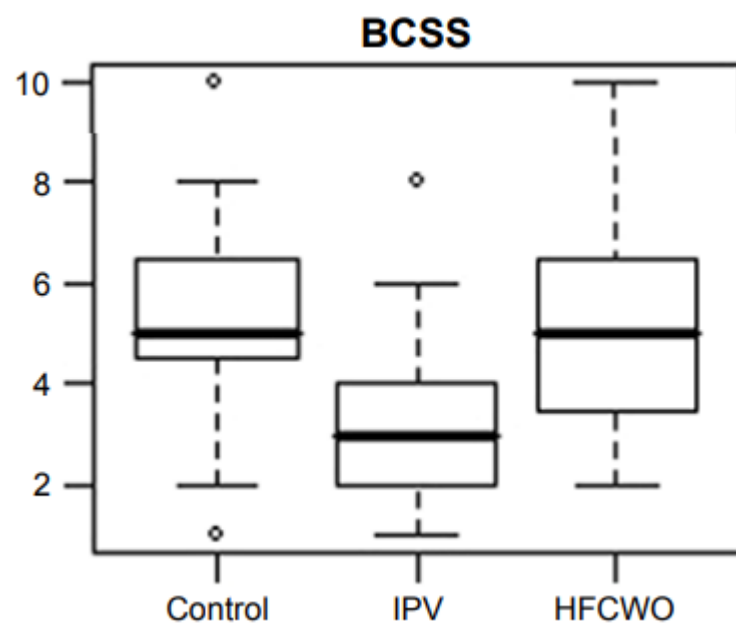


Six months after  
IPV therapy

# Safety and effectiveness of the high-frequency chest wall oscillation vs intrapulmonary percussive ventilation in patients with severe COPD

**Table 2** Results of primary outcomes

	Before treatment			After treatment			Regression analysis <i>p</i> -value		
	Control group	IPV group	HFCWO group	Control group	IPV group	HFCWO group	IPV vs control	HFCWO vs control	IPV vs HFCWO
Sex =0	10	15	9						
Sex =1	10	5	11						
Age (years)	74±3	72±7	74±6						
BCSS	4.6±1.7	6.3±1.4	6.6±2.8	5.5±2.1	3.1±1.7	5.2±2.2	<0.001	0.007	0.001*
mMRC	3.1±0.8	2.7±0.9	2.5±1.0	3.2±0.8	2.4±0.9	2.4±0.9	0.01**	0.04**	0.6
CAT	23.7±7.4	24.7±5.9	24.9±6.4	26.9±7.6	17.0±6.3	20.9±6.9	<0.001	<0.001	0.02**



# Contents

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Devices for Assessment of ventilation

Devices for Airway clearance therapy

**Devices for Muscle training**

# Muscle function and COPD

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Muscle dysfunction

: muscle strength ↓ (muscle weakness) or endurance impairment (muscle fatigue)

**Upper-limb muscles, Lower-limb muscles / Respiratory muscles**

# Respiratory muscles

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## Inspiratory muscles:

- Diaphragm
- Accessory inspiratory muscles: ext. intercostal muscles, upper rib cage muscle

## Expiratory muscles:

- Int. intercostal muscles
- Abdominal muscles

Respiratory muscle dysfunction → dyspnea, respiratory failure

# Muscle dysfunction in COPD

---

## Limb muscles

Fiber atrophy

↓ % Type I fibers

↓ Capillary contacts

↓ Mitochondrial density

↓ Enzyme capacity

↓ Myoglobin

Damage/impaired regeneration

Apoptosis

Autophagy

Oxidative stress

↑ Proteolysis / ↓ protein synthesis

## Respiratory muscles

↑ % Type I fibers

↑ Capillary contacts

↑ Mitochondrial density

↑ Myoglobin

↑ Aerobic enzyme capacity

Shorter sarcomere

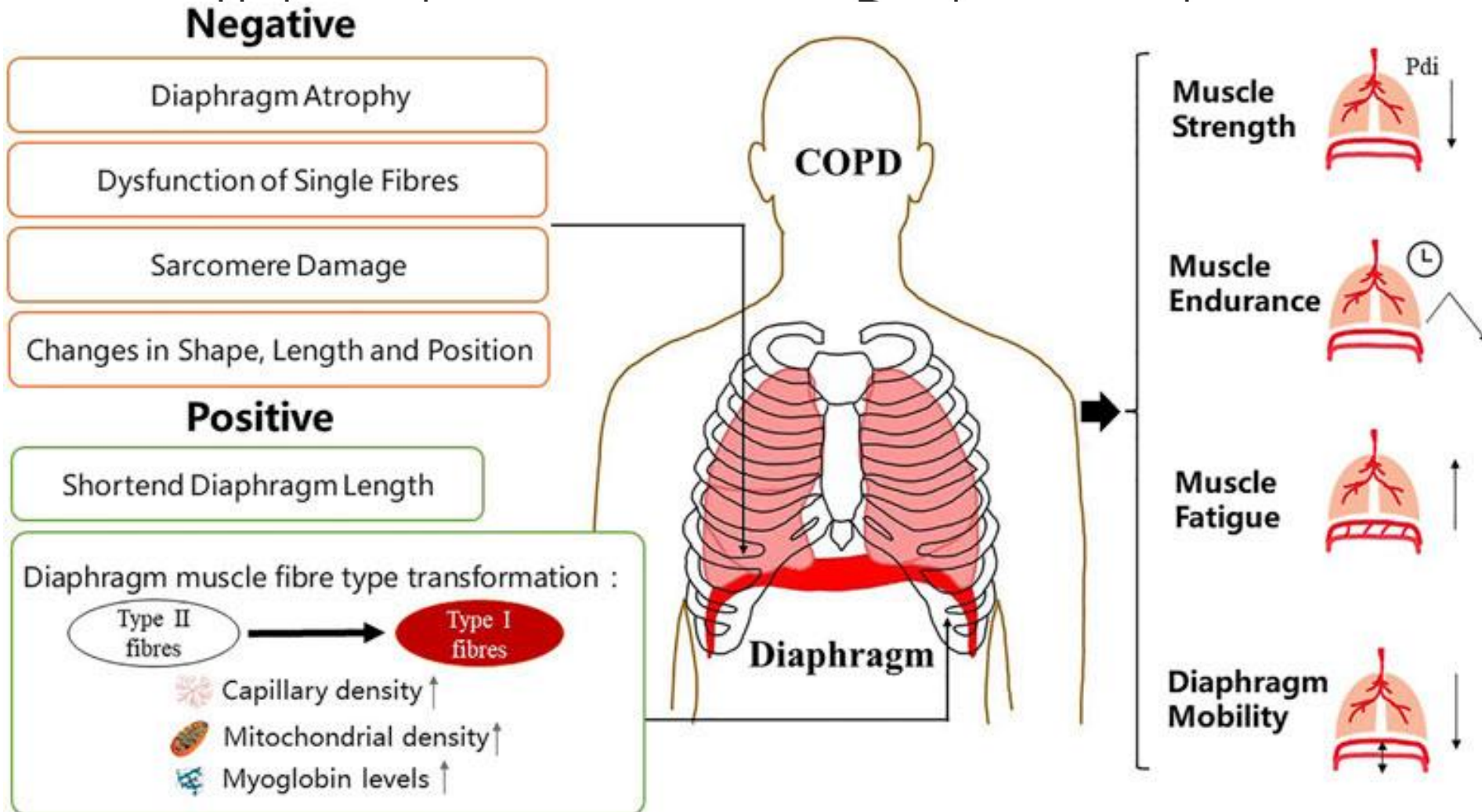
Oxidative stress

↑ Proteolysis / ↓ protein synthesis

Damage

Apoptosis

# Diaphragm dysfunction in COPD



# Respiratory muscle strength test

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**Maximal inspiratory pressure (P<sub>imax</sub>, MIP)**

**Maximal expiratory pressure (P<sub>emax</sub>, MEP)**

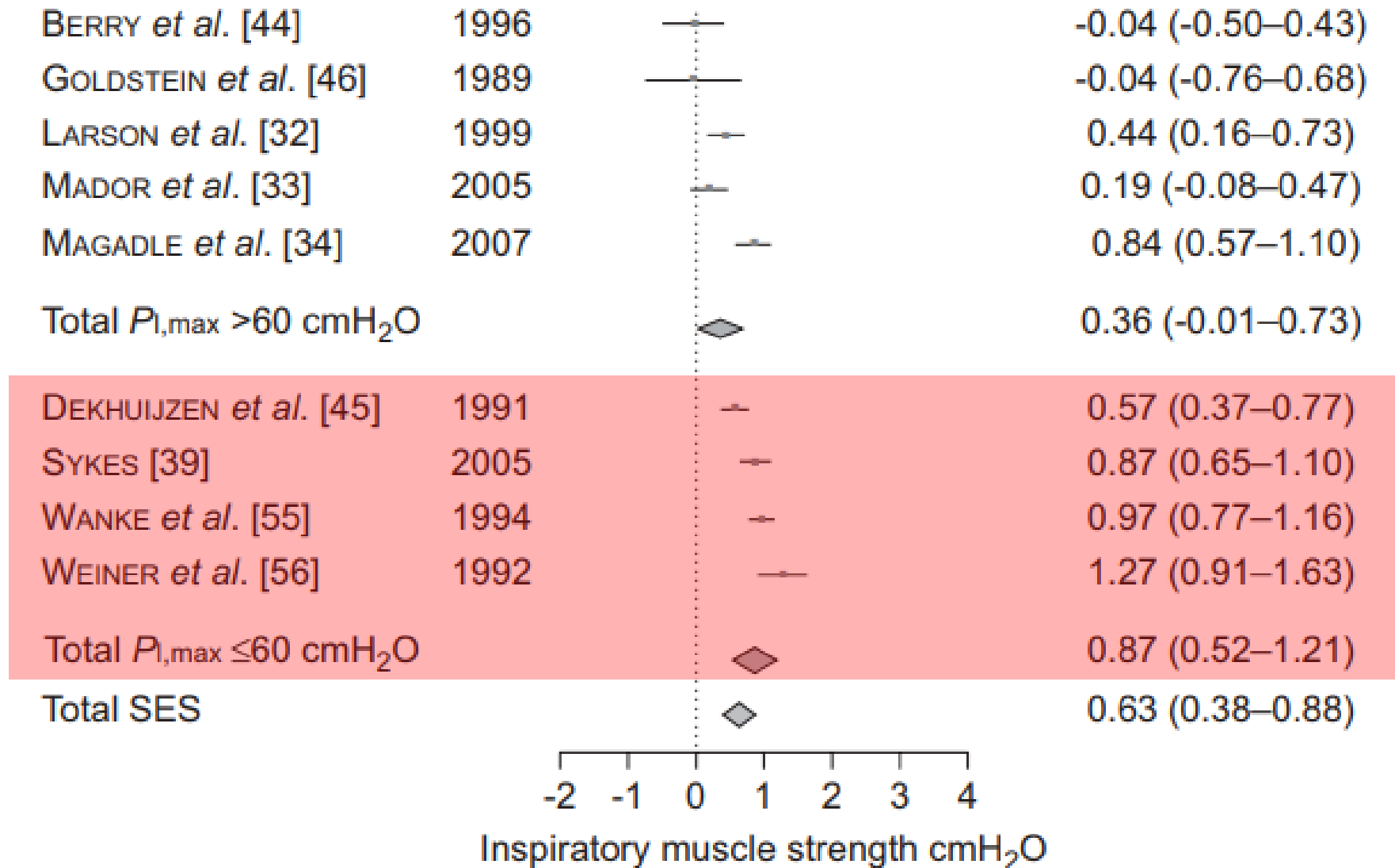


# Impact of inspiratory muscle training in patients with COPD

**TABLE 1** Overall results of the meta-analysis

Outcome measures	Subjects n	Q-statistic	I <sup>2</sup>	SES	95% CI	p-value (z-statistic)	Natural units
<i>P</i> <sub>I,max</sub>	32	57.8	46	0.73	0.53–0.93	0.001	+13 cmH <sub>2</sub> O
RMET	14	47.3	73	1.05	0.62–1.49	0.001	+261 s
ITL	11	16.8	3	0.98	0.72–1.25	0.001	+13 cmH <sub>2</sub> O
MVV	4	1.2	0	0.23	-0.27–0.72	0.373	+3 L·min <sup>-1</sup>
Functional exercise capacity	22	14.3	0	0.28	0.12–0.44	0.001	6MWD: +32 m 12MWD: +85 m
Dyspnoea Borg score	14	15.6	17	-0.45	-0.66– -0.24	0.001	-0.9
Dyspnoea TDI	4	6.3	52	1.58	0.86–2.3	0.001	+2.8
Quality of life CRQ	9	10.4	20	0.34	0.09–0.60	0.007	+3.8

# Impact of inspiratory muscle training in patients with COPD



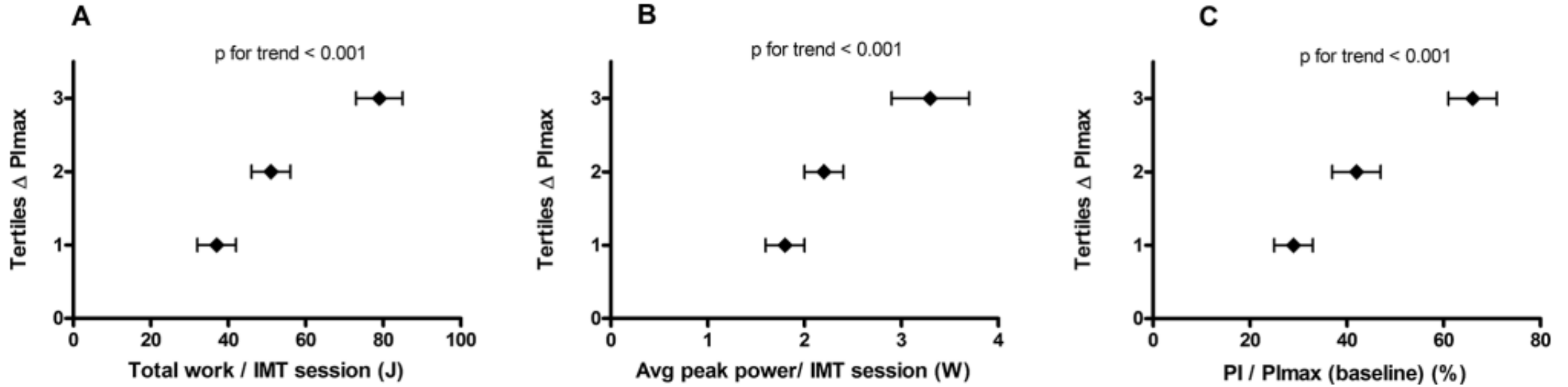
# Respiratory Muscle Strength in Patients With Chronic Obstructive Pulmonary Disease

Nam-Sik Kim, MD<sup>1</sup>, Jeong-Hwan Seo, MD, PhD<sup>1</sup>, Myoung-Hwan Ko, MD, PhD<sup>1</sup>,  
Sung-Hee Park, MD, PhD<sup>1</sup>, Seong-Woong Kang, MD, PhD<sup>2,3</sup>, Yu Hui Won, MD, PhD<sup>1</sup>

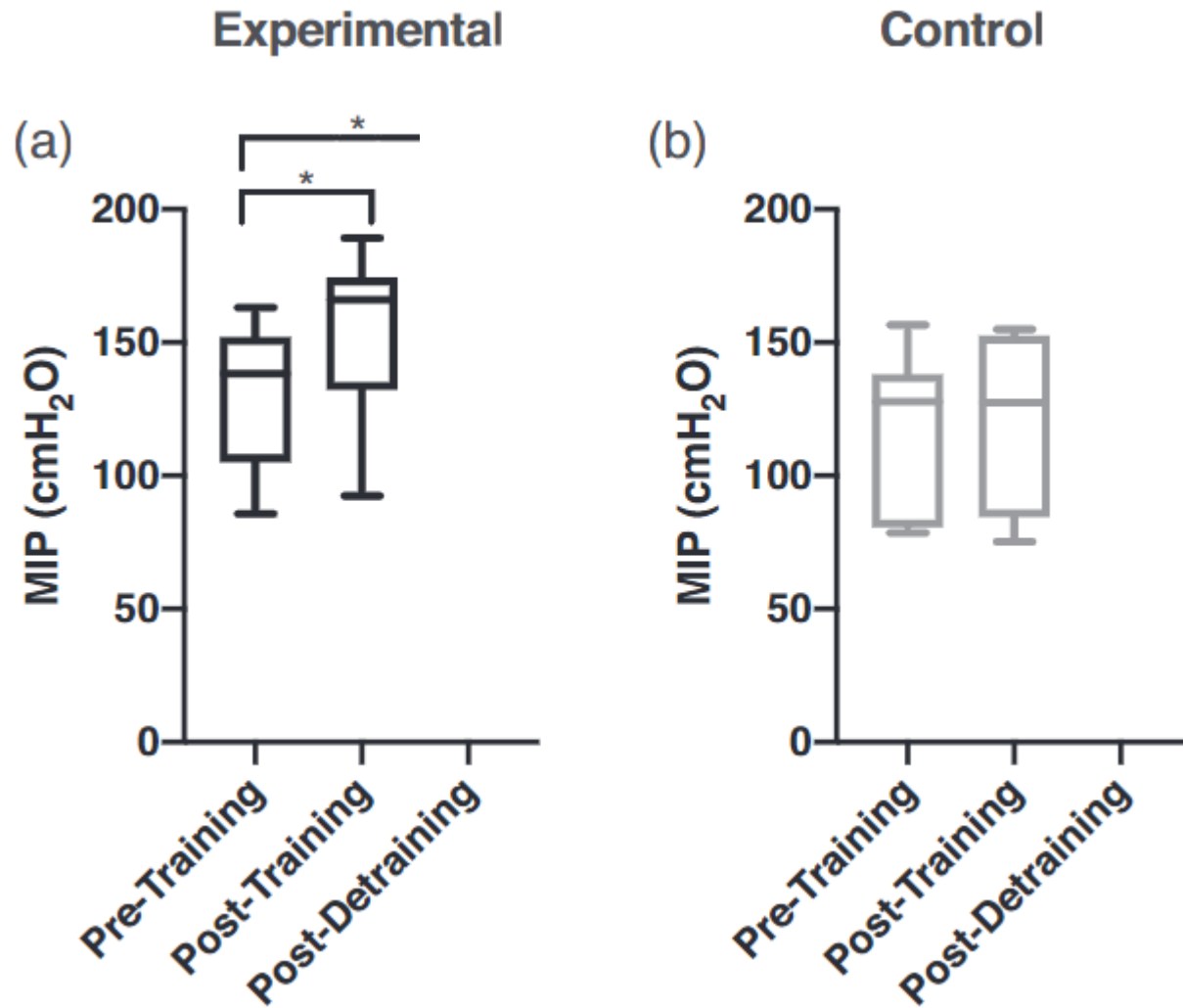
**Table 5.** Comparisons of parameters in stable COPD group according to different stage (n=36)

	Stage 1 (n=4)	Stage 2 (n=15)	Stage 3 (n=12)	Stage 4 (n= 5)	p-value <sup>a)</sup>
MIP (cmH <sub>2</sub> O)	84.50±10.66	80.06±28.36	54.41±11.22	50.40±21.09	0.005**
MIP (% pred)	120.17±10.01	115.65±27.94	78.57±15.08	64.13±21.81	<0.001***
MEP (cmH <sub>2</sub> O)	116.25±30.10	107.93±42.85	81.00±26.70	90.40±30.11	0.133
MEP (% pred)	99.97±28.70	89.87±40.35	85.85±28.56	73.67±22.97	0.600
FEV1 (L)	2.34±0.56	1.30±0.30	0.99±0.19	0.52±0.10	<0.001***
FEV1 (% pred)	92.25±10.71	61.00±8.15	39.75±5.36	19.60±3.50	<0.001***
FEV1/FVC (%)	63.00±7.78	56.46±9.01	48.16±9.71	35.00±3.31	<0.001***
mMRC	1.25±0.50	1.60±0.82	3.00±1.22	2.00±1.12	0.050
CAT	8.25±3.77	14.93±6.70	17.25±5.17	15.33±6.42	0.095

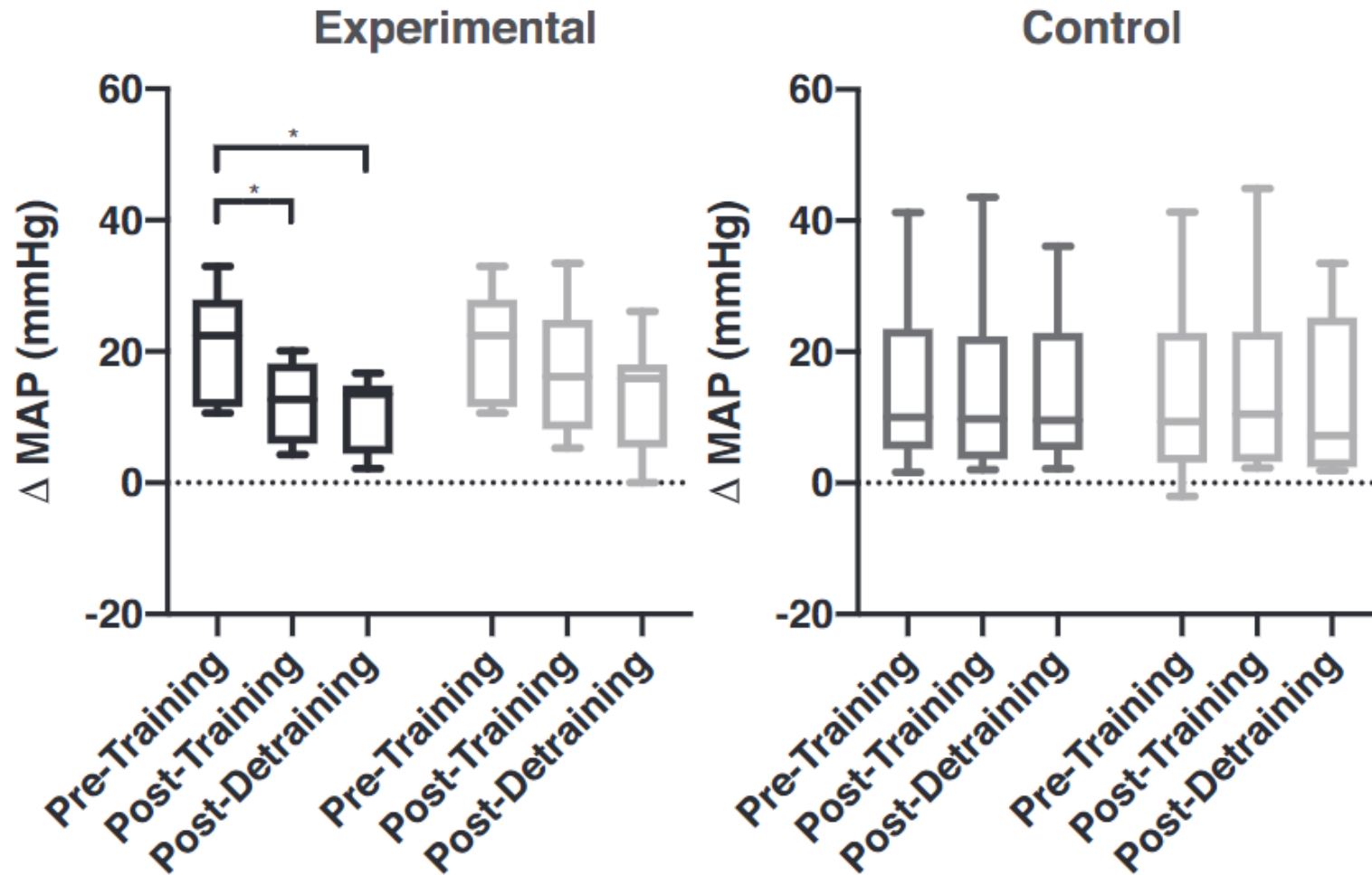
# Training quality indices and improvements in P<sub>lmax</sub>



# Inspiratory muscle training and detraining



# Inspiratory muscle training and detraining



# Inspiratory muscle exercise

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흡기 저항 훈련 (inspiratory resistance training)

흡기 역치 훈련 (inspiratory threshold training)

등탄산 과호흡 훈련 (isocapnic hyperventilation)

# Inspiratory muscle training (IMT)

---



**Inspiratory resistance training  
(=Flow resistive training)**



**Inspiratory threshold training  
(flow independent)**

# POWERbreathe



£562.50

**K5 IMT**



**Add to basket**



£499.17

**K4 IMT**



**Add to basket**



£458.33

**K3 IMT**



**Add to basket**



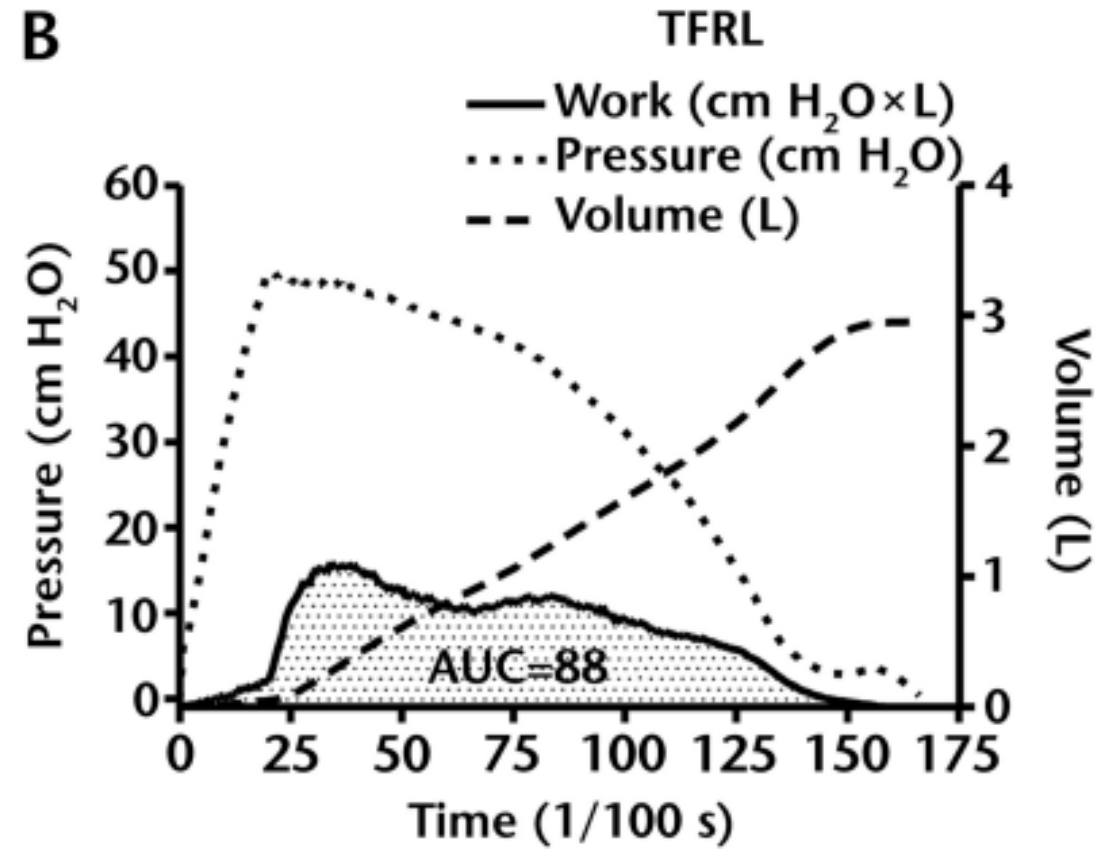
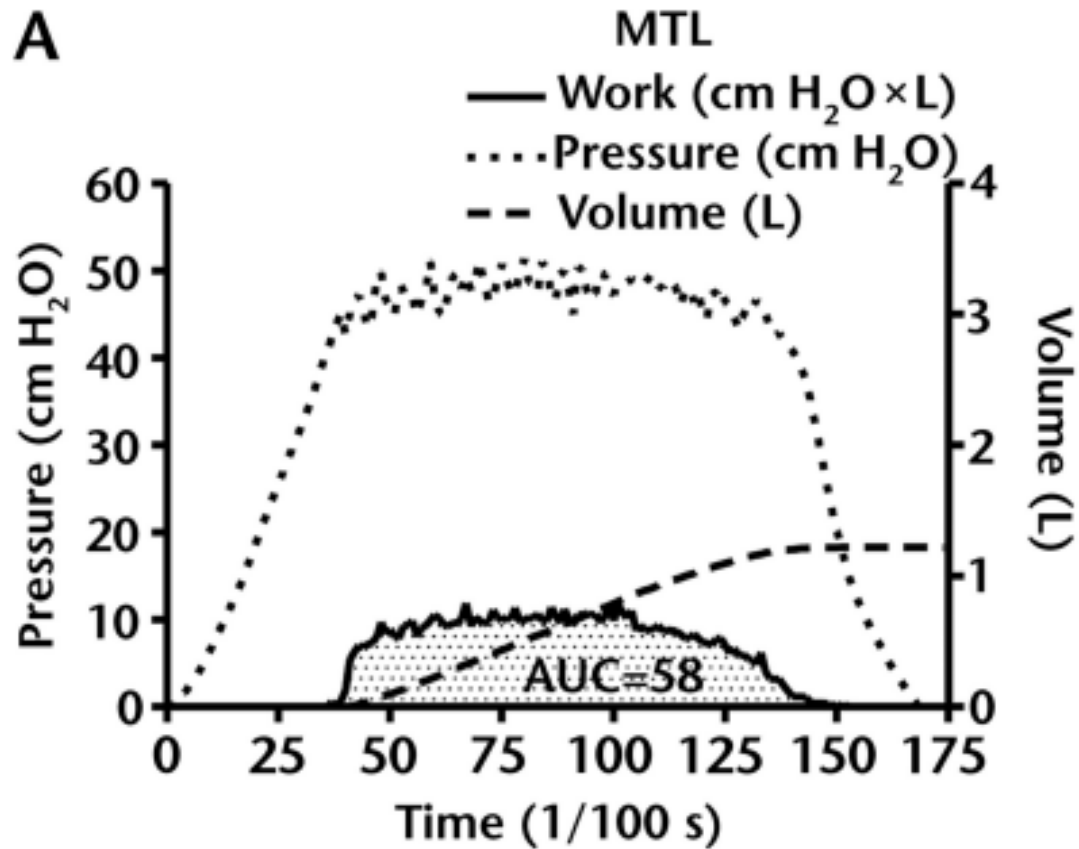
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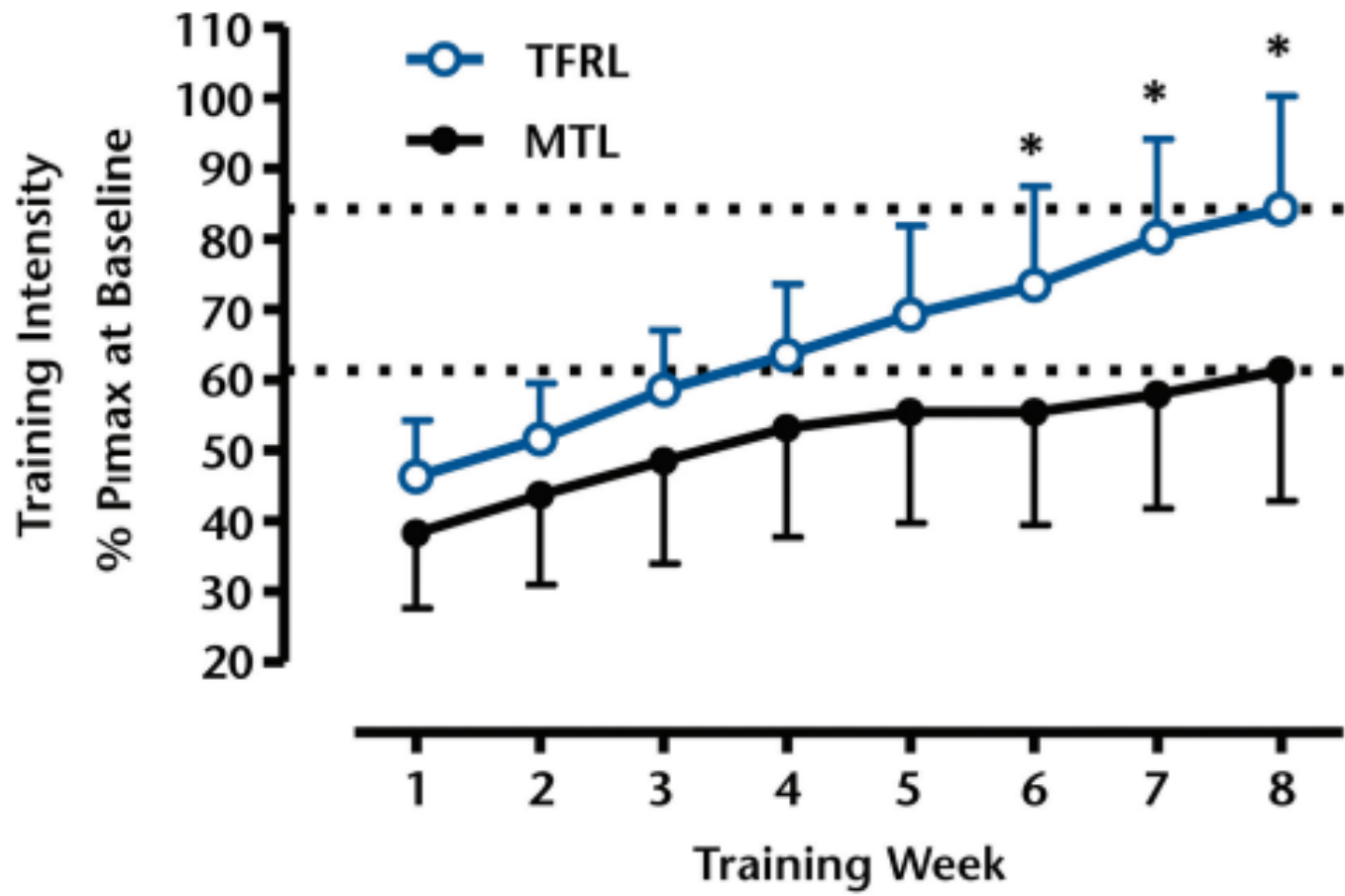
**K1 IMT**



**Add to basket**

## Novel Method for IMT in COPD





# Response to One-Legged Cycling in Patients With COPD\*

*Thomas E. Dolmage, MSc; and Roger S. Goldstein, MD*



**Table 2—Incremental One-Legged and Two-Legged Cycle Exercise\***

Variables	Control Group (n = 9)		COPD Group (n = 9)	
	Two Legs	One Leg	Two Legs	One Leg
Power, W	191 ± 38	97 ± 17†	50 ± 19	40 ± 9†
$\dot{V}O_{2peak}$ , L/min	2.28 ± 0.47	1.71 ± 0.36†	0.61 ± 0.16	0.64 ± 0.20
Peak $\dot{V}CO_2$ , L/min	2.93 ± 0.71	2.00 ± 0.52†	0.62 ± 0.20	0.63 ± 0.21
Respiratory exchange ratio	1.23 ± 0.08	1.11 ± 0.07†	1.00 ± 0.12	0.99 ± 0.03
$\dot{V}E_{peak}$ , L/min	88.6 ± 23.6	60.1 ± 15.7†	29.7 ± 4.7	28.0 ± 4.4
<i>f</i> , breaths/min	43 ± 8	37 ± 8†	32 ± 7	31 ± 7
<i>V</i> <sub>T</sub> , L	2.05 ± 0.37	1.65 ± 0.33†	0.98 ± 0.26	0.96 ± 0.30
HR, beats/min	172 ± 12	148 ± 15†	121 ± 15	115 ± 17
Dyspnea, scale of 10	6.3 ± 2.6	5.6 ± 1.8	7.3 ± 2.0	6.8 ± 1.8
Leg effort, scale of 10	7.9 ± 1.7	8.4 ± 2.0	6.2 ± 2.2	7.3 ± 2.3
SpO <sub>2</sub> , %	95 ± 1	95 ± 2	88 ± 3	91 ± 2†
DH, mL/min/L	0 ± 9	- 6 ± 7	36 ± 16	39 ± 22

**Table 3—Constant-Power One-Legged and Two-Legged Cycle Exercise\***

Variables	Healthy Control Subjects (n = 9)		COPD Group 2 (n = 9)	
	Two Legs	One Leg	Two Legs	One Leg
Endurance, min‡	4.07 ± 0.89	7.63 ± 4.98†	6.42 ± 2.96	23.39 ± 8.63†
Power, W	163 ± 31	82 ± 16†	38 ± 13	19 ± 6†
Total work, kJ	39.66 ± 9.80	35.64 ± 21.38	14.04 ± 6.52	26.52 ± 11.94†
$\dot{V}E_{peak}$ , L/min§	86.3 ± 21.8	67.8 ± 12.2†	39.6 ± 9.5	34.4 ± 12.0†
HR, beats/min	166 ± 11	151 ± 16†	122 ± 12	112 ± 12†
Dyspnea, scale of 10	7.4 ± 2.2	5.7 ± 2.0†	8.2 ± 1.3	5.3 ± 1.7†
Leg effort, scale of 10	8.6 ± 2.4	8.6 ± 1.9	7.9 ± 1.9	8.2 ± 2.0
SpO <sub>2</sub> , %	95 ± 2	95 ± 2	91 ± 5	95 ± 1

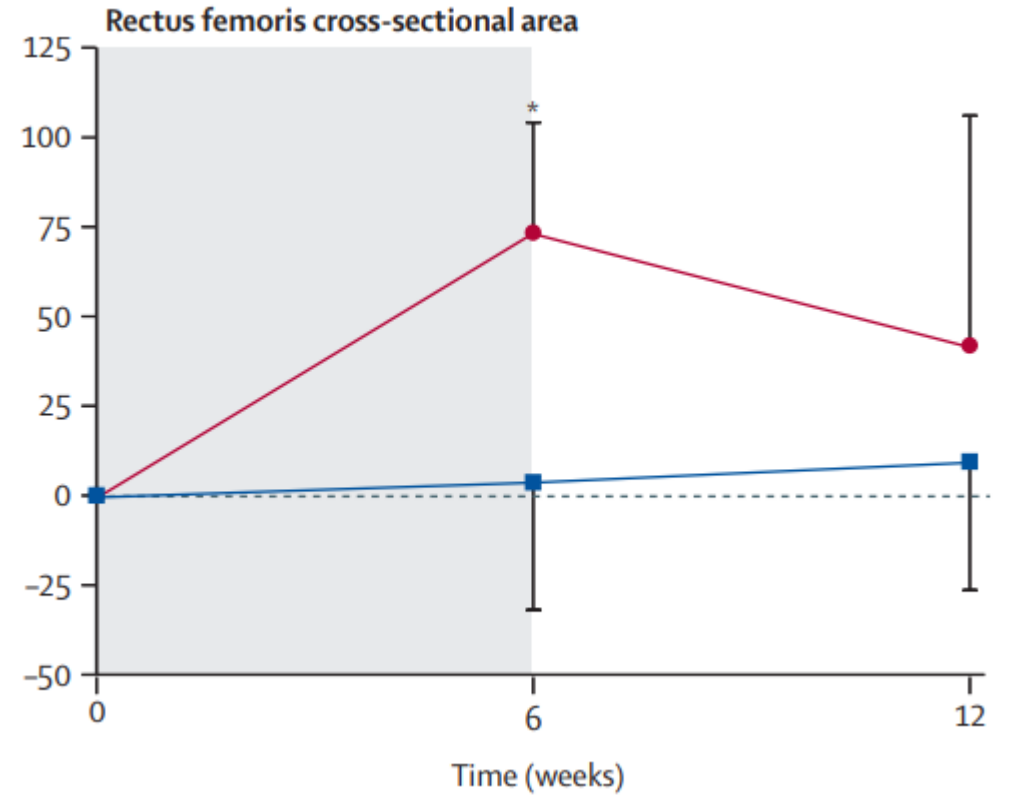
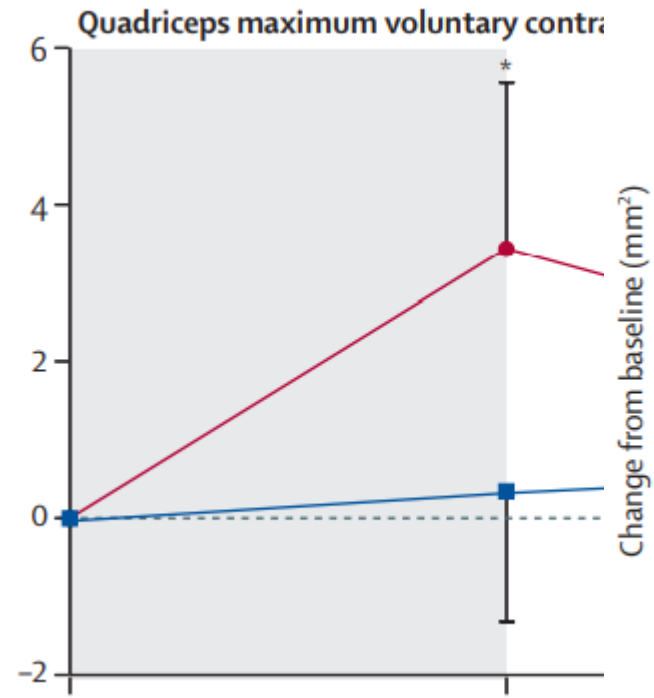
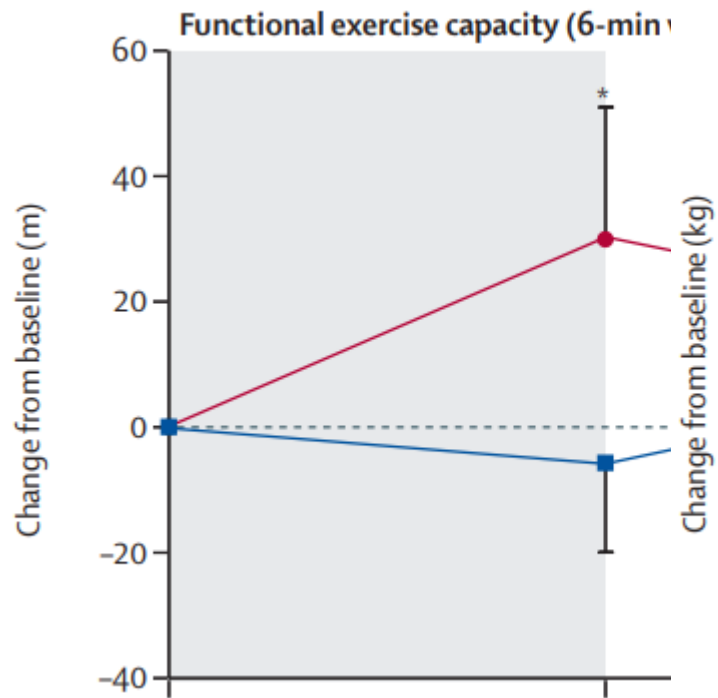
# Patient satisfaction of one-legged cycling in COPD

Question to participant:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I understand why I was asked to cycle one leg at a time	7	10	2	0	0
I found cycling with one leg easy to learn	11	7	1	0	0
I feel I could progress the training load by myself	2	8	5	4	0
I found single leg cycling helped me to exercise	6	10	3	0	0
I enjoyed single leg cycling	7	4	7	1	0
I would recommend single leg cycling for other patients	9	6	4	0	0
I would like to continue single leg cycling	9	3	6	1	0

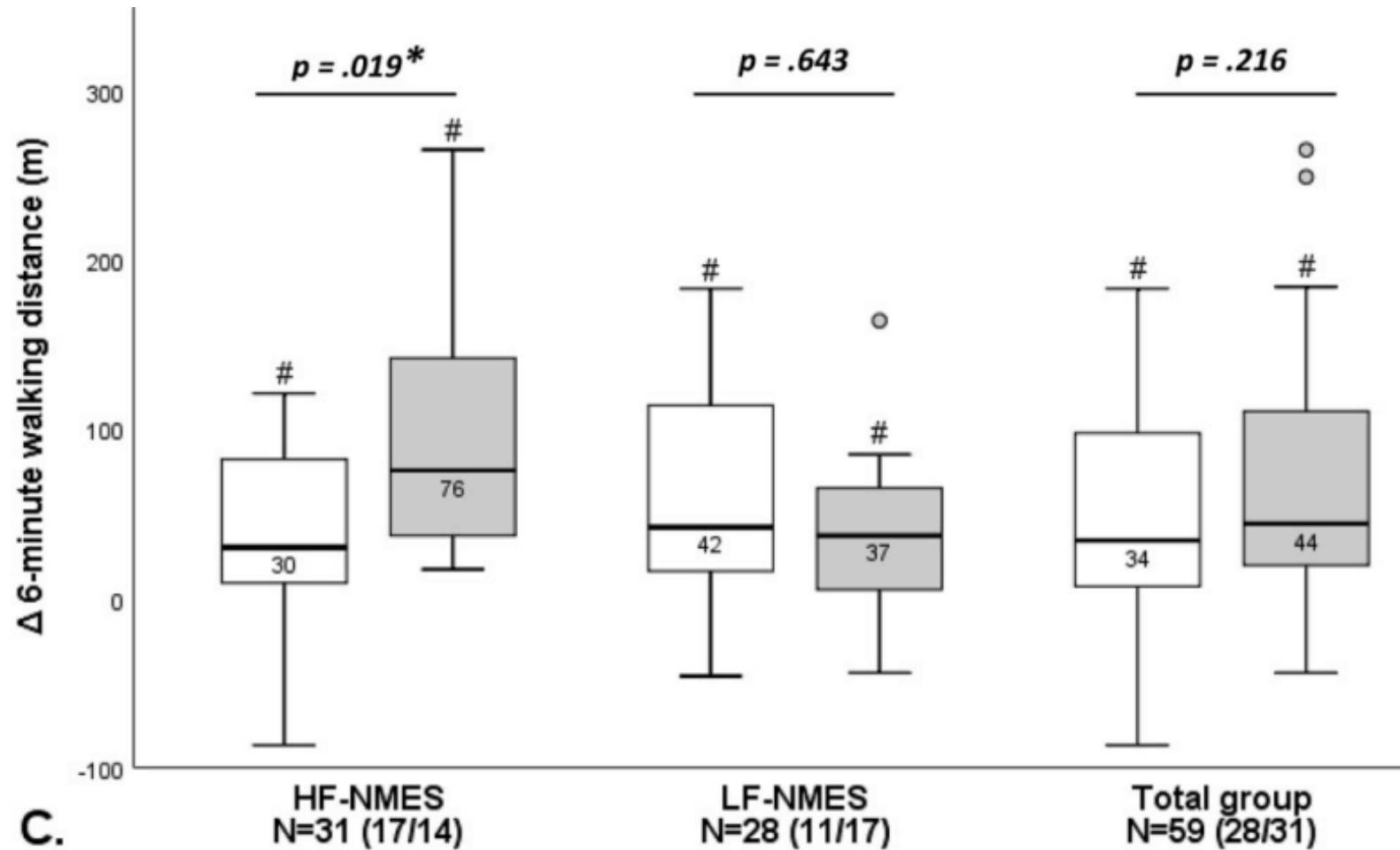
# Neuromuscular electrical stimulation to improve exercise capacity in patients with severe COPD: a randomised double-blind, placebo-controlled trial

*Matthew Maddocks, Claire M Nolan, William D-C Man, Michael I Polkey, Nicholas Hart, Wei Gao, Gerrard F Rafferty, John Moxham, Irene J Higginson*



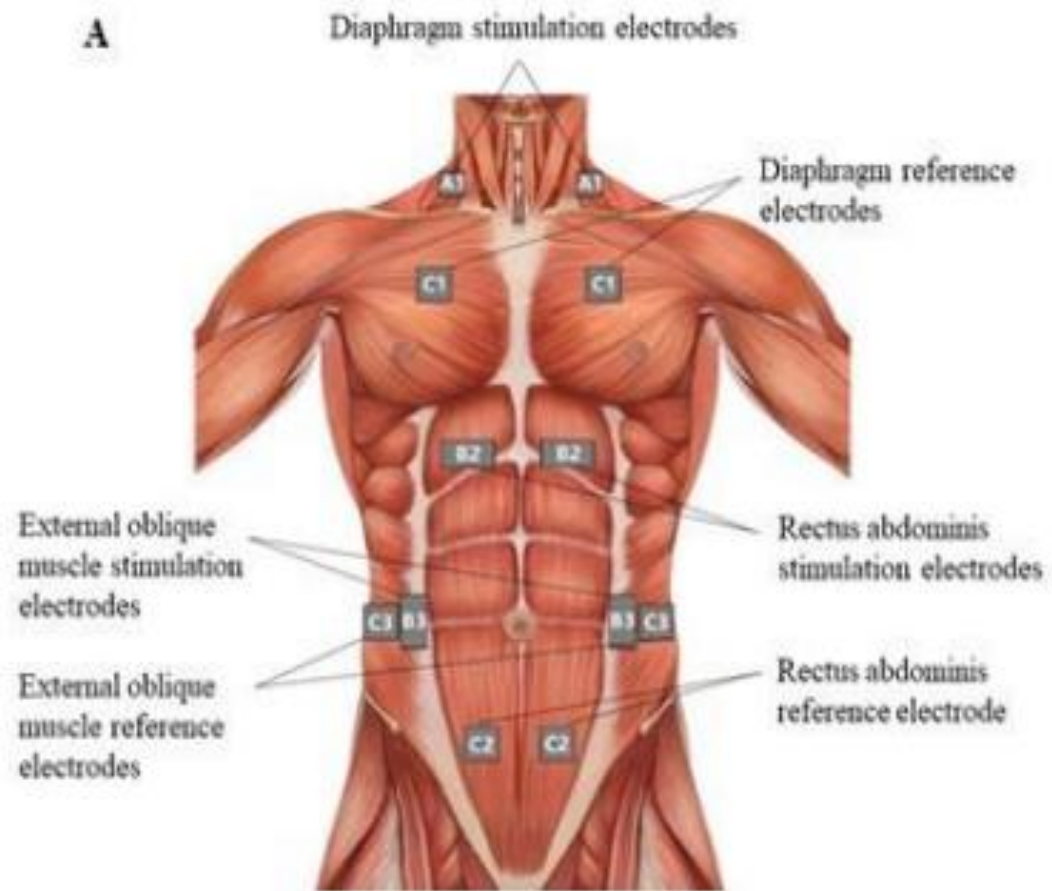


# high-frequency (HF; 75 Hz) vs low-frequency (LF; 15 Hz)

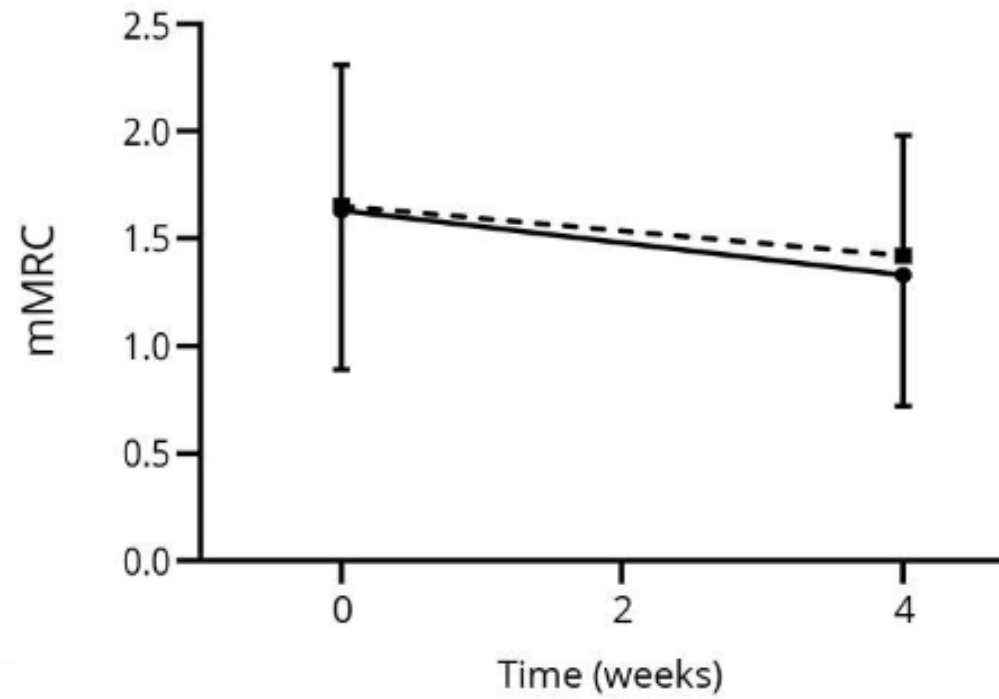
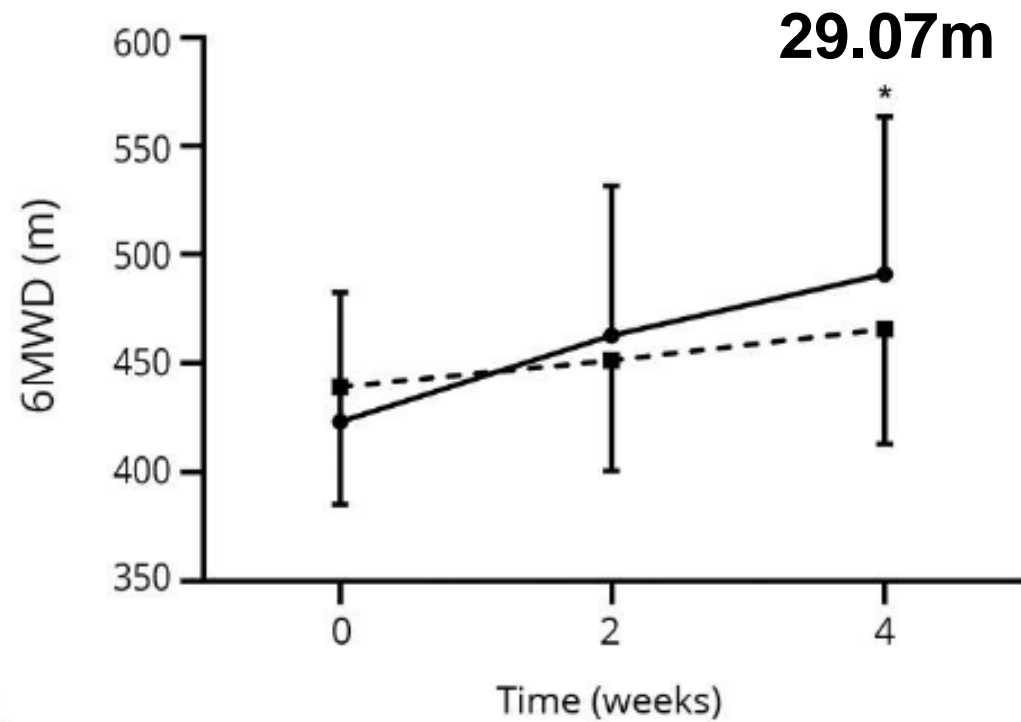


Stimulation of both inspiratory and expiratory muscles  
*versus* diaphragm-only paradigm for rehabilitation  
in severe chronic obstructive pulmonary disease  
patients: a randomized controlled pilot study

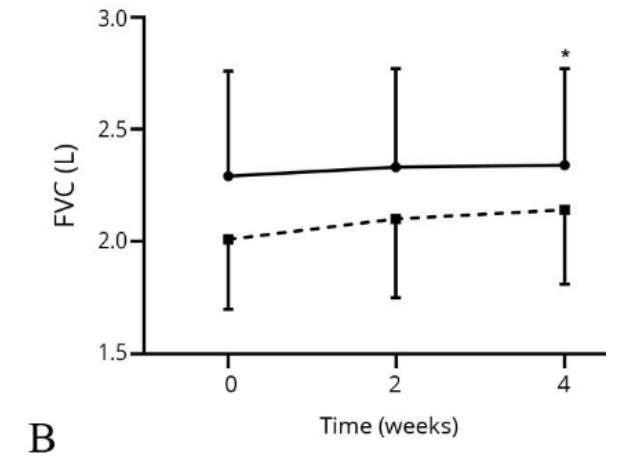
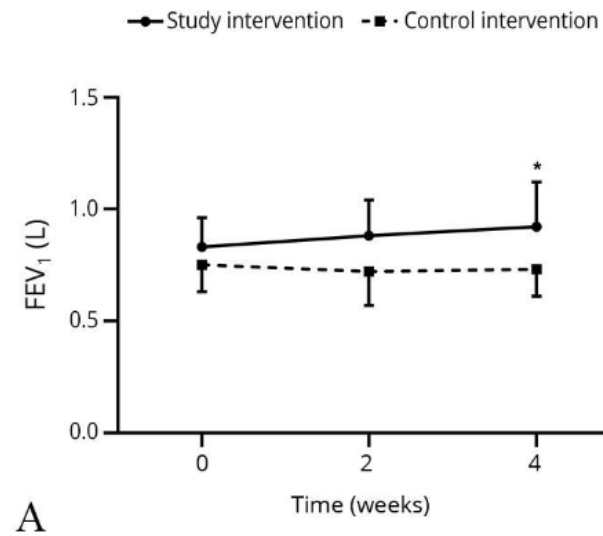
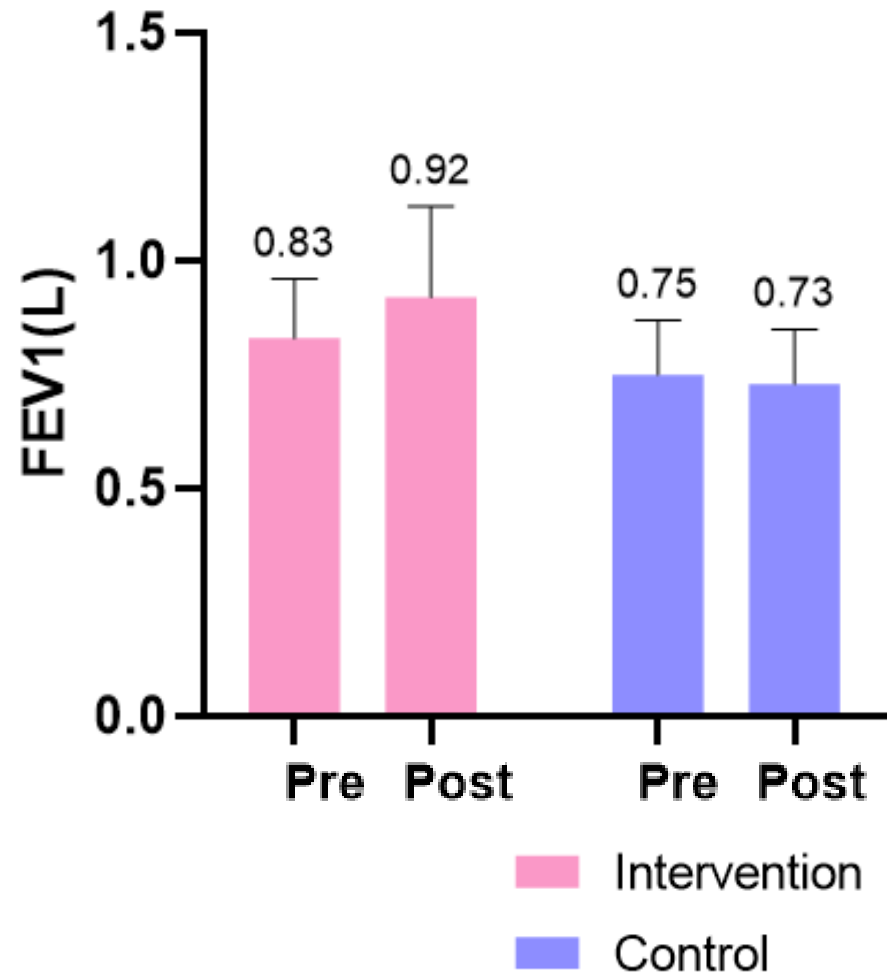
Zhiling ZHAO <sup>1</sup>, Wuzhuang SUN <sup>2</sup>, Xiaoyun ZHAO <sup>3</sup>, Xiaojuan WANG <sup>4</sup>, Yingxiang LIN <sup>1</sup>, Shu ZHANG <sup>1</sup>,  
Zhu LI <sup>2</sup>, Yong LU <sup>1</sup>, Juanni GONG <sup>1</sup>, Yanxia YU <sup>1</sup>, Bojun LI <sup>3</sup>, Xiujuan HU <sup>3</sup>, Yuechuan LI <sup>3</sup>, Zhaohui TONG <sup>1</sup> \*



● Study intervention    ■ Control intervention



# Pulmonary function change in GOLD 4



# COPD and Balance

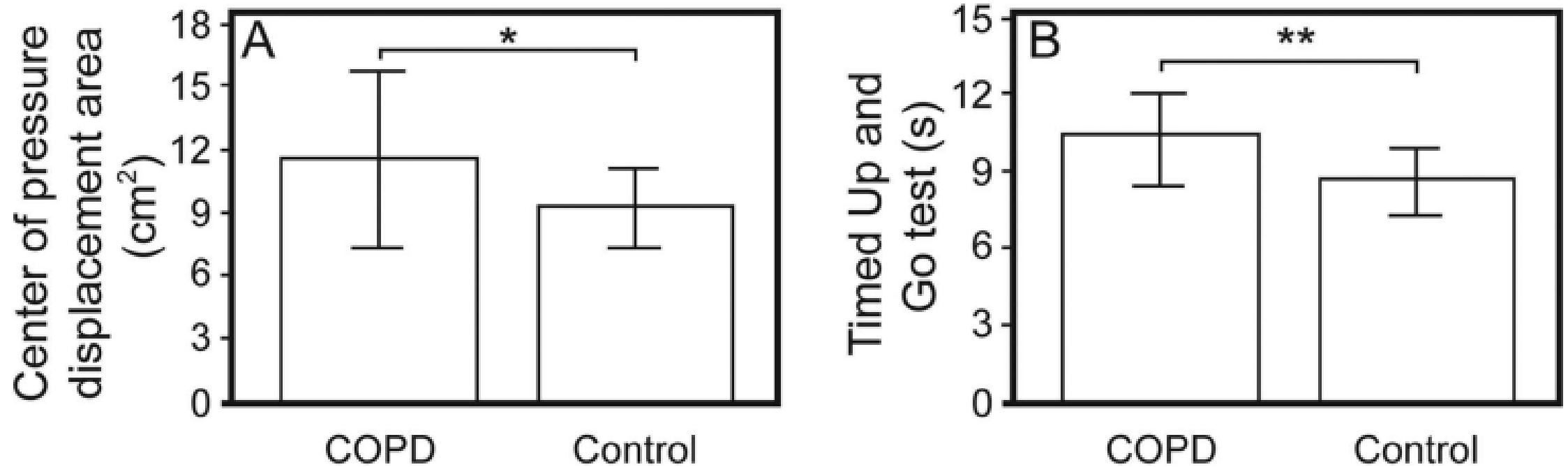
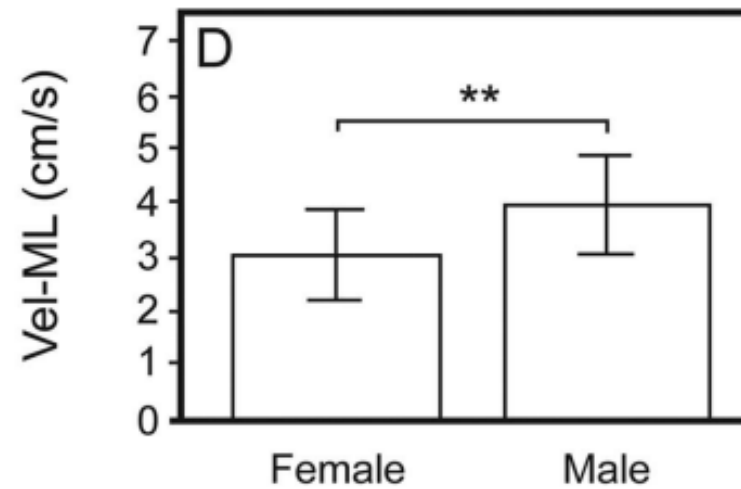
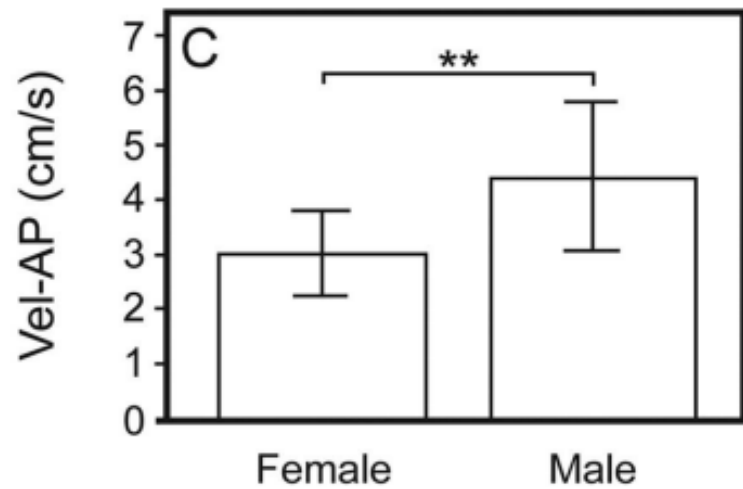
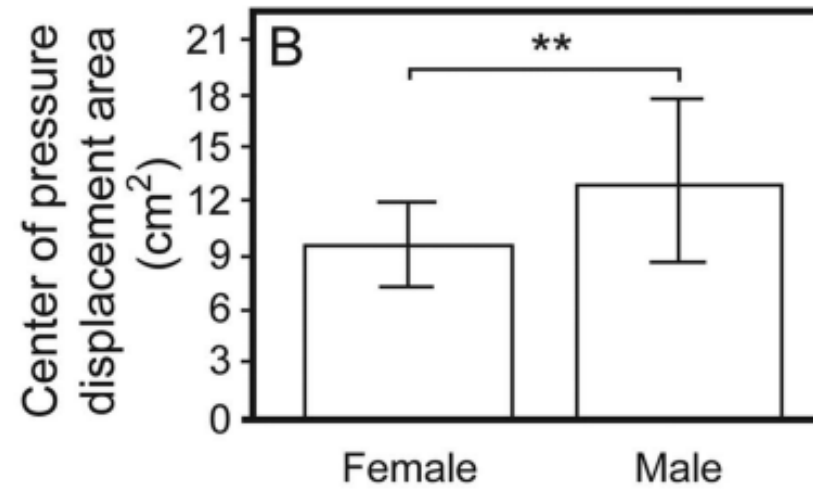
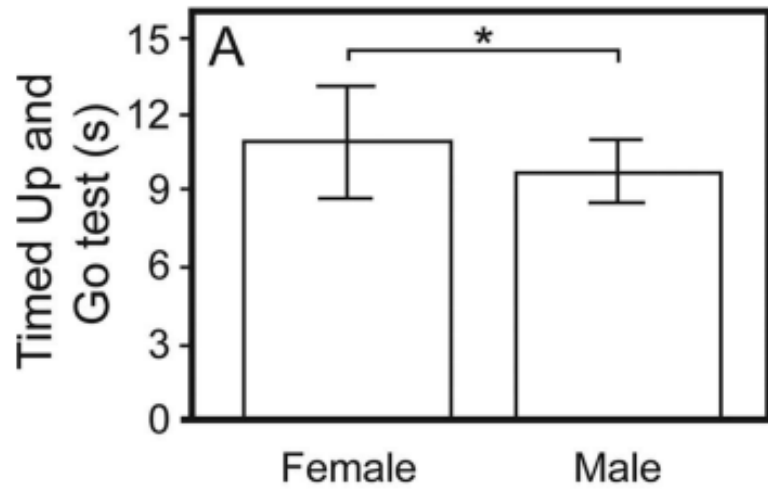


Fig. 1. Comparison of static balance (A) and functional balance (B) between subjects with COPD and healthy control individuals. Data are presented as mean  $\pm$  SD. \* $P = .01$ ; \*\* $P < .001$ .

# COPD and Balance

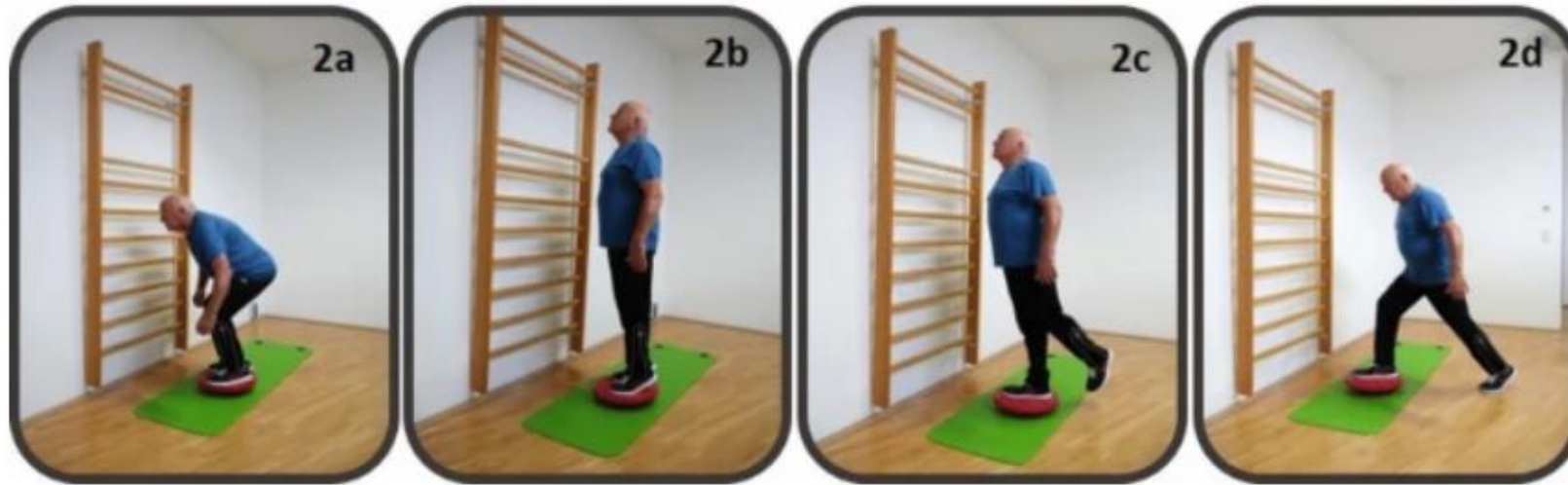




# Whole-body vibration training versus conventional balance training in patients with severe COPD—a randomized, controlled trial

Rainer Gloeckl<sup>1,2\*</sup> , Tessa Schneeberger<sup>1,2</sup>, Daniela Leitl<sup>1,2</sup>, Tobias Reinold<sup>3</sup>, Christoph Nell<sup>4</sup>, Inga Jarosch<sup>1,2</sup>, Klaus Kenn<sup>1,2</sup> and Andreas R. Koczulla<sup>1,2,5</sup>

**Fig. 1**



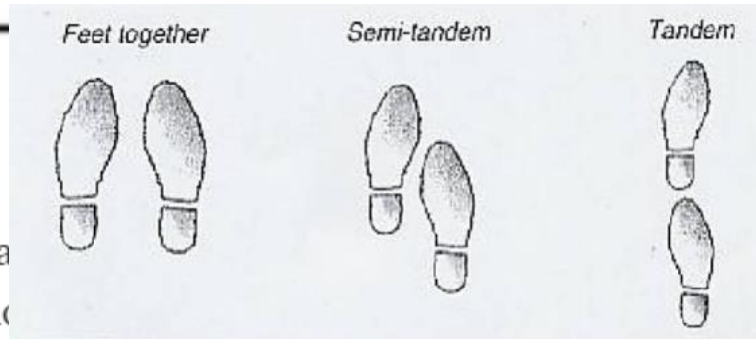
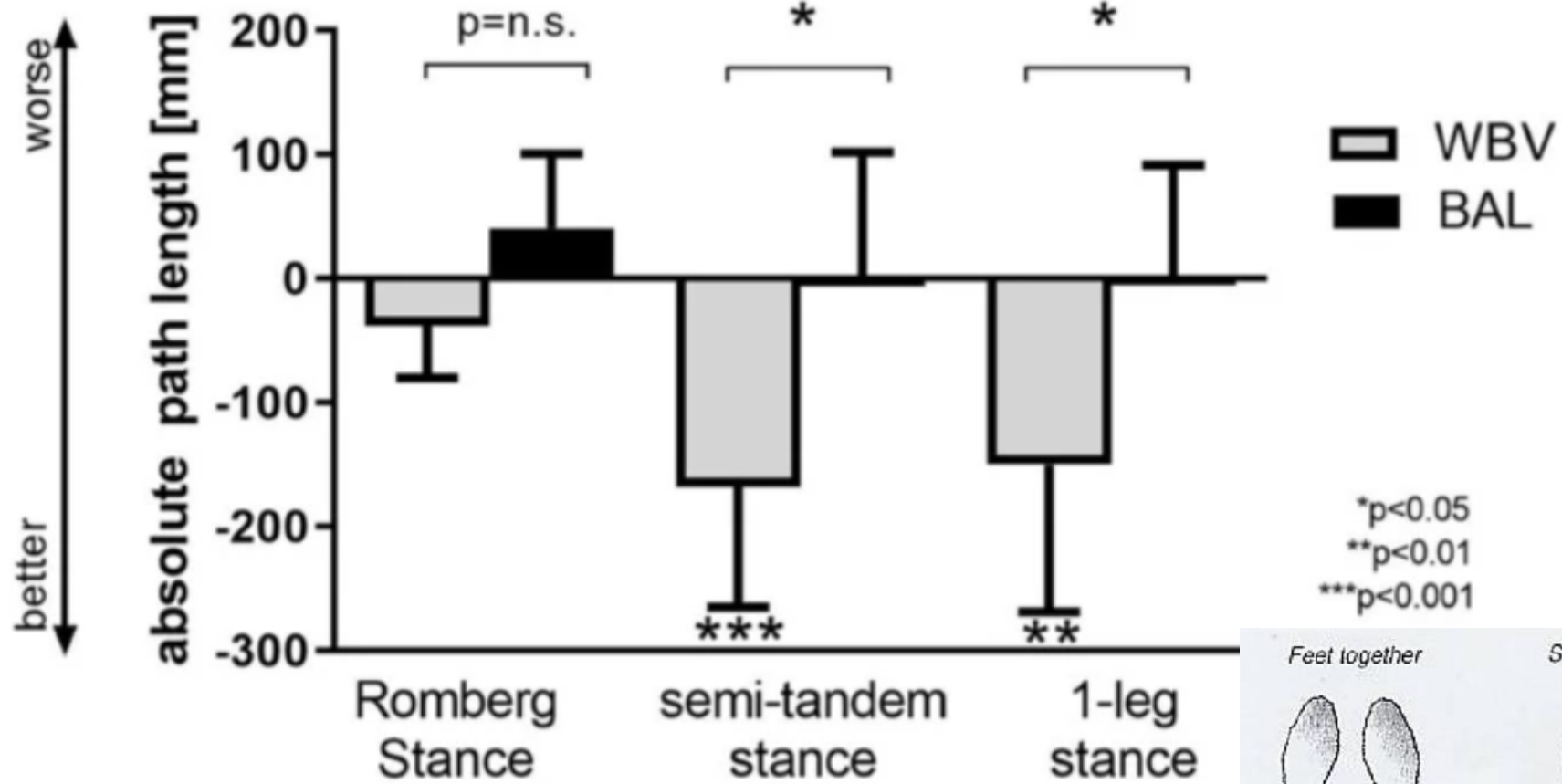
Exercises performed during whole-body vibration balance training. Whole body vibration training and conventional balance training performed for 2 sets of 1 min per exercise and training session: **a** dynamic squats, **b** dynamic heel raises, **c** static one-leg stance, and **d** dynamic lunge step. (patients provided written informed consent for the use of these figures)

**Fig. 1**



Exercises performed during whole-body vibration balance training. Whole body vibration training and conventional balance training performed for 2 sets of 1 min per exercise and training session: **a** dynamic squats, **b** dynamic heel raises, **c** static one-leg stance, and **d** dynamic lunge step. (patients provided written informed consent for the use of these figures)

## Δ static balance tests



Changes in balance performance during Romberg stance, semi-tandem stance, and 1-leg stance following a whole-body vibration (WBV) balance training or conventional balance training.

# Contents

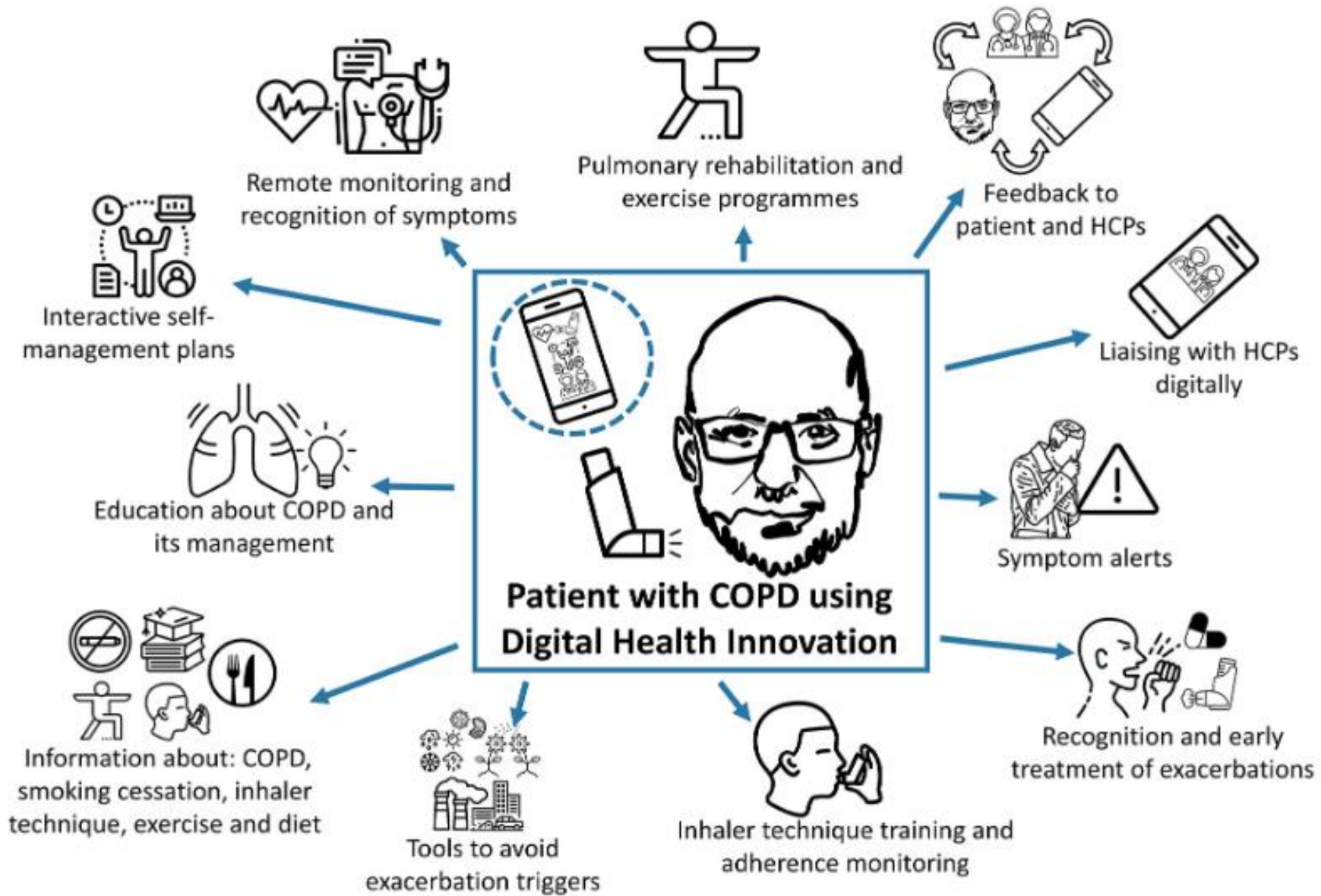
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Devices for Assessment of ventilation

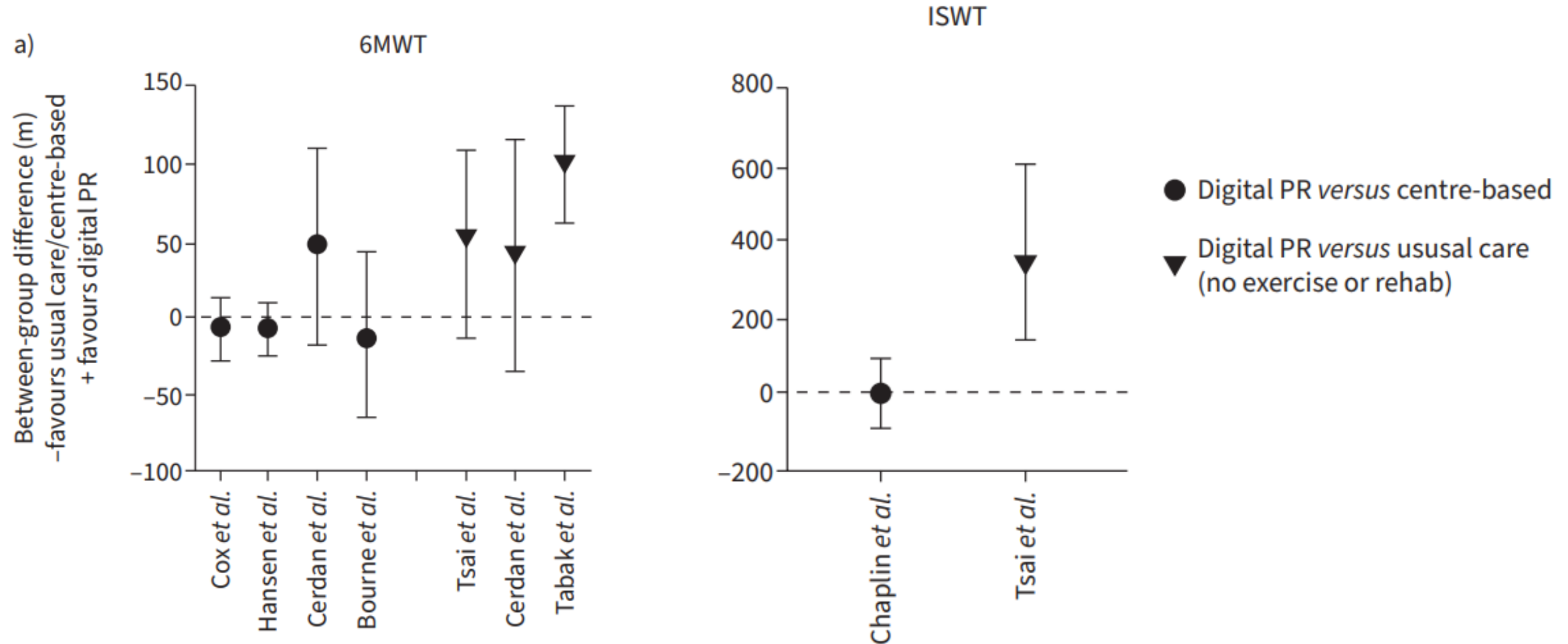
Devices for Airway clearance therapy

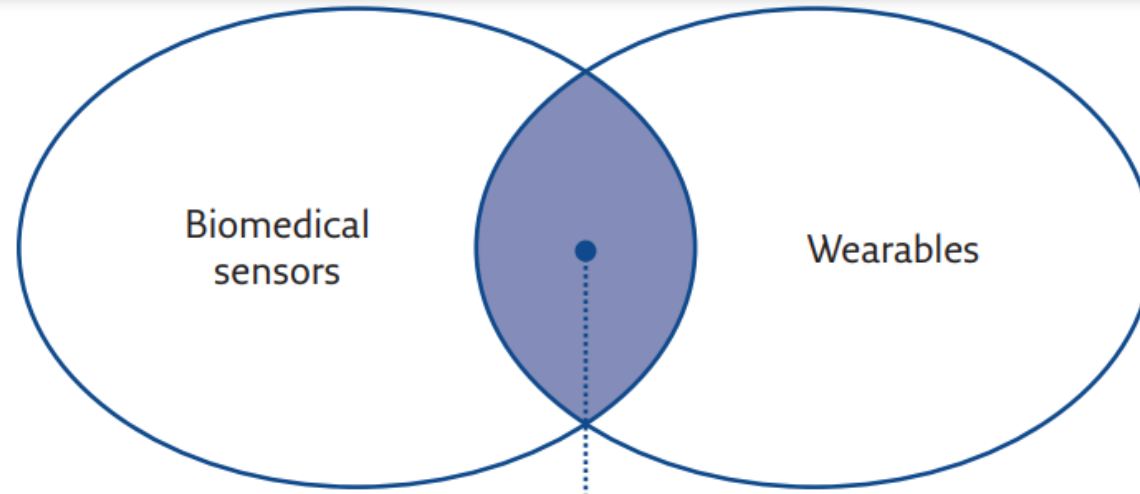
Devices for Respiratory muscle training

**Digital health device**

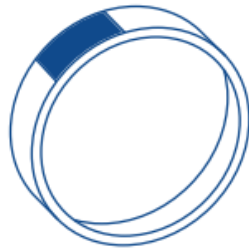


# Exercise tolerance and Digital PR





Wearable biomedical sensors



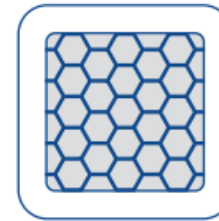
Activity trackers



Smart watches



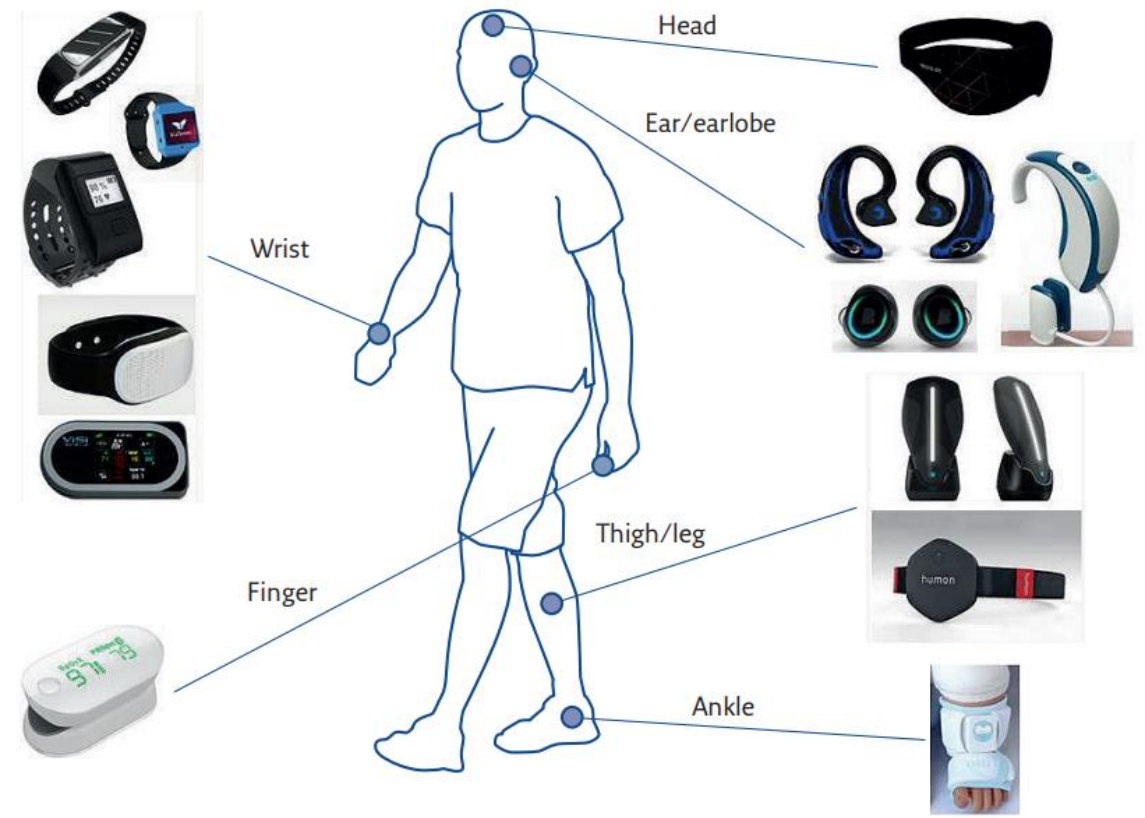
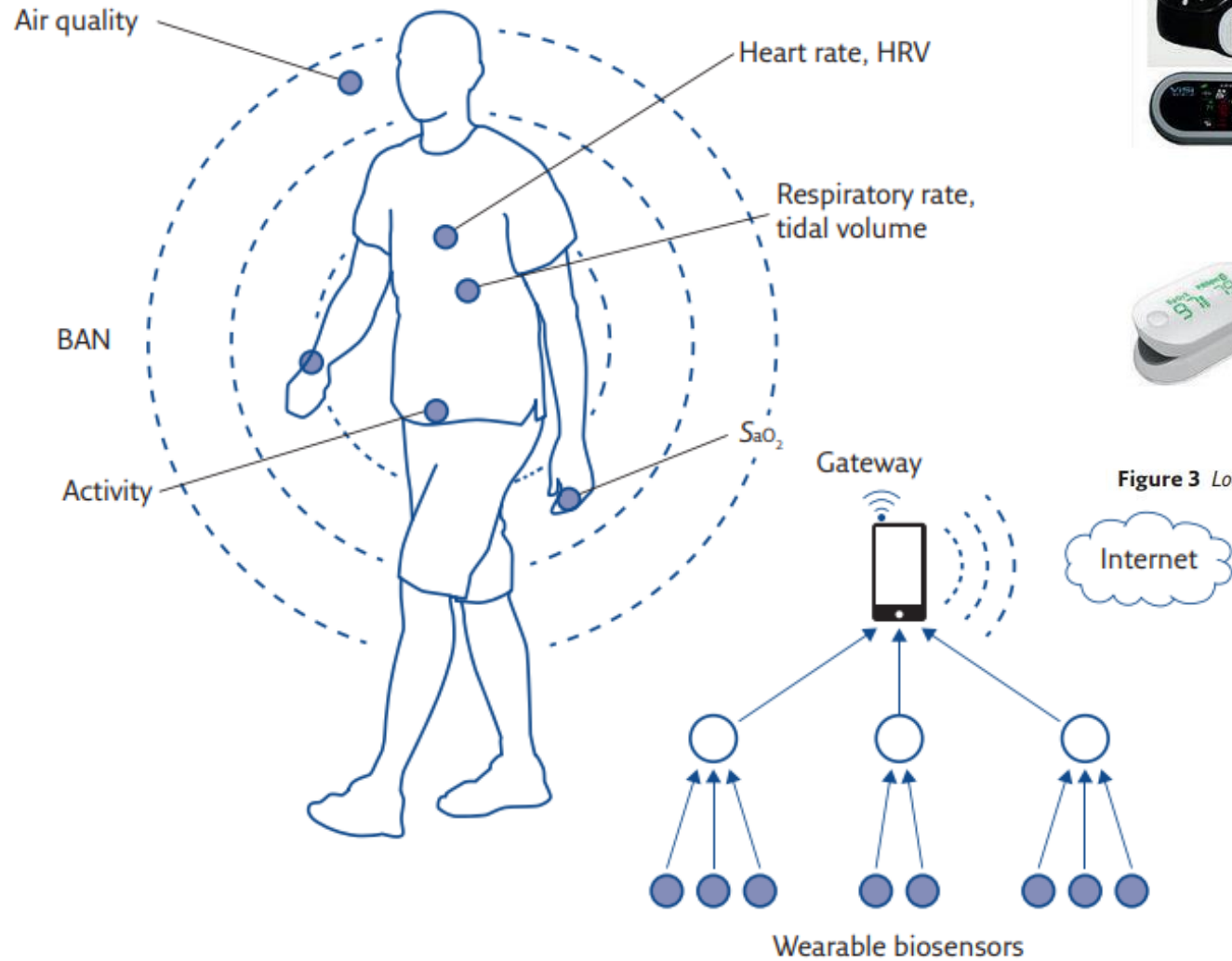
Smart clothing



Patches/  
tattoos



Ingestibles/  
smart implants



**Figure 3** Location on the body of several commercially available wearable devices able to perform pulse oximetry.







OPEN ACCESS

Original research

# Using a smartphone application maintains physical activity following pulmonary rehabilitation in patients with COPD: a randomised controlled trial

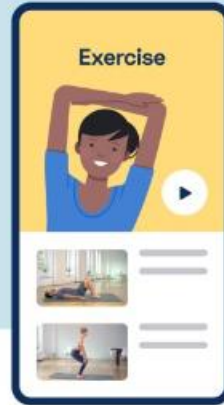
Marc Spielmanns <sup>1,2</sup> Rainer Gloeckl,<sup>3,4</sup> Inga Jarosch,<sup>3,4</sup> Daniela Leitl,<sup>3,4</sup> Tessa Schneeberger,<sup>3,4</sup> Tobias Boeselt,<sup>5</sup> Stephan Huber,<sup>6</sup> Pawandeep Kaur-Bollinger,<sup>6</sup> Bernhard Ulm,<sup>7</sup> Claudia Mueller,<sup>6</sup> Jonas Bjoerklund,<sup>6</sup> Sabine Spielmanns,<sup>1</sup> Wolfram Windisch <sup>2,8</sup> Anna-Maria Pekacka-Egli,<sup>1</sup> Andreas Rembert Koczulla<sup>3,4</sup>

# Kaia's digital solution provides affordable, accessible digital pulmonary rehabilitation



## Comprehensive COPD education

Relevant information in concise modules to boost self efficacy



## Customized daily training sessions

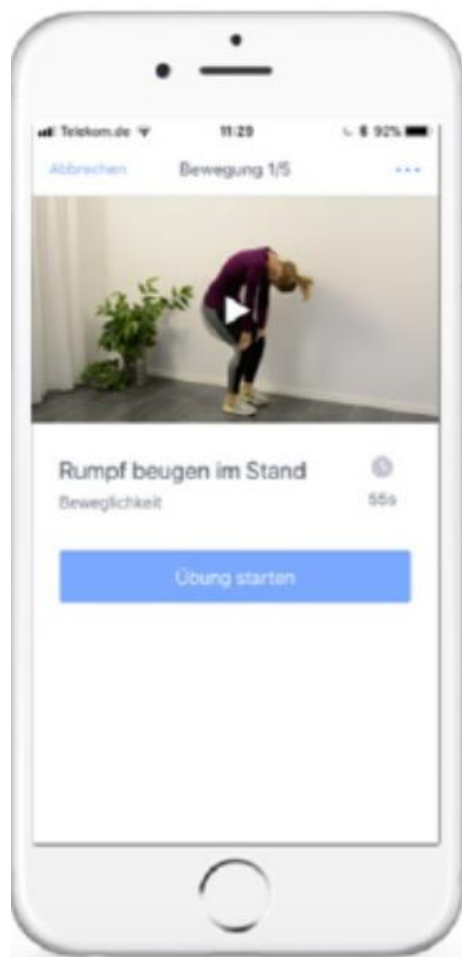
15 minutes of daily COPD-relevant exercises using motion coach



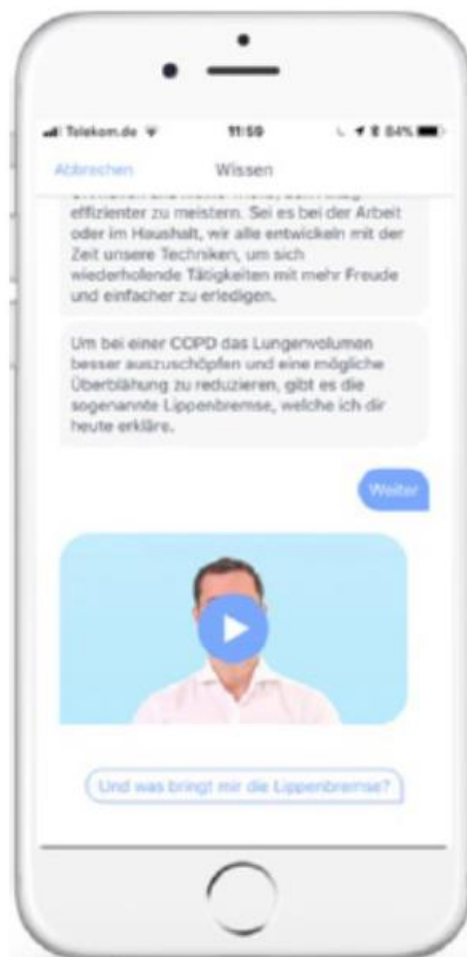
## Mindfulness and stress relief

Tailored mindfulness, breathing, and relaxation exercises

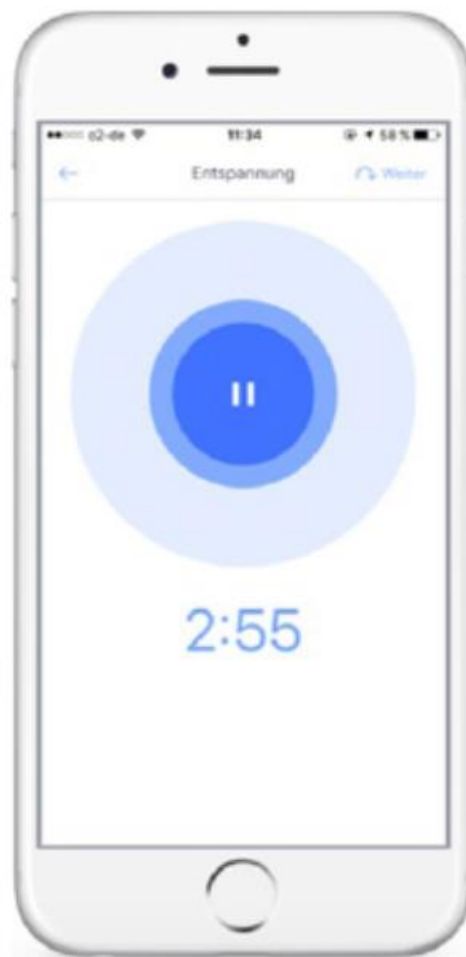
## Physical exercises



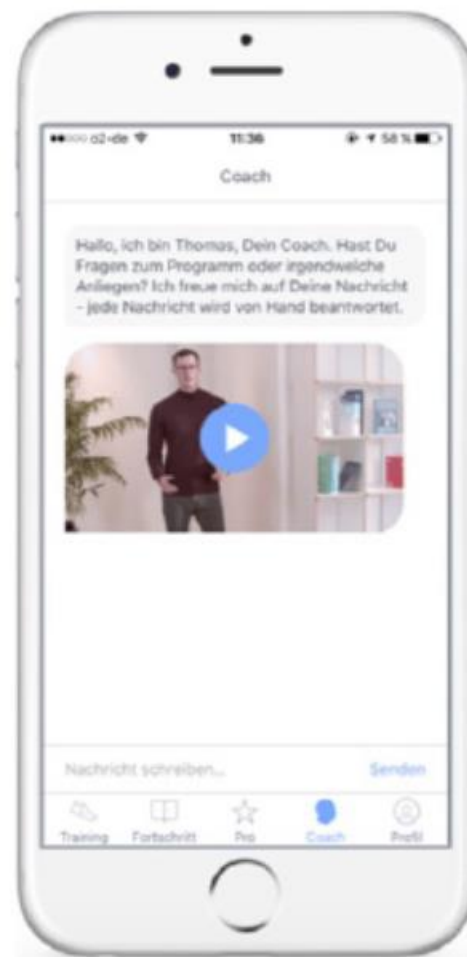
## Patient education



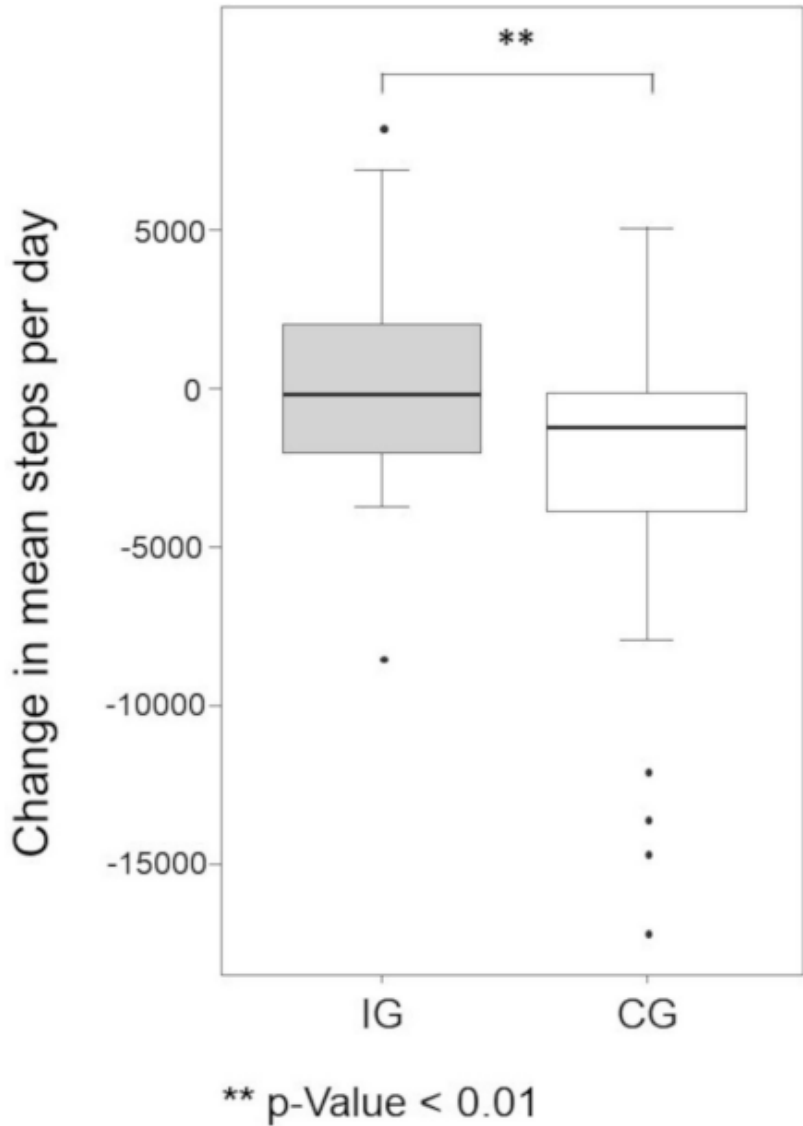
## Psychological exercises



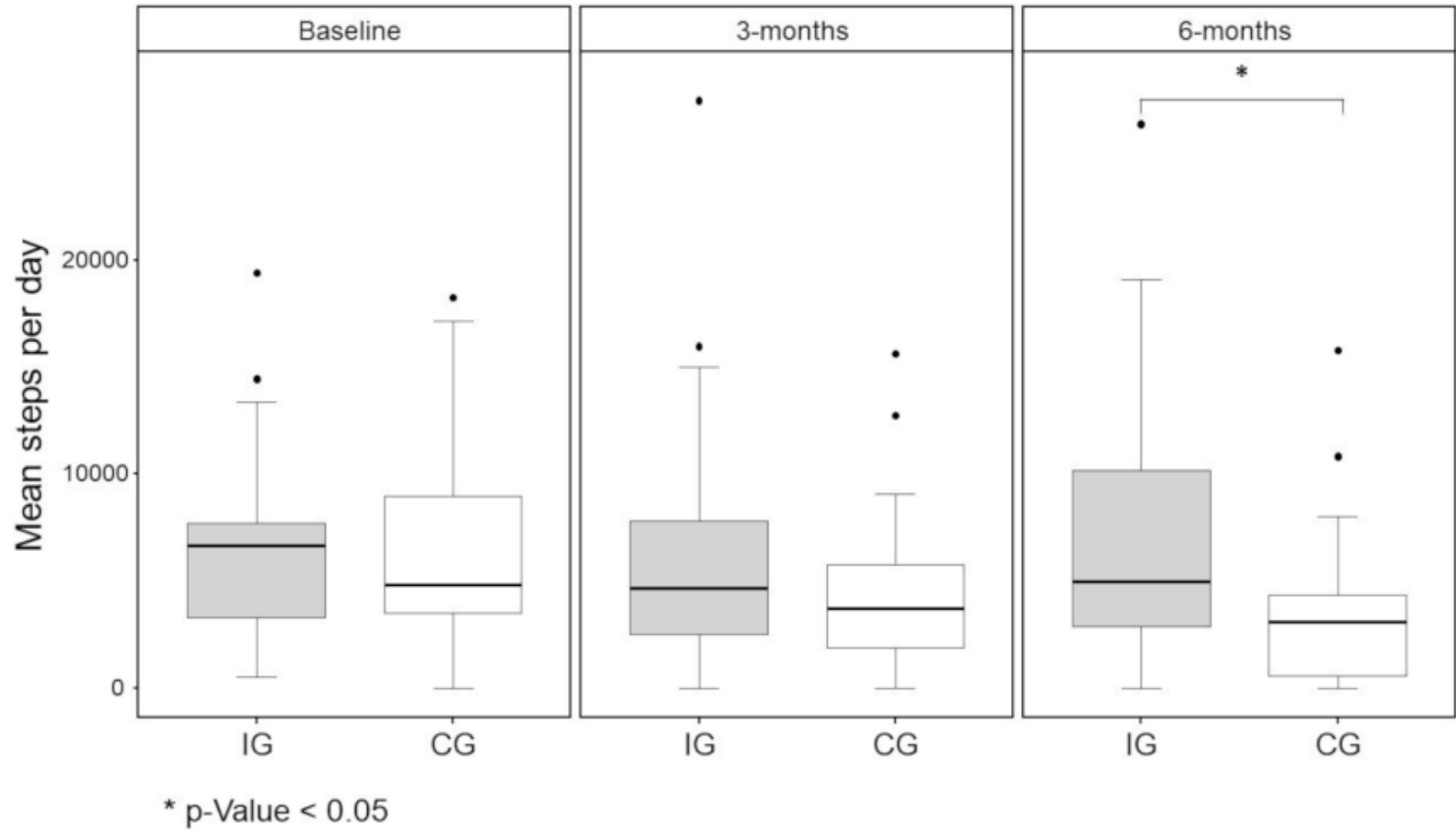
## Coaching



# Changes in steps per day from baseline to 6 months



# Mean steps per day



# Summary

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Devices for Assessment of ventilation

Devices for Airway clearance therapy

Devices for Respiratory muscle training

Digital health device