Controverse:
L'électrostimulation
POUR

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Kinesiología UC

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Cheryl HICKMANN, Bruxelles

☑ Je n'ai pas de lien d'intérêt potentiel à déclarer

Haute École Condorcet – Laboratoire de l'effort & du mouvement, Tournai-Belgium – Cliniques universitaires Saint-Luc UCL Bruxelles – Pontificia Universidad Católica de Chile – Wallonie - Bruxelles International.be – SKR Société de Kinésithérapie de Réanimation – réanimation 2023 Paris 14-16 juin

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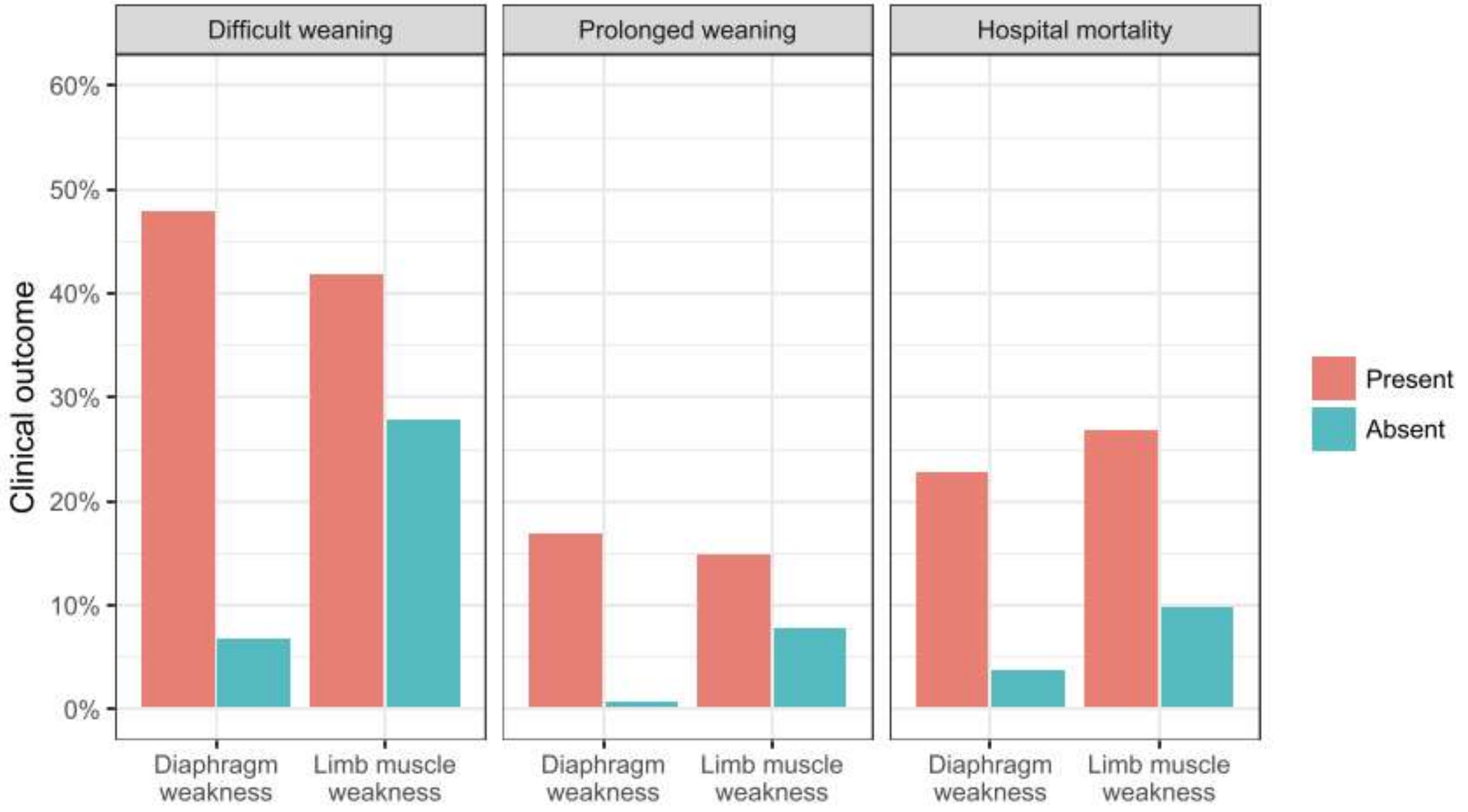
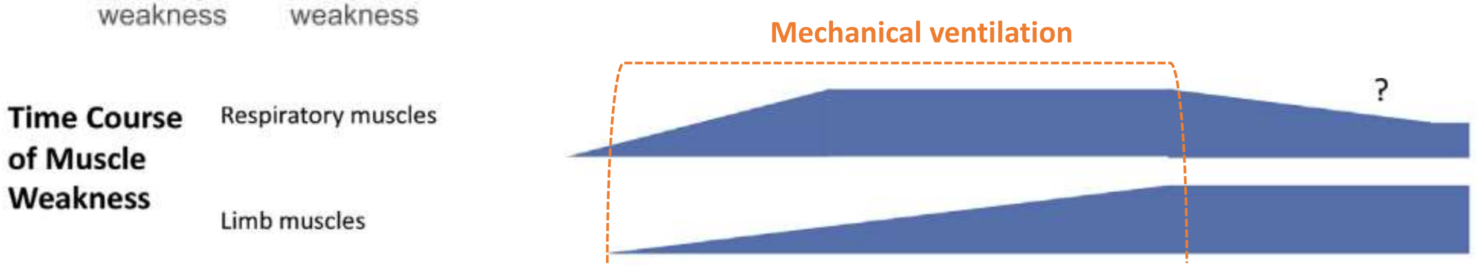
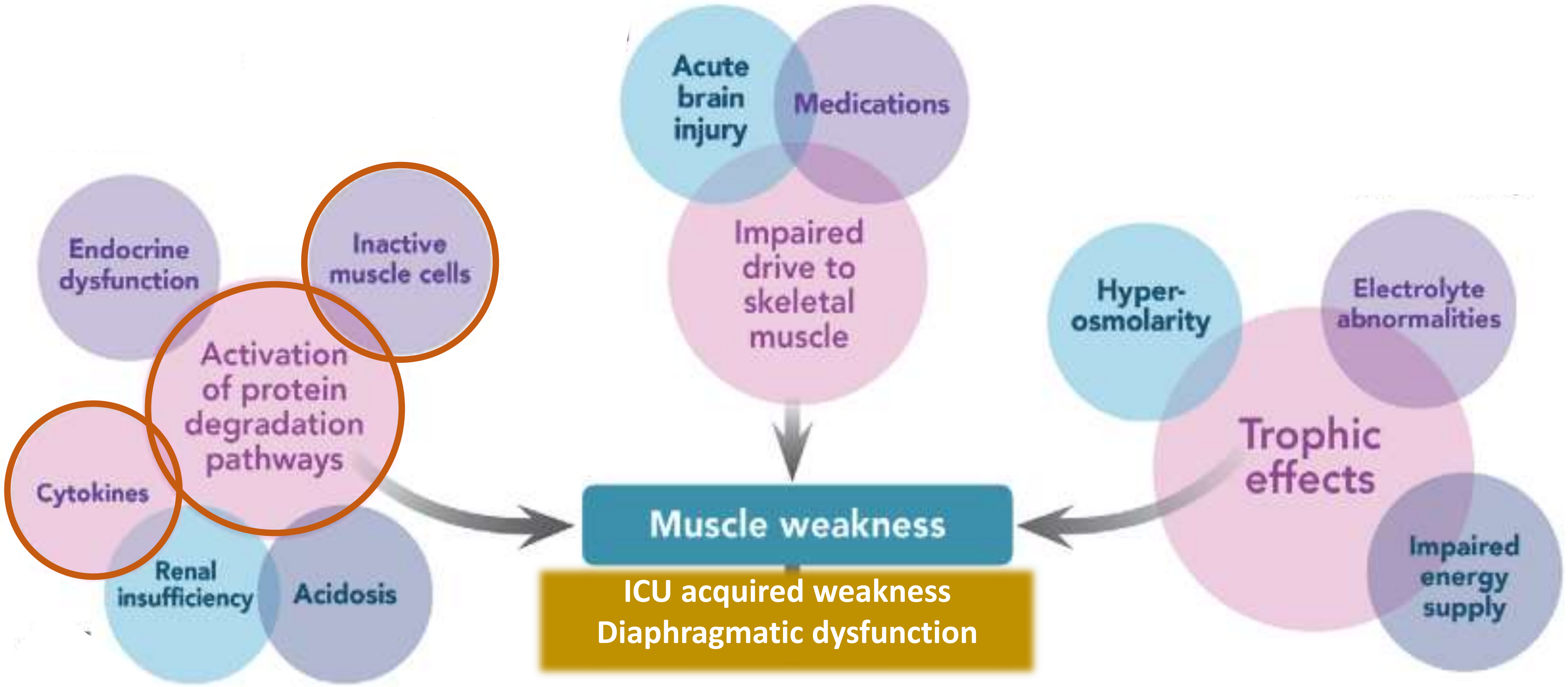


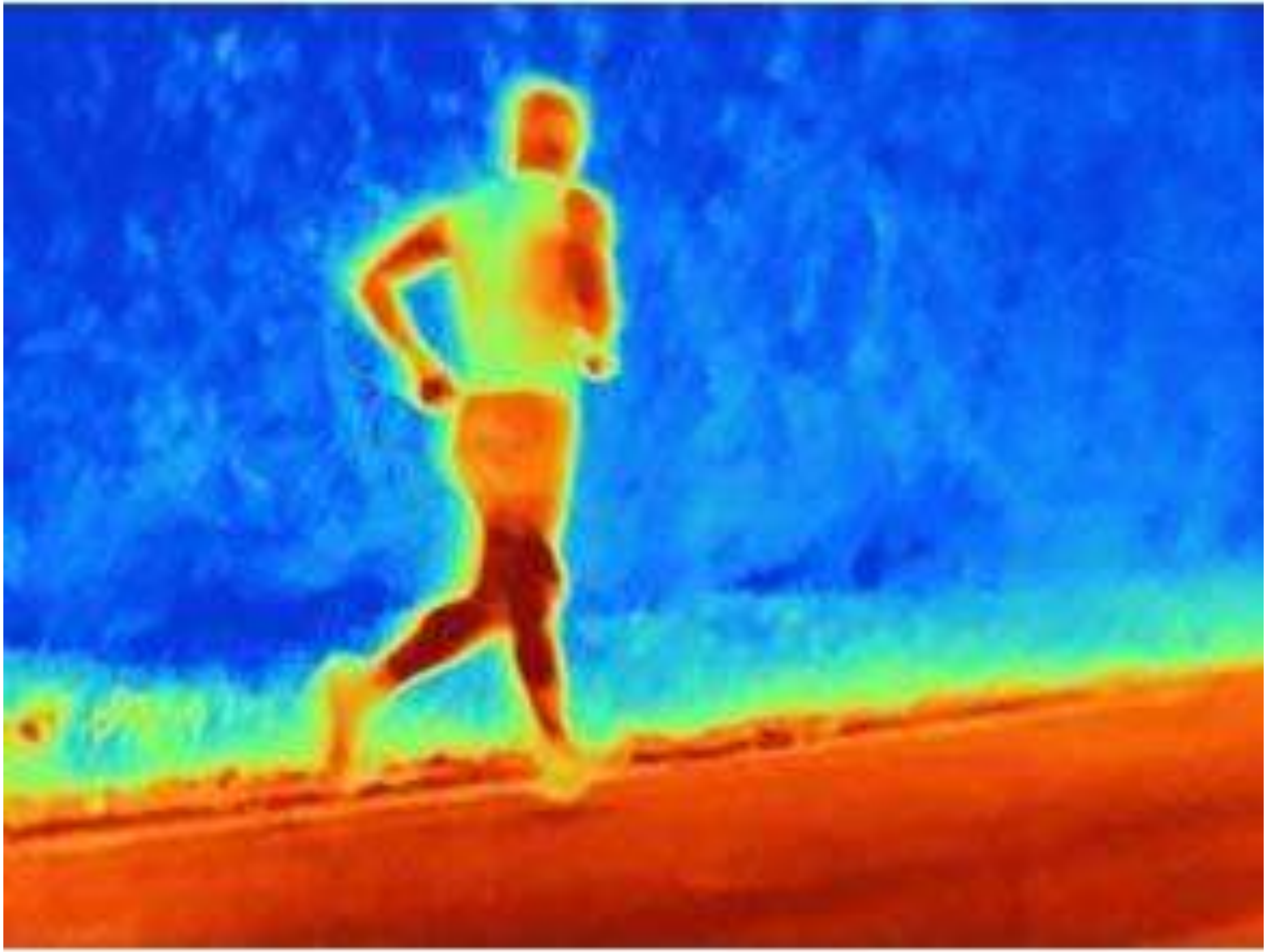


Schreiber A, Bertoni M, Goligher EC. Avoiding Respiratory anc
Diaphragm-Protective Ventilation and Early Mobilization. Crit



Inactivité des muscles
+
Environnement inflammatoire

Farhan H,. Anesthesiology. 2016



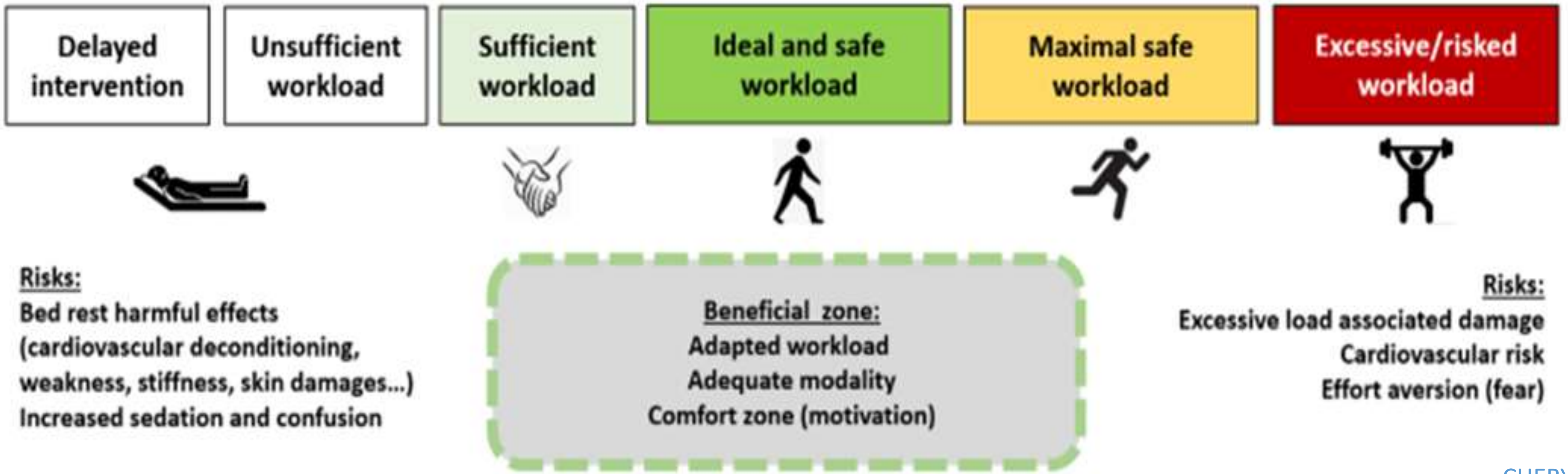
Les preuves manquent encore:

- Meilleure technique de mobilisation précoce
- Délai d'initiation adéquat
- Dosage-réponse
- Type d'entraînement

- Intensité
- Durée
- Fréquence
- Temps de repos

EVALUATION

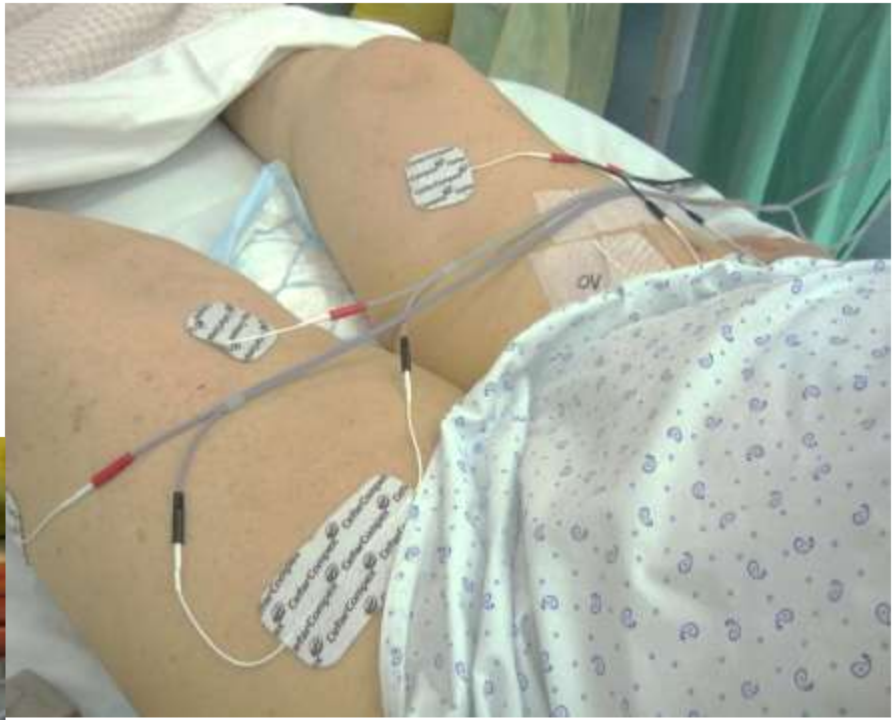
INDIVIDUALISATION



CHERYL ®

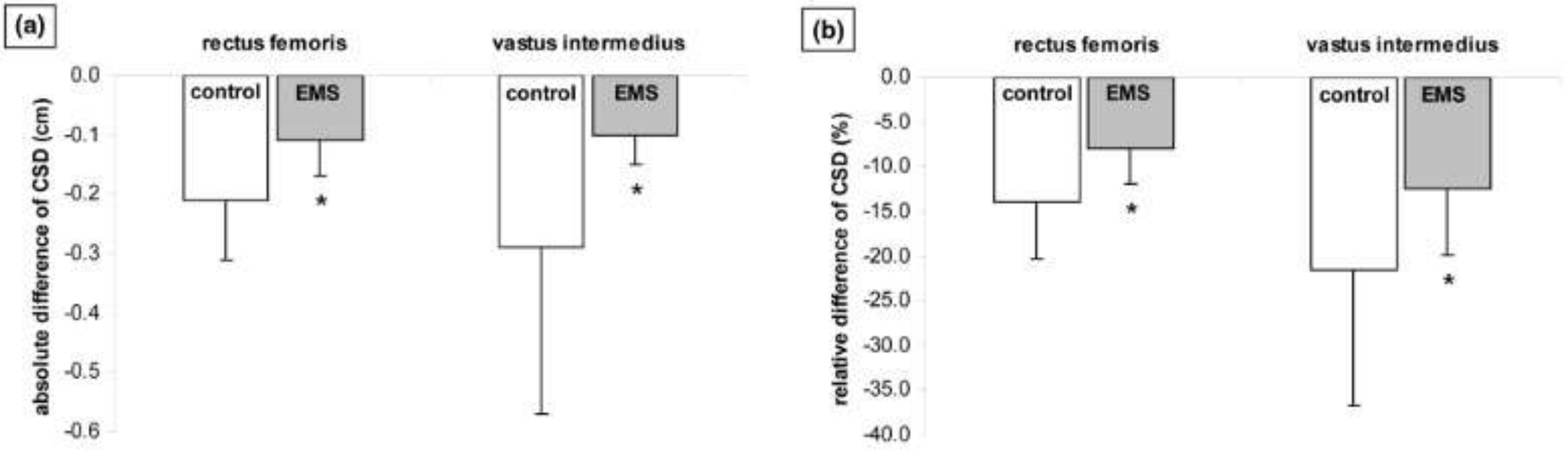
Electrostimulation neuromusculaire (NMES)

Alternative ou complément à l'activité contractile volontaire.



Effets sur l’atrophie musculaire

Twenty-six ICU patients



Gerovasili V, et al. Electrical muscle stimulation preserves the muscle mass of critically ill patients: A randomized study. Crit Care. 2009

Effets sur l'atrophie musculaire

Neuromuscular electrical stimulation prevents muscle wasting in critically ill comatose patients

Marlou L. Dirks*, Dominique Hansen†, Aimé Van Assche†, Paul Dendale† and Luc J. C. Van Loon*

*NUTRIM School for Nutrition, Toxicology and Metabolism, Maastricht University, Maastricht, The Netherlands
†Jessa Hospital, Heart Centre Hasselt, Hasselt, and Rehabilitation Research Center (REVAL), Hasselt University, Faculty of Medicine, Diepenbeek, Belgium

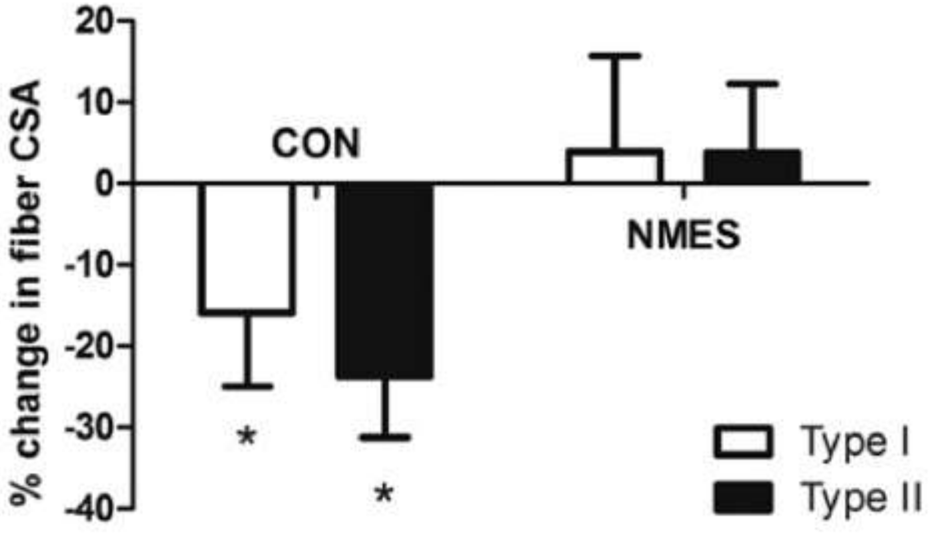


Figure 1 Changes in muscle fibre CSA in the CON and stimulated (NMES) leg of sedated patients, after 7 ± 1 days of twice-daily NMES
A significant interaction effect ($P < 0.05$) was observed and a time-effect in the CON leg ($P < 0.05$). *Significantly different change from zero ($P < 0.05$).

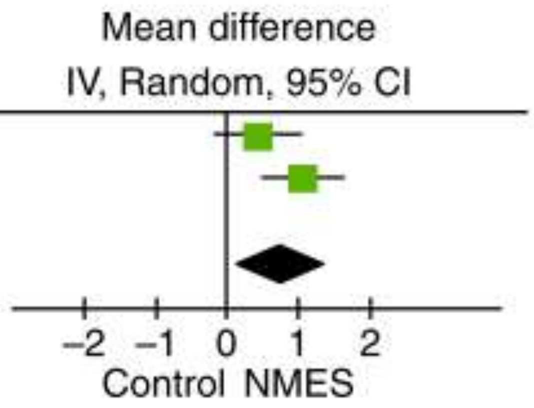
Dirks ML. et al. clinical science 2015

Effet sur la fonction des muscles périphériques

Study or subgroup	NMES Mean	NMES SD	NMES Total	Control Mean	Control SD	Control Total	Weight	Mean difference IV, Random, 95% CI
Rodriguez et al. (22)	3.07	0.73	14	2.64	0.93	14	48.5%	0.43 [−0.19, 1.05]
Routsi et al. (23); Karatzanos et al. (20)	4.69	0.53	24	3.61	1.45	28	51.5%	1.08 [0.50, 1.66]
Total (95% CI)			38			42	100.0%	0.77 [0.13, 1.40]

Heterogeneity: Tau^2=0.12; Chi^2=2.26, df=1 (P=0.13); I^2=56%

Test for overall effect: Z=2.36 (P=0.02)

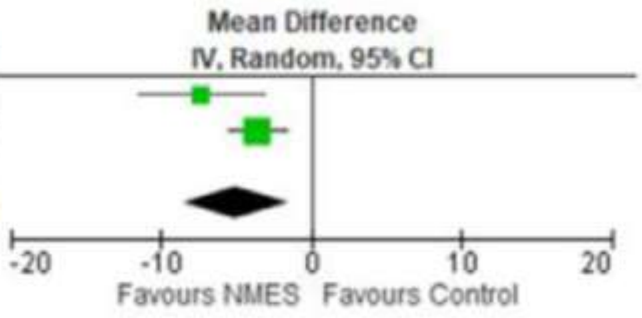


Wageck B, et al. Application and effects of neuromuscular electrical stimulation in critically ill patients: Systematic review. Med Intensiva [Internet]. 2014

A Effets sur la fonctionnalité (temps du lit au chaise)

Study or Subgroup	NMES Mean [days]	NMES SD [days]	NMES Total	Control Mean [days]	Control SD [days]	Control Total	Weight	Mean Difference IV, Random, 95% CI
Akar 2015	5.25	2.62	10	12.6	6.3	10	37.2%	-7.35 [-11.58, -3.12]
Zanotti 2003	10.75	2.41	12	14.33	2.53	12	62.8%	-3.58 [-5.56, -1.60]
Total (95% CI)			22			22	100.0%	-4.98 [-8.55, -1.41]

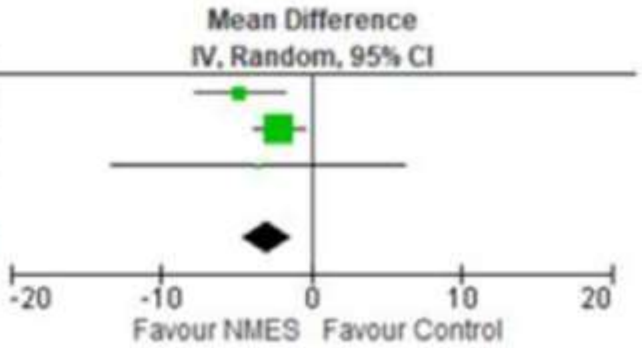
Heterogeneity: Tau² = 4.27; Chi² = 2.51, df = 1 (P = 0.11); I² = 60%
Test for overall effect: Z = 2.73 (P = 0.006)



B Effet sur la durée de la VM

Study or Subgroup	NMES Mean [days]	NMES SD [days]	NMES Total	Control Mean [days]	Control SD [days]	Control Total	Weight	Mean Difference IV, Random, 95% CI
Akar 2015	2	0.65	10	6.75	4.85	10	27.8%	-4.75 [-7.78, -1.72]
Chen 2019	5.12	2.01	27	7.24	4.35	29	69.2%	-2.12 [-3.88, -0.36]
Koçan 2015	14.6	10.97	11	18.13	11.08	9	3.0%	-3.53 [-13.25, 6.19]
Total (95% CI)			48			48	100.0%	-2.89 [-4.58, -1.21]

Heterogeneity: Tau² = 0.27; Chi² = 2.19, df = 2 (P = 0.34); I² = 9%
Test for overall effect: Z = 3.36 (P = 0.0008)



BPCO

Ruvistay Gutierrez-Arias, Yorschua Jalil , et al. Effectiveness of neuromuscular electrostimulation in COPD subjects on mechanical ventilation. A systematic review and meta-análisis. Clinics 77 (2022)

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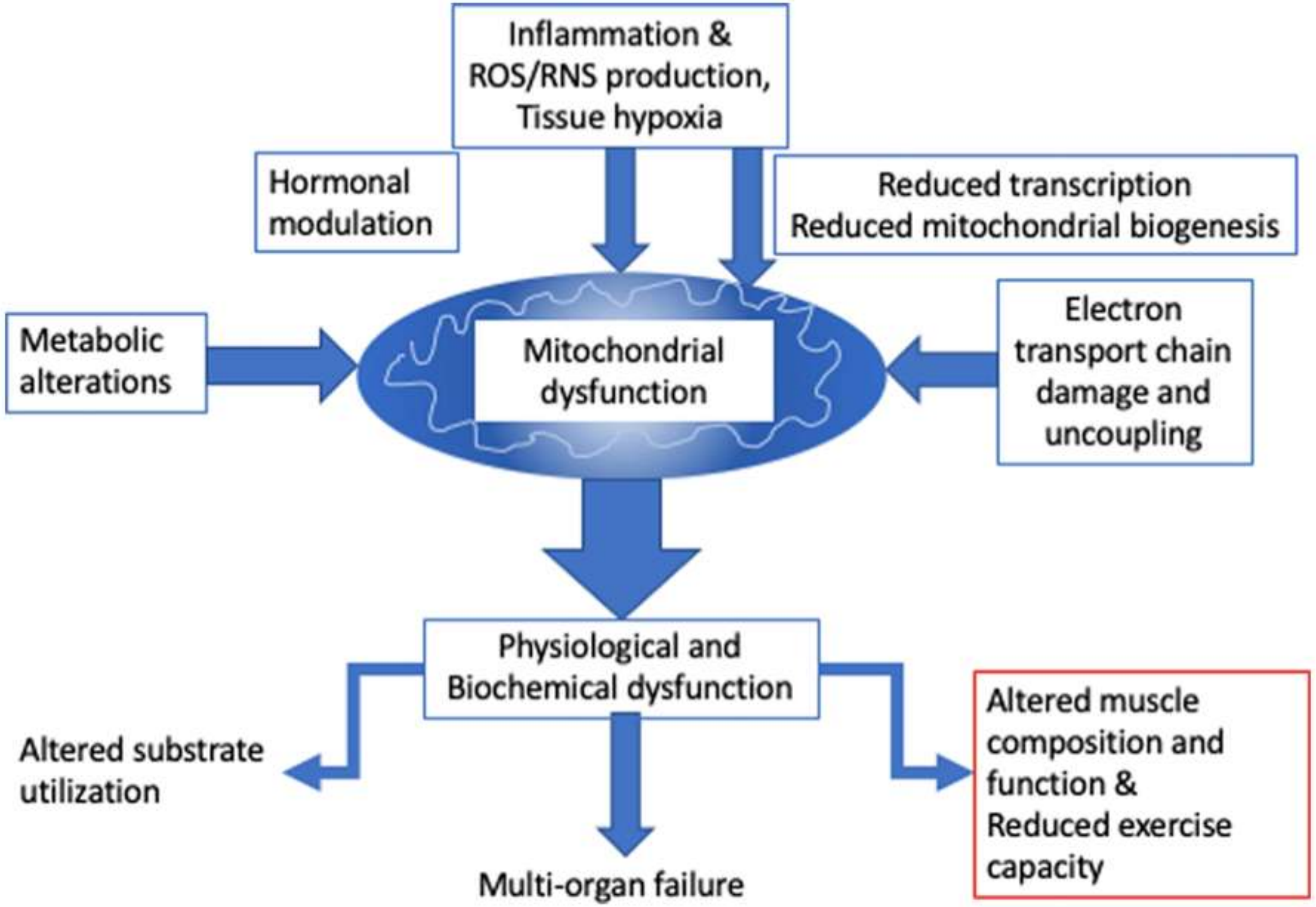
References	Sample (n)	Age (years)	Session duration (min.)	Baseline SOFA score	Baseline APACHE II score	Diagnosis	Main outcome	Influence on: Muscle strength/ volume/ histology	SOFA/ APACHE II score	Functional independence/ ambulation	Biomarker	Duration of mechanical ventilation/ICU length of stay
Stimulated muscle: quadriceps muscle only												
Treatment ≤ 10d												
Chen et al. (2019)	33 (SG = 16, CTRL = 17)	75.7 ± 16.1	60 min	n.a	20.5 ± 6.8	Respiratory failure	Increase in leg muscle strength	↑	↔	↔	n.a	↔
Dirks (2015)	6 (SG = 6, CTRL* = 6)	63.0 ± 6.0	60 min	n.a	29.3 ± 3.7	Multiple	Decrease in type 1 and type 2 muscle–fiber CSA in CTRL leg, no muscle atrophy in stimulated leg	↑	n.a	n.a	n.a	n.a
Fischer et al. (2016)	54 (SG = 27, CTRL = 27)	66.5 ± 14.6	60 min	7.3 ± 9.4	n.a	Cardiac surgery#	Increased muscle strength, no difference in muscle layer thickness	↑ ↔	n.a	↔	n.a	↔
Koutsioumpa et al. (2018)	80 (SG = 38, CTRL = 42)	65.1 ± 12.7	60 min	7.5 ± 4.2	19.1 ± 8.0	Multiple#	No effect on myopathy, increase in MRC	↑ ↔	↔	↔	n.a	↔
Poulsen et al. (2011)	8 (SG = 8, CTRL* = 8)	67.7 ± 7.0	60 min	11.4 ± 4.4	24.6 ± 7.9	Septic shock	No difference in muscle volume between stimulated and non-stimulated thigh	↔	↔	n.a	n.a	n.a
Strasser et al. (2009)	26 (SG = 26, CTRL* = 26)	60.0 ± 10.0	30 min	n.a	n.a	Abdominal surgery	Increase in total RNA content and reduced protein degradation	n.a	n.a	n.a	Increased total RNA content	n.a

Maryam Balke, et al. Therapeutic Potential of Electromyostimulation (EMS) in Critically Ill Patients—A Systematic Review. Frontiers in Physiology, May 2022,

References	Sample (n)	Age (years)	Session duration (min.)	Baseline SOFA score	Baseline APACHE II score	Diagnosis	Main outcome	Influence on: Muscle strength/ volume/ histology	SOFA/ APACHE II score	Functional independence/ ambulation	Biomarker	Duration of mechanical ventilation/ICU length of stay
						Treatment > 10d						
Meesen et al. (2010)	19 (SG = 7, CTRL* = 12)	67 ± 13.0	30 min	n.a	n.a	Multiple	Reduction of muscle atrophy in stimulated limb	↑	n.a	n.a	n.a	n.a
Dos Santos (2020)	51 (SG = 36, CTRL = 15)	53.2 ± 12.2	55 min	n.a	15.9 ± 3.5	Multiple#	Shorter MV duration	n.a	↔	n.a	n.a	↓
Abu-Khaber et al. (2013)	80 (SG = 40, CTRL = 40)	58.3 ± 6.1	60 min	n.a	25.3 ± 6.1	Respira-tory failure#	Reduced MV time	↔	n.a	n.a	n.a	↓
Berney et al. (2020)‡	162 (SG = 80, CTRL = 82)	59.1 ± 14.0	60 min	10.4 ± 4.9	15.9 ± 8.7	Multiple#	No effect on muscle strength	↔	↔	↔	n.a	↔
Fossat et al. (2018)‡	312 (SG = 158, CTRL = 154)	65.6 ± 14.0	50 min	n.a	n.a	Multiple#	No improvement of global muscle strength at discharge	↔	n.a	↔	n.a	↔
Gruther et al. (2010)	33 (SG = 16, CTRL = 17)	56.0 ± 11.8	30 min (week 1), 60 min (week 2)	n.a	n.a	Multiple#	Increase in muscle layer thickness (long-term patient)	↑	n.a	n.a	n.a	n.a

References	Sample (n)	Age (years)	Session duration (min.)	Baseline SOFA score	Baseline APACHE II score	Diagnosis	Main outcome	Influence on: Muscle strength/ volume/ histology	SOFA/ APACHE II score	Functional independence/ ambulation	Biomarker	Duration of mechanical ventilation/ICU length of stay
Stimulated muscle: 2–4 leg muscle groups												
Treatment ≤ 10 days												
Fontes Cerqueira et al. (2018)	59 (SG = 26, CTRL = 33)	42 ± 13.7	60 min	n.a	n.a	Cardiac surgery	No effect on muscle strength, functional independenc, and quality of life	↔	n.a	↔	n.a	↔
Gerovasili et al. (2009)	26 (SG = 13, CTRL = 13)	57.5 ± 19.7	55 min	9.0 ± 3.1	18.5 ± 4.7	Multiple#	Less decrease of CSD of the right rectus femoris and vastus intermedius	↑	n.a	n.a	n.a	n.a
Waldauf et al. (2021)	150 (SG = 75, CTRL = 75)	61.1 ± 15.3	31.1 min	8.8 ± 2.9	22.2 ± 6.6	Multiple#	No difference in physical component summary of SF-36 at 6 months followup	↔	↔	↔	Less negative daily nitrogen balance	↔
Treatment > 10 days												
Falavigna et al. (2014)	11 (SG = 11, CTRL* = 11)	34.0 ± 17.3	20 min	n.a	15.7 ± 4.5	Multiple#	No effect on muscle atrophy	↔	n.a	n.a	n.a	n.a
Kho et al. (2015)	34 (SG = 16, CTRL = 18)	55.1 ± 16.9	60 min	5.9 ± 3.4	25.0 ± 6.9	Multiple#	Greater increase in lower extremity strength from awakening to ICU discharge in	↑	↔	↔	n.a	↔
Routsi et al. (2010)	140 (SG = 68, CTRL = 72)	59.5 ± 18.5	55 min	9.0 ± 3.0	18.0 ± 4.5	Multiple#	Higher Muscle strength and reduced ICU time	↑	n.a	n.a	n.a	↓
Zanotti et al. (2003)	24 (SG = 12, CTRL = 12)	65.4 ± 6.3	30 min	n.a	n.a	COPD	Improvement of muscle strength and faster ambulation	↑	n.a	↑	n.a	n.a

Défaillance énergétique



Molinger J. Curr Opin Crit Care. 2021

Comparison of exercise intensity during four early rehabilitation techniques in sedated and ventilated patients in ICU: a randomised cross-over trial

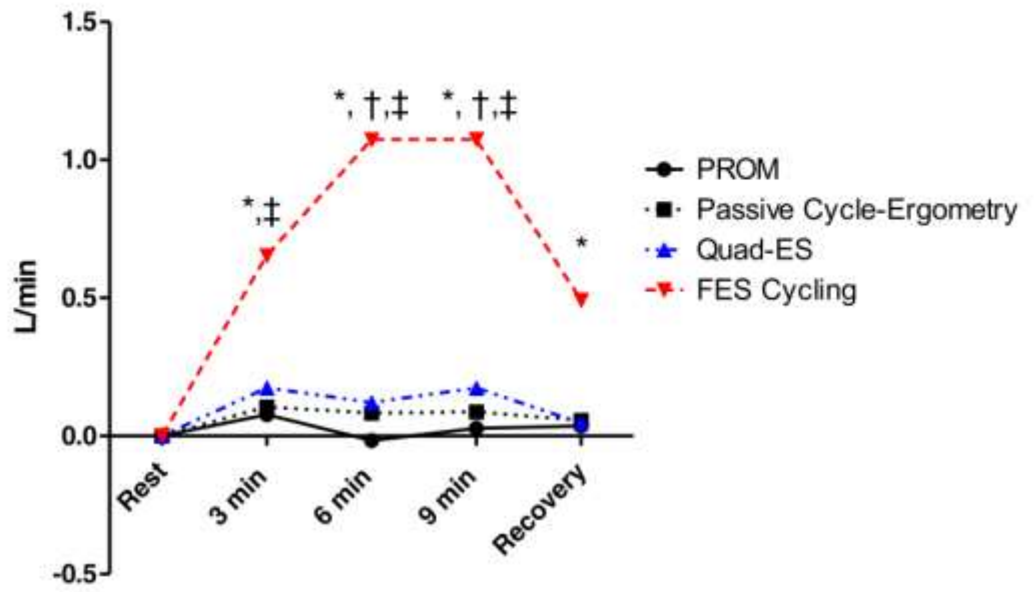
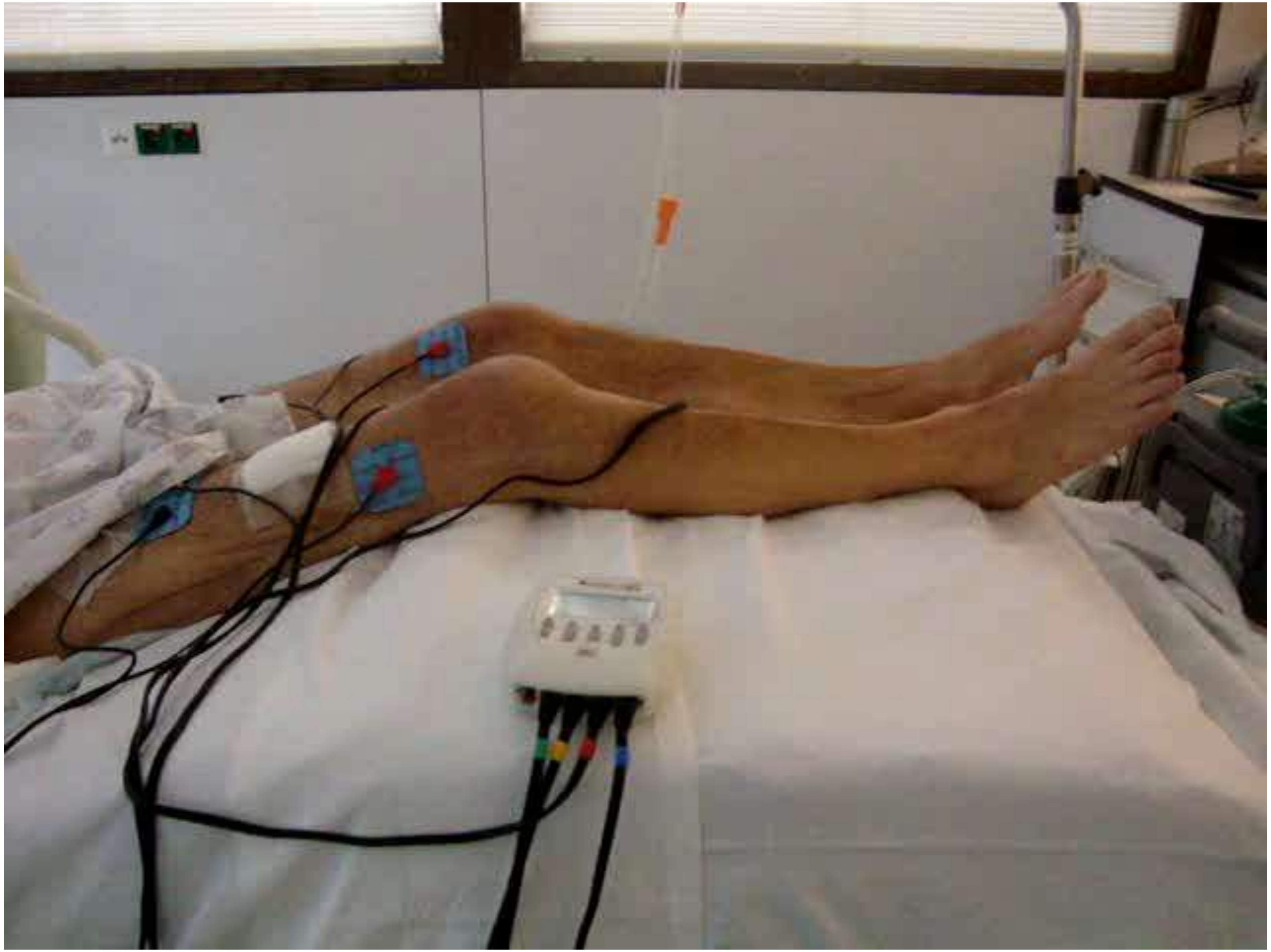
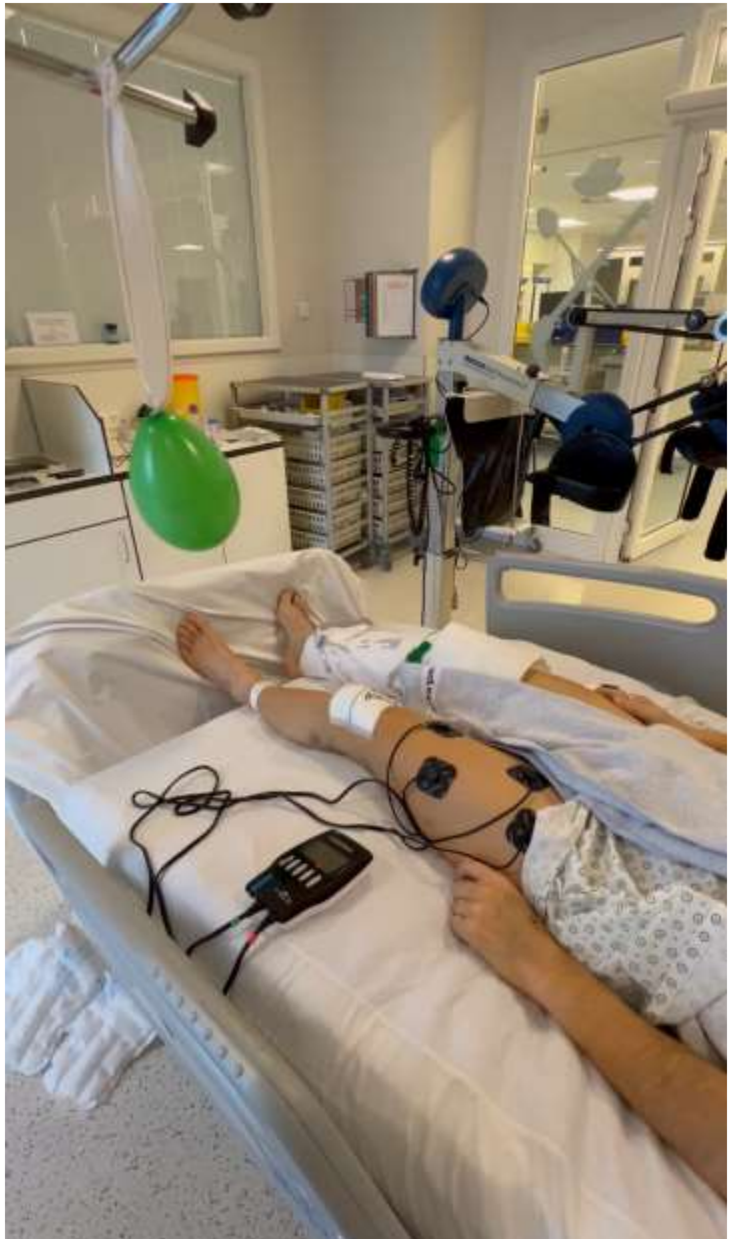


Fig. 2 Cardiac output over time for each exercise. Black circles represent passive range of leg movement (PROM); black squares represent passive cycle-ergometry; blue triangles represent quadriceps electrical stimulation; red triangles represent functional electrical stimulation cycling (FES-Cycling). *Significantly different between PROM and FES-Cycling; †significantly different between passive cycle-ergometery and FES-Cycling; ‡significantly different between quadriceps electrical stimulation and FES-Cycling

Medrinal C. et al. Crit Care 2018





Video: Valentin Durant
Hopital Ambroise Paré Mons – Belgique

Acute effect of passive cycle-ergometry and functional electrical stimulation on nitrosative stress and inflammatory cytokines in mechanically ventilated critically ill patients: a randomized controlled trial

4 groups:

Control

PCE = Passive cycle-ergometry (20min, 30 cpm)

FES = Functional electrical stimulation (20min)

FES + PCE (20min+20min)

França E.E.T. , Braz J Med Biol Res 2020

Table S1. Nitric oxide (NO) production in stimulated (C+) and non-stimulated (C-) monocytes assessed before and after applying the study protocol to the four groups.

Nitric oxide	Groups							
	Control (n=10)		FES (n=9)		FES + PCE (n=7)		PCE (n=9)	
	Before	After	Before	After	Before	After	Before	After
NO (C+) (μM)	10.78 ± 10.6	11.51 ± 12.4	8.19 ± 6.4	6.96 ± 5.4	12.95 ± 6.1	13.60 ± 7.1	20.82 ± 16.2	17.72 ± 16.7
	P=0.3123		P=0.0188*		P=0.2644		P=0.0002*	
NO (C-) (μM)	10.30 ± 9.9	11.84 ± 13.2	8.64 ± 6.7	7.49 ± 5.6	14.12 ± 8.5	15.25 ± 9.2	29.90 ± 23.7	18.72 ± 19.6
	P=0.2852		P=0.0258*		P=0.6743		P=0.0007*	

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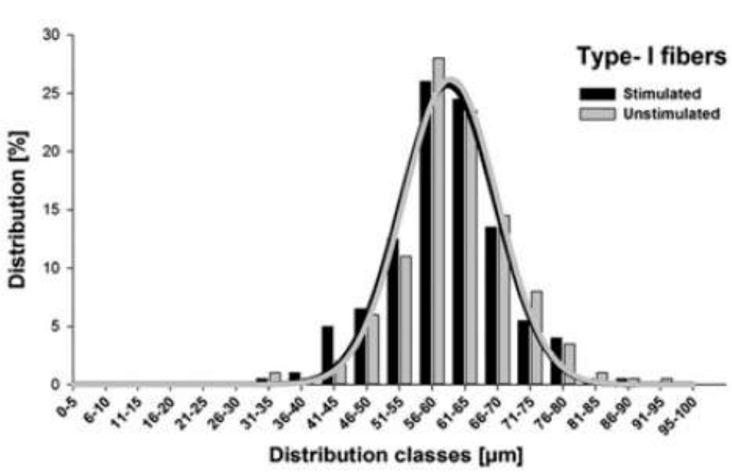
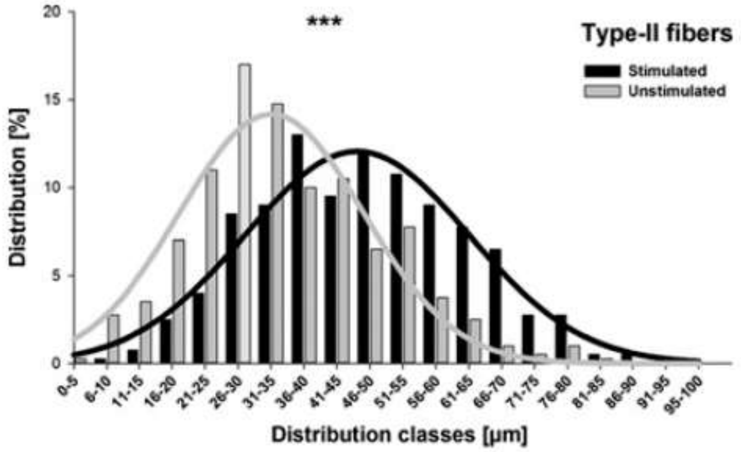
Critical Illness Myopathy and GLUT4

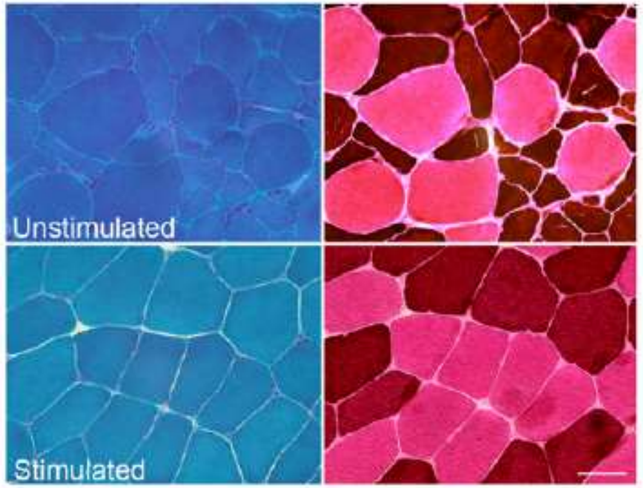
Significance of Insulin and Muscle Contraction

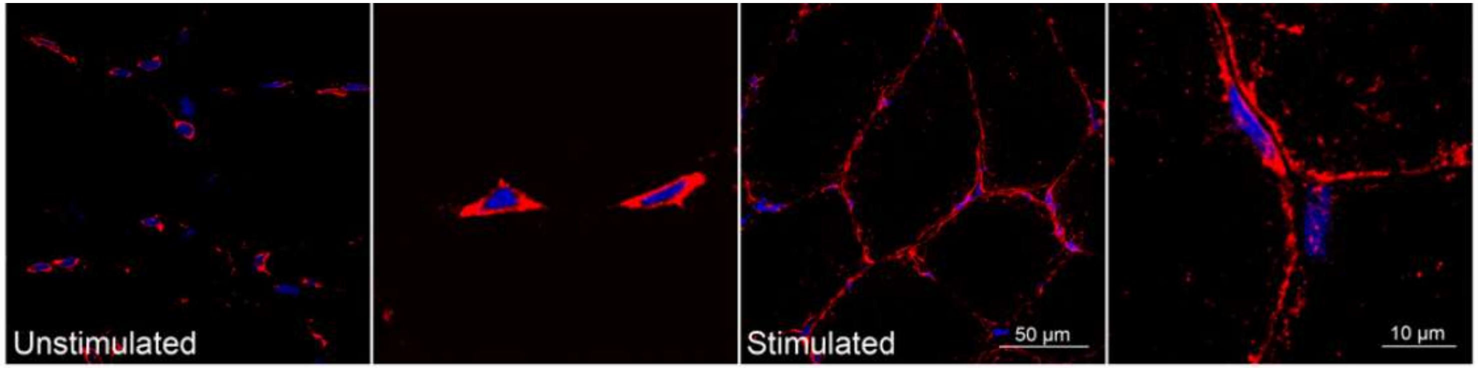
Electrical muscle stimulation

n=4, ARDS and sepsis









(GLUT4, red; nuclei, blue)

EMS may:

- Diminish protein breakdown
- Prevent muscle-specific AMPK failure
- Restore GLUT4 disposition

Weber-Carstens S, et al. AJRCCM 2013

Wallonie - Bruxelles International.be

Resistance training + NMES

american physiological society

JOURNAL OF APPLIED PHYSIOLOGY

J Appl Physiol 131: 265–276, 2021.
First published May 13, 2021; doi:10.1152/japplphysiol.01029.2020

RESEARCH ARTICLE

Neuromuscular electrical stimulation resistance training enhances oxygen uptake and ventilatory efficiency independent of mitochondrial complexes after spinal cord injury: a randomized clinical trial

Ashraf S. Gorgey,[1,2] Raymond E. Lai,[1,2] Refka E. Khalil,[1] Jeannie Rivers,[3] Christopher Cardozo,[4,5,6] Qun Chen,[7,8] and Edward J. Lesnefsky[7,8]

[1]Spinal Cord Injury and Disorders Hunter Holmes McGuire VA Medical Center, Richmond, Virginia; [2]Department of

Gorgey AS, Appl Physiol (1985) 2021

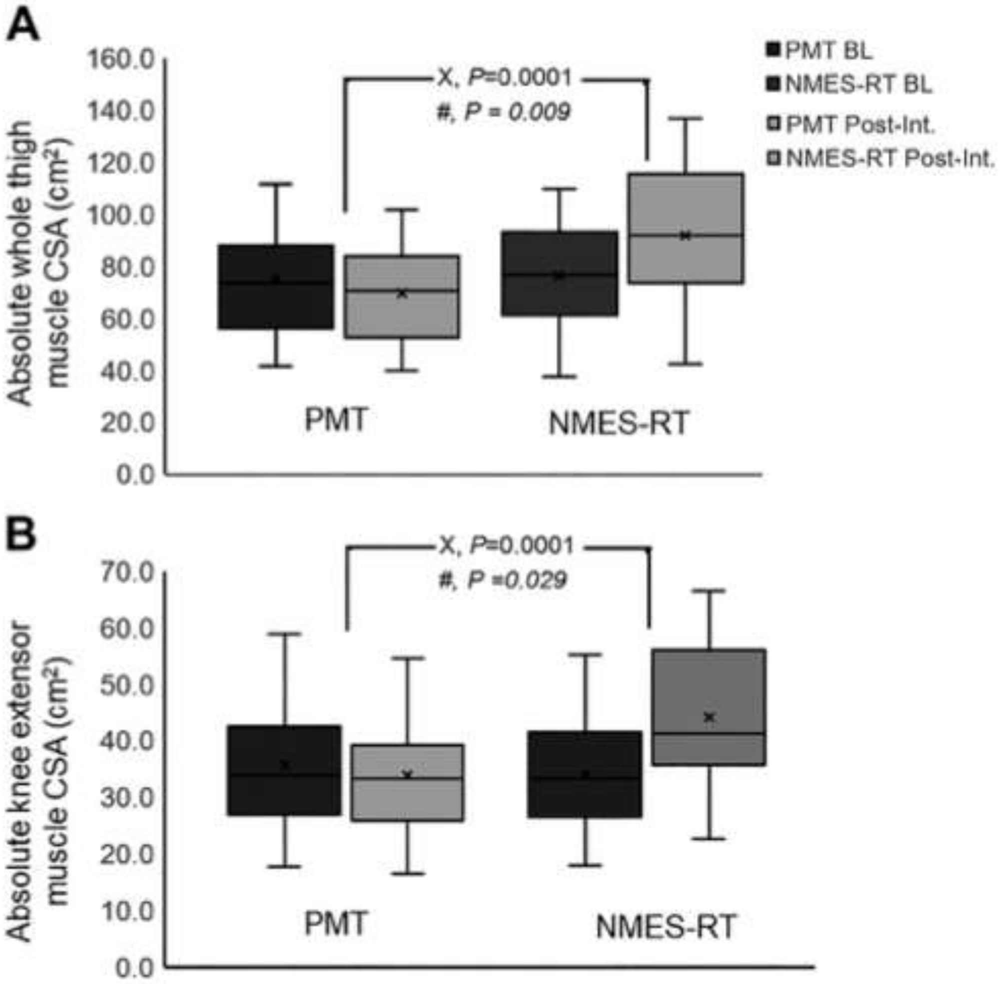
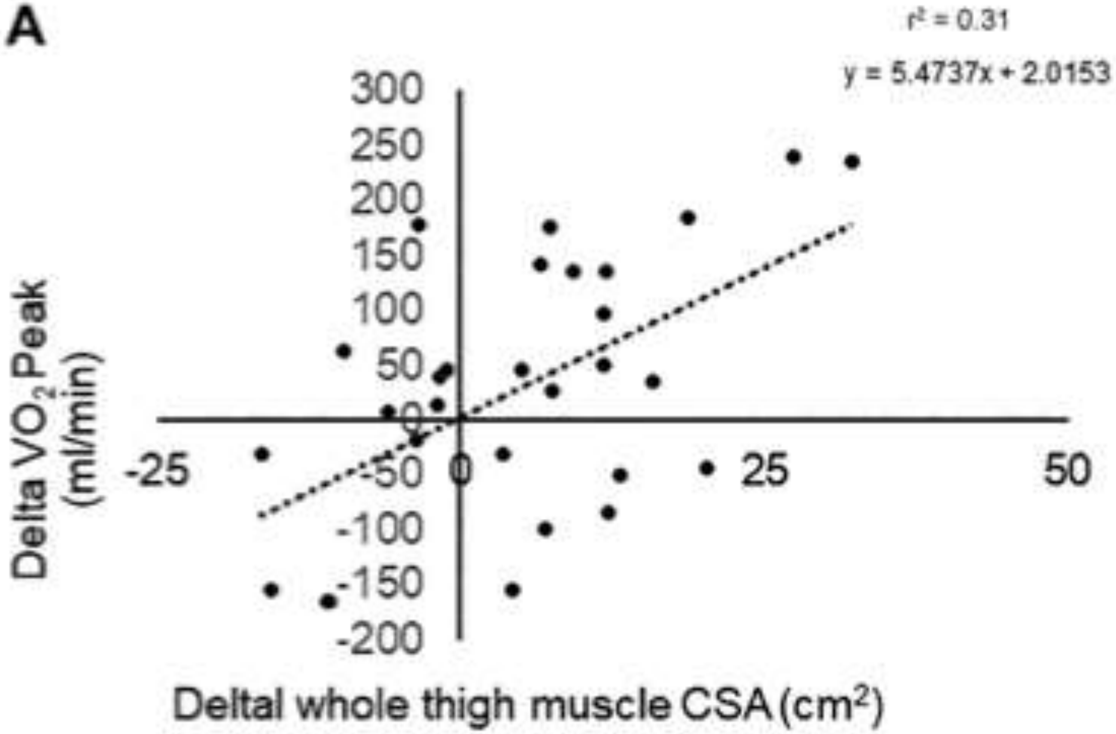


Figure 1. Distribution of muscle cross-sectional area (means ± SD) during baseline (BL) and postintervention (postint.) for both the PMT and NMES-RT groups for thigh muscle CSA (*A*) and knee extensor muscle CSA (*B*) in persons with SCI. CSA, cross-sectional area; NMES-RT, neuromuscular electrical stimulation-resistance training; PMT, passive movement training; SCI, spinal cord injury.

Resistance training + NMES



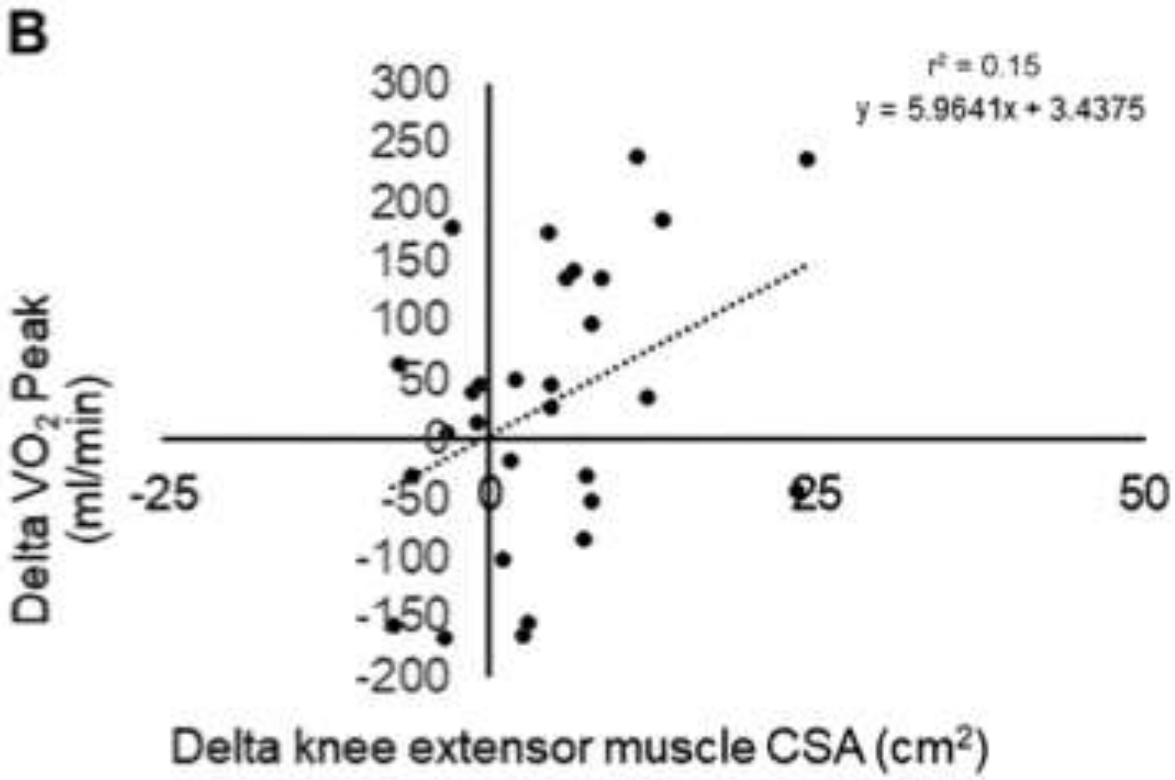
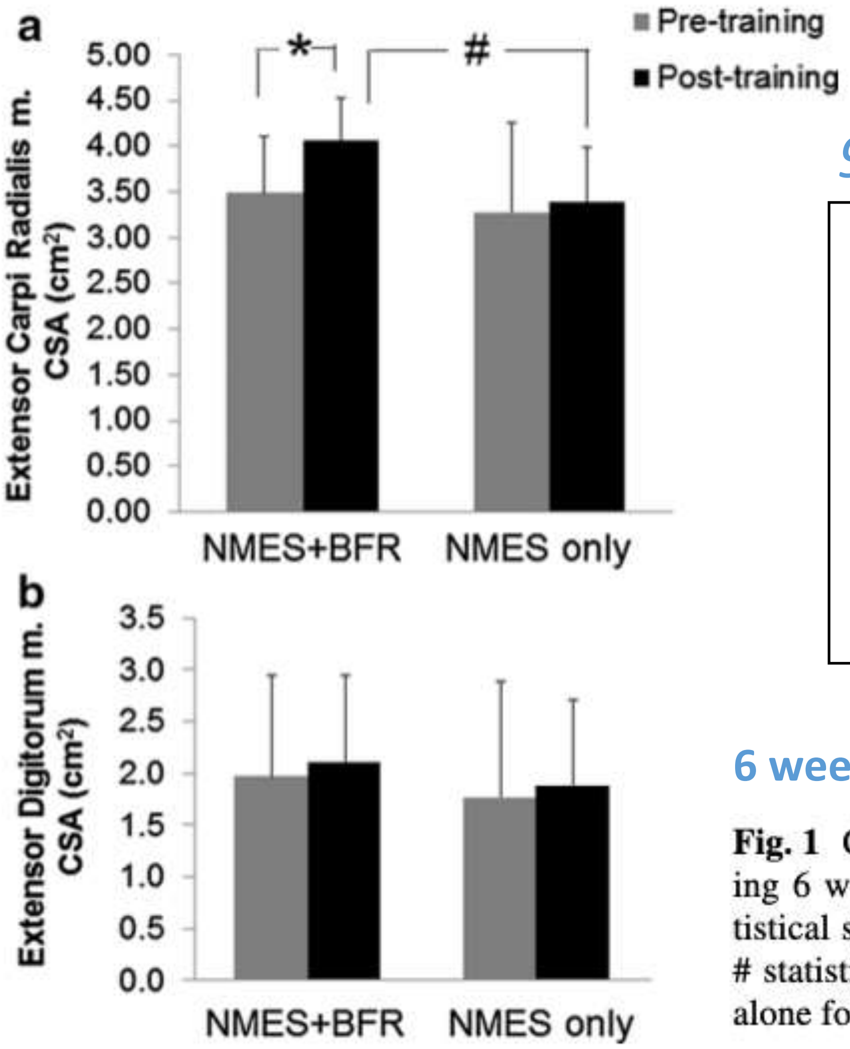
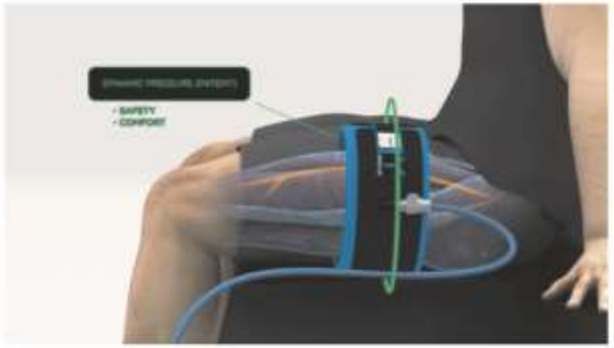


Figure 3. Relationships between changes in $\dot{V}O_2$ with respect to changes in thigh and knee extensor muscle CSAs at the start and end of training for both PMT and NMES-RT groups. $\Delta\dot{V}O_2$ vs. Δthigh muscle CSA (*A*) and $\Delta\dot{V}O_2$ vs. Δknee extensor muscle CSA (*B*). $\dot{V}O_2$, postintervention $\dot{V}O_2$ - baseline $\dot{V}O_2$; Δthigh muscle CSA, postintervention thigh muscle CSA - baseline thigh muscle CSA; Δknee extensor muscle CSA, postintervention knee extensor muscle CSA - baseline knee extensor muscle CSA; CSA, cross-sectional area; NMES-RT, neuromuscular electrical stimulation-resistance training; PMT, passive movement training; $\dot{V}O_2$, oxygen uptake.

Gorgey AS, Appl Physiol (1985) 2021

BFR + NEMS





9 spinal cord injury patients

The increase in endothelial-dependent nitric oxide secretion with BFR may likely contribute to skeletal muscle hypertrophy and improvement in FMD in persons with SCI.

Flow mediated dilatation — Spinal cord injury

6 weeks of training, twice weekly for 30 min

Fig. 1 Changes in skeletal muscle CSAs of ECRL and EDC following 6 weeks of training using NMES+BFR or NMES alone. * Statistical significance in ERCL CSA from pre-training to post-training; # statistical significance in ECRL between NMES+BFR and NMES alone following 6 weeks of training

Gorgey AS 2016
Eur J Appl Physiol

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USE OF NEUROMUSCULAR ELECTRICAL STIMULATION TO PRESERVE THE THICKNESS OF ABDOMINAL AND CHEST MUSCLES OF CRITICALLY ILL PATIENTS: A RANDOMIZED CLINICAL TRIAL

Fig. 2. Representative image of the positioning of electrodes on the straight muscles of the abdomen and chest to perform the protocol.

n = 11 patients **EMS** + conventional PT
n = 14 patients sham + conventional PT
For ~5 days, 1 x 30 min
From first 48 h of MV

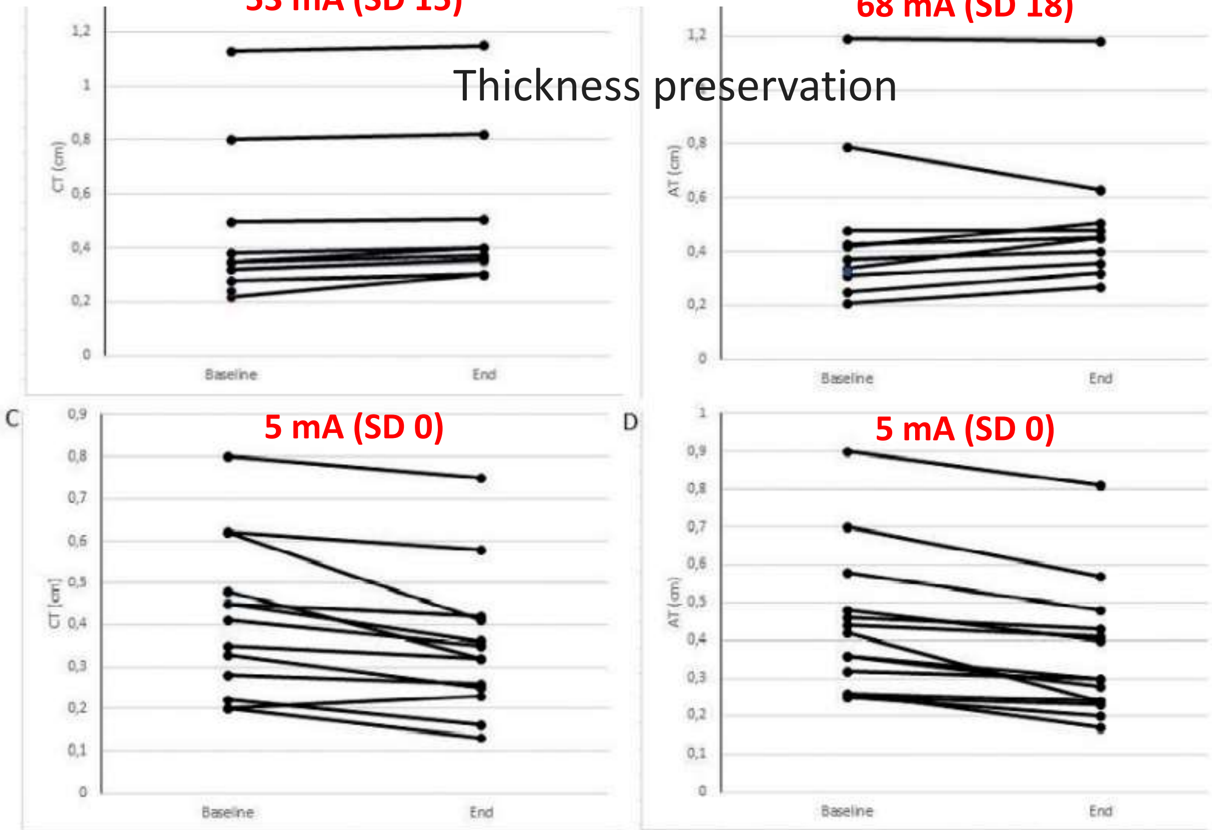

Fig. 4. Individual behaviour of the thickness of chest and abdominal muscles at baseline and at the end of the study for each group. (A) Variation in chest muscle thickness (CT) in the intervention group. (B) Variation in abdominal muscle thickness (AT) in the intervention group. (C) Variation of CT in the control group. (D) Variation of AT in the control group.

↓ in length of stay in the ICU
= MV duration

A.M. Dall' Acqua et al. J Rehabil Med 49, 2017

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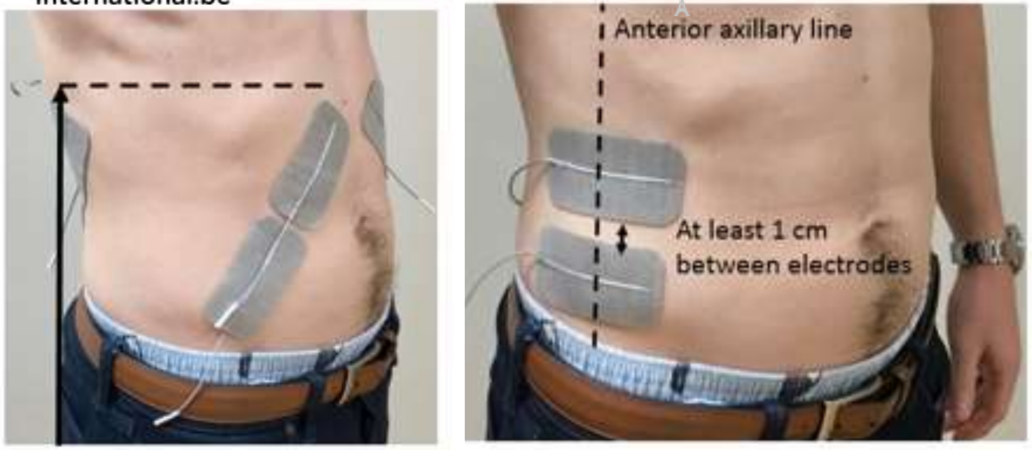
Breath-synchronized electrical stimulation of the expiratory muscles in mechanically ventilated patients: a randomized controlled feasibility study and pooled analysis

n = 10 patients= **breath-synchronized EMS** (60-100mA)
n = 10 patients= sham (10mA)
expiratory muscle FES (30 min, twice daily, 5 days/week until weaned)



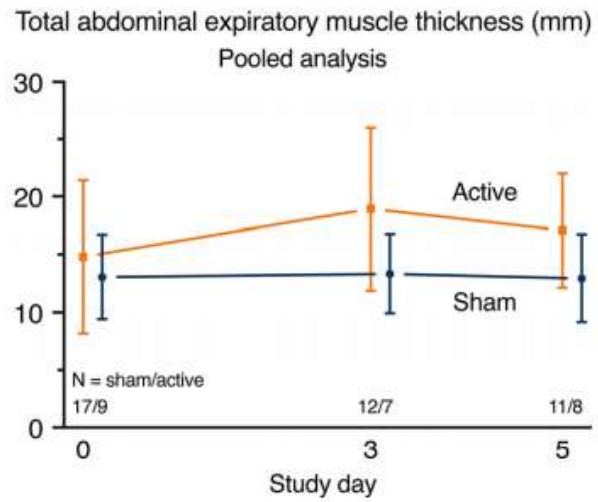


Fig. 3 Pooled results for total abdominal expiratory muscle thickness changes over the first 5 days after randomization. On day 3, changes from baseline were different between groups as per a linear mixed model analysis ($P = 0.02$). Data represent the absolute means ± standard deviation

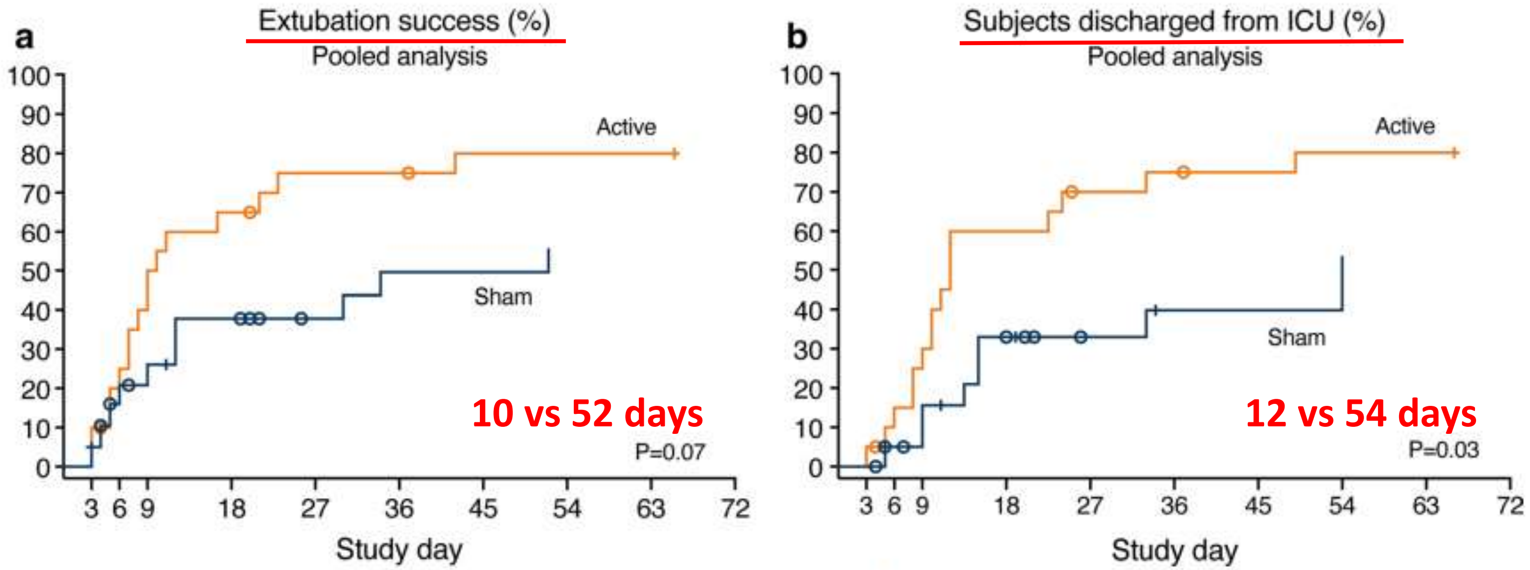


Fig. 4 Pooled results on clinical endpoints. **a** Pooled results on extubation success. **b** Pooled results on ICU length of stay. *P* values are based on Gray's test. Cumulative event rates were estimated based on competing risk analysis, with the competing risks of death or withdrawal of ICU treatment (e.g., ventilator support) with the intention of subsequent death. Symbols: o for competing events; + for censored data

Early FES did not induce systemic inflammation (plasma cytokines levels)

Jonkman et al. Crit Care 2020

NEMS des muscles ORL

MHH

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Electrical muscle stimulation prevents critical illness polyneuromyopathy: a randomized parallel intervention trial

n= 52 ICU patients (APACHEII>13)

n= 24 in the EMS group

n= 28 in the control group.

EMS 55 min daily (from day-2 to ICU discharge)

- Higher MRC score at discharge
- Shorter weaning period
- Prevents the development of CIPNM

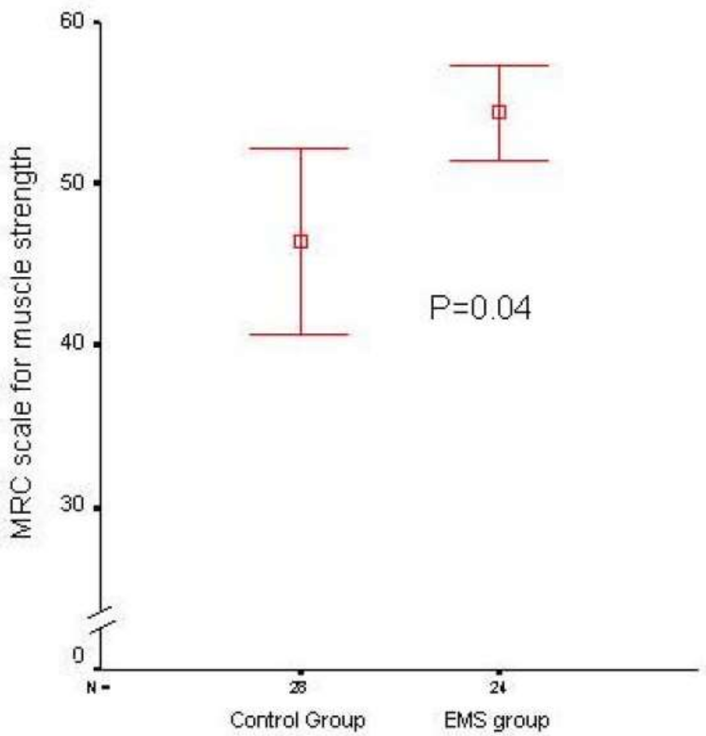

Figure 2 Difference in the MRC scale for muscle strength between patients assigned to the EMS group as compared with patients assigned to the control group (mean ± 2 standard errors). *P* = 0.04. EMS, electrical muscle stimulation; MRC, Medical Research Council.

Table 2: Diagnosis of CIPNM in patients assigned to the EMS group as compared with patients assigned to the control group (*P* = 0.04)

	EMS group (n) (%)	Control group (n)(%)	Total
CIPNM	3 (12.5)	11 (39.3)	14
	(OR = 0.22; CI: 0.05 to 0.92, *P* = 0.04).		
No CIPNM	21 (87.5)	17 (60.7)	38
Total	24	28	52

CIPNM, critical illness polyneuromyopathy; EMS, electrical muscle stimulation.

Routsi *et al. Critical Care* 2010

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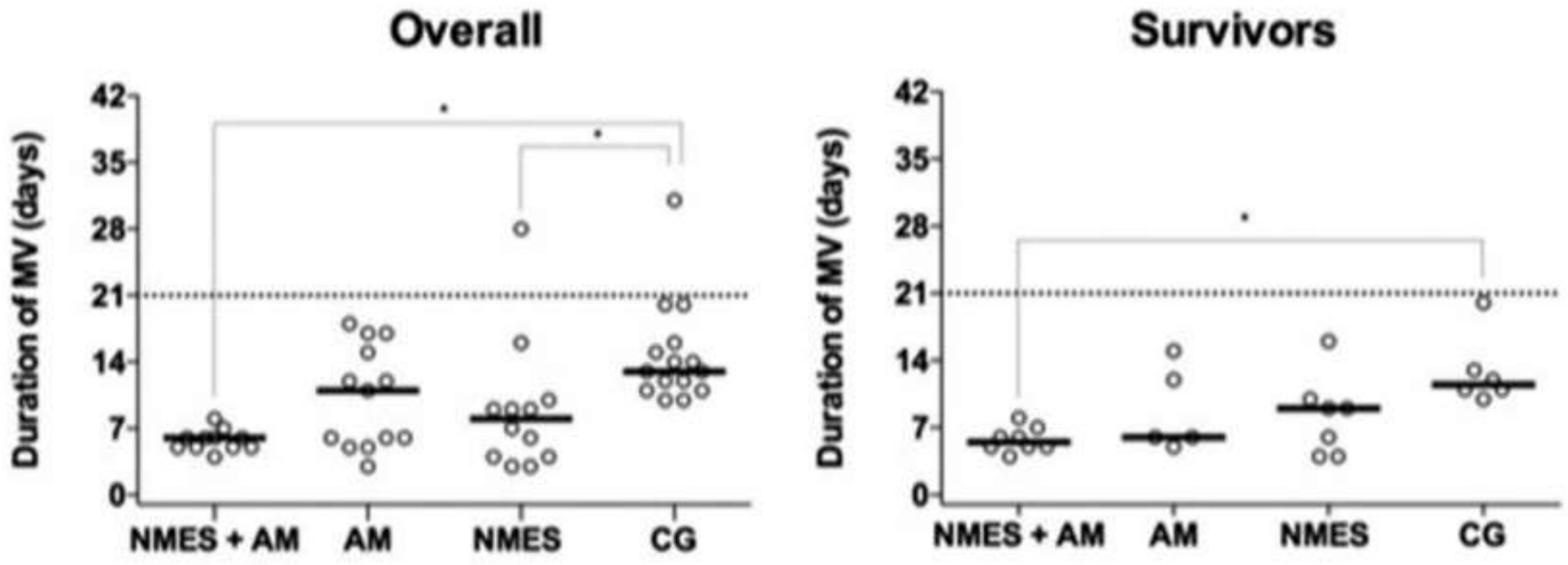
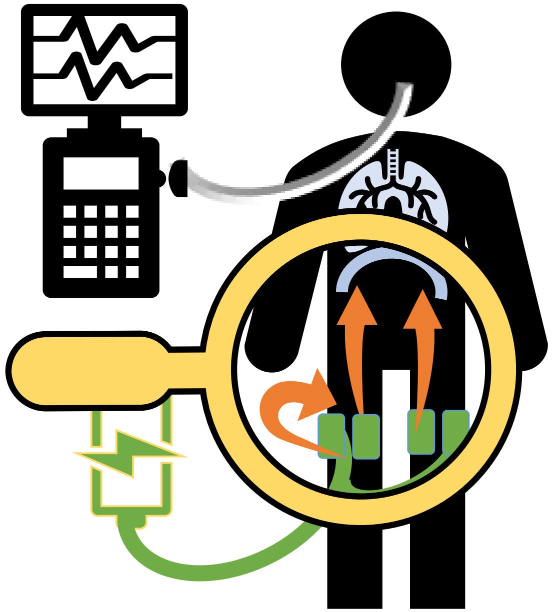
Duration of mechanical ventilation

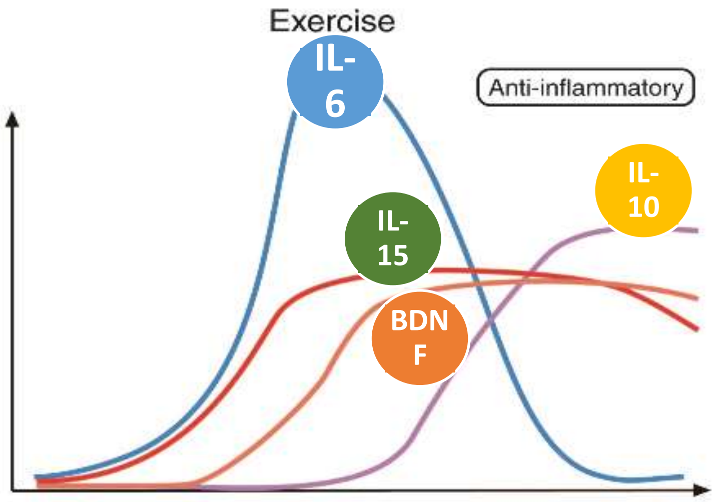
Dos Santos et al. Neuromuscular electrical stimulation combined with exercise decreases duration of mechanical ventilation in ICU patients: A randomized controlled trial. PHYSIOTHERAPY THEORY AND PRACTICE 2020

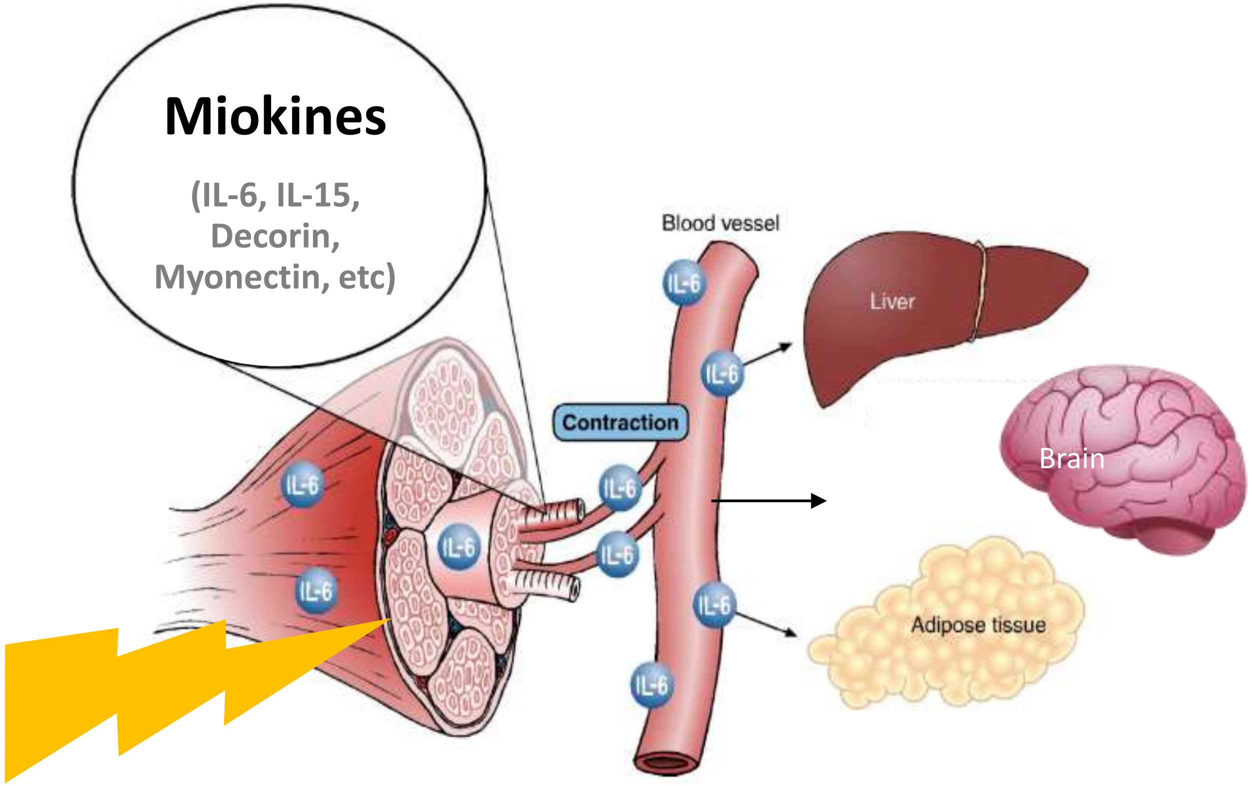


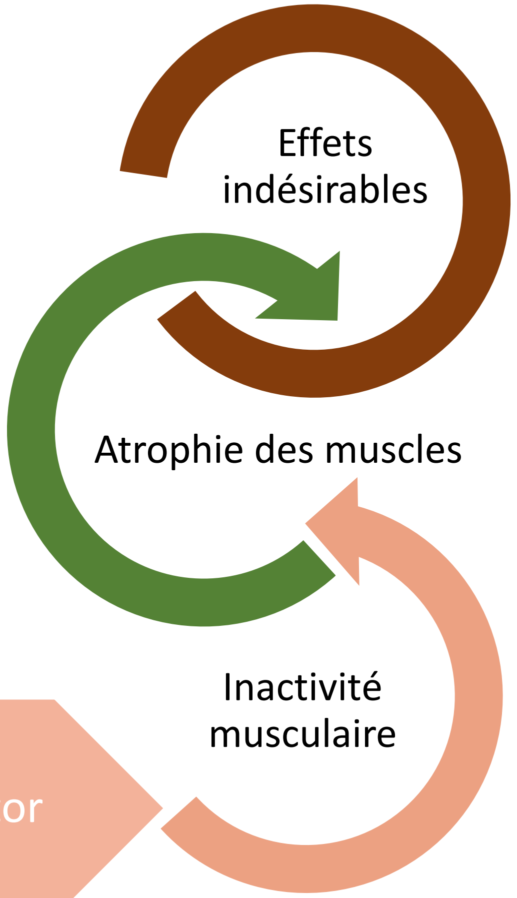
n=12 n=13 n = 11 n= 15

P value= 0.007





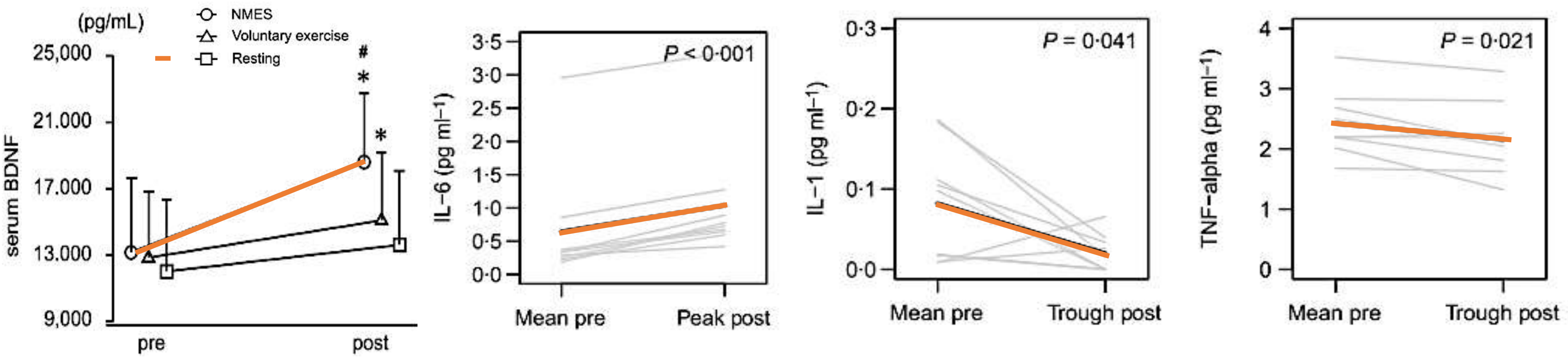




ENM → Contracción muscular → Perfil protector

Pedersen BK, Febbraio MA. Muscle as an endocrine organ: Focus on muscle-derived interleukin-6. Physiol Rev. 2008;88(4):1379–406.

Effet systémique antiinflammatoire (sujets sains)



Brain-derived neurotrophic factor (BDNF) plays several important roles in nervous system function including neuronal growth and plasticity.

Kimura T, et al. Neuromuscular electrical stimulation increases serum brain-derived neurotrophic factor in humans. Exp Brain Res. 2019;237(1):47–56.

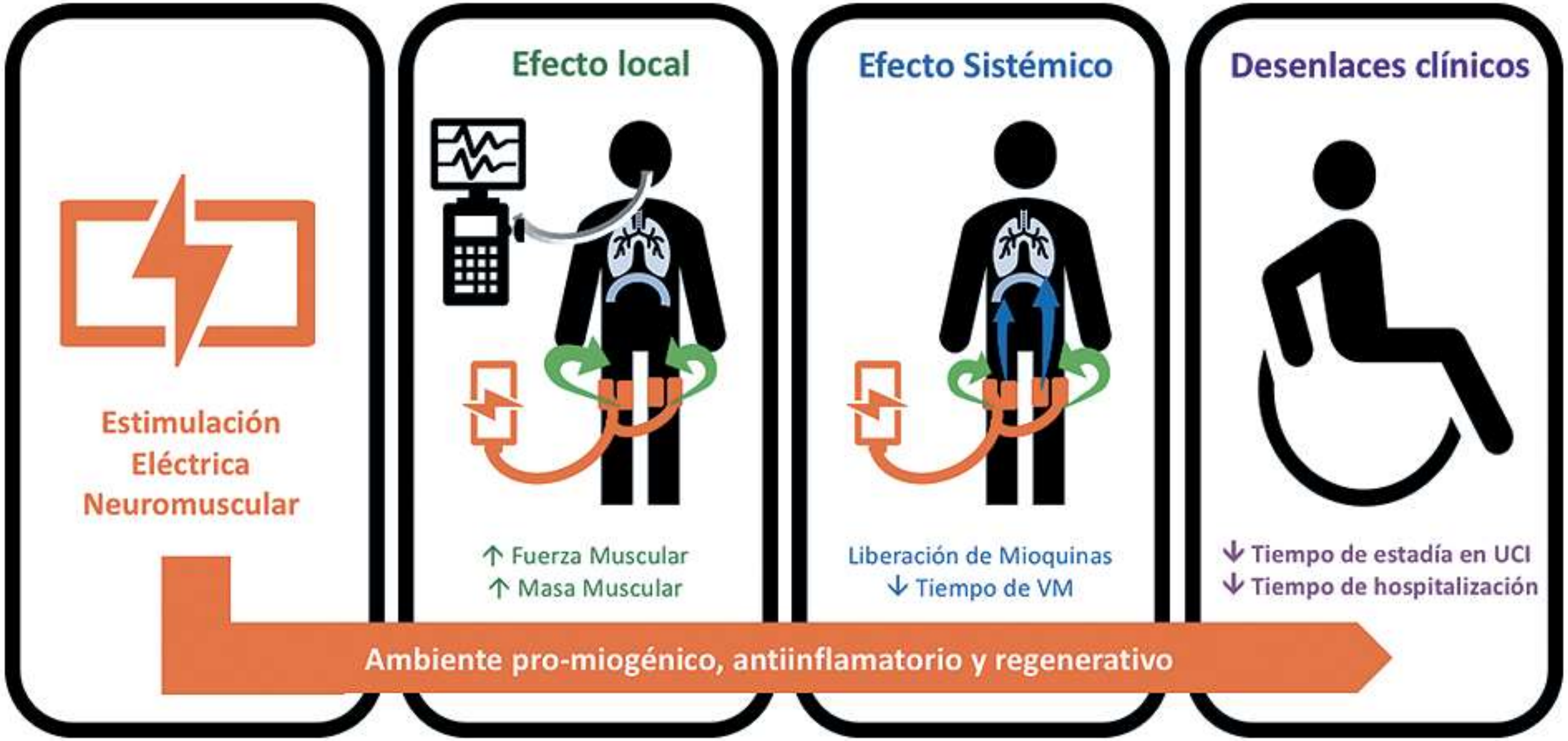
Effet systémique antiinflammatoire (sujets sains)

	FES ($n=16$) (mean ± SD)	Controls ($n=8$) (mean ± SD)	*P* value between groups
TNF-α (pg/ml)			
Before	7.75 ± 1.97	7.74 ± 2.07	0.972
After	6.39 ± 1.50	7.90 ± 1.98	
P value within groups	0.007	0.624	
IL-6 (pg/ml)			
Before	5.64 ± 1.25	8.23 ± 3.03	0.045
After	5.46 ± 1.20	8.41 ± 3.20	
P value within groups	0.554	0.799	

Brain-derived neurotrophic factor (BDNF) plays several important roles in nervous system function including neuronal growth and plasticity.

Truong et al. Effects of neuromuscular electrical stimulation on cytokines in peripheral blood for healthy participants: a prospective, single-blinded Study. Clin Physiol Funct Imaging. 2017

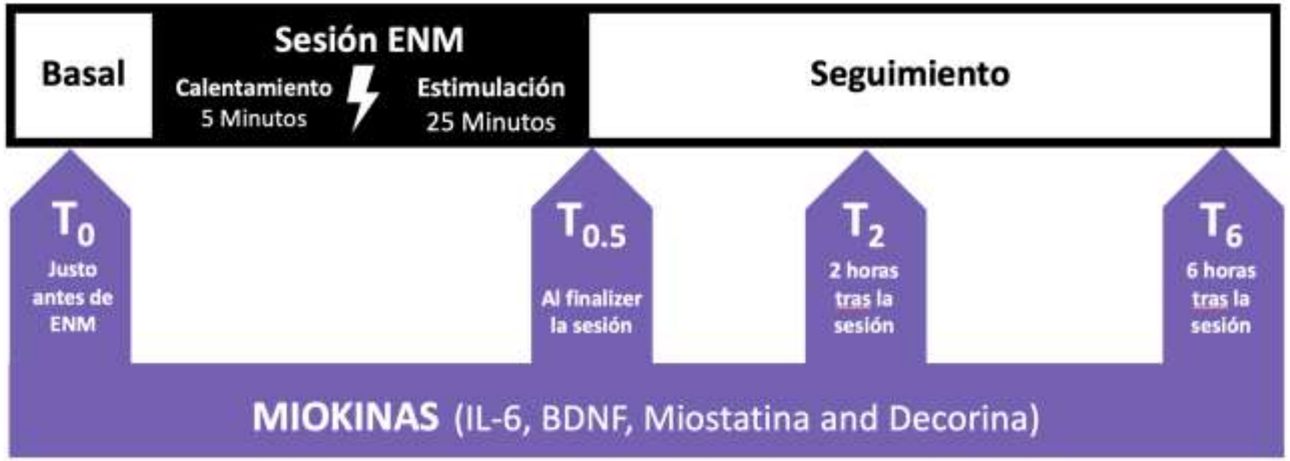
Effets sur l'atrophie musculaire



Ruvistay Gutierrez-Arias, Yorschua Jalil. Estimulación eléctrica neuromuscular en el paciente crítico. Una revisión narrativa. Revista Chilena de Anestesia 2021

Protocole d'étude

Obtención muestra → Almacenaje y procesamiento → Kit ELISA multiplex → Analisis de miokinas (IL-6, BDNF, Myostatin y Decorin) → Resultados



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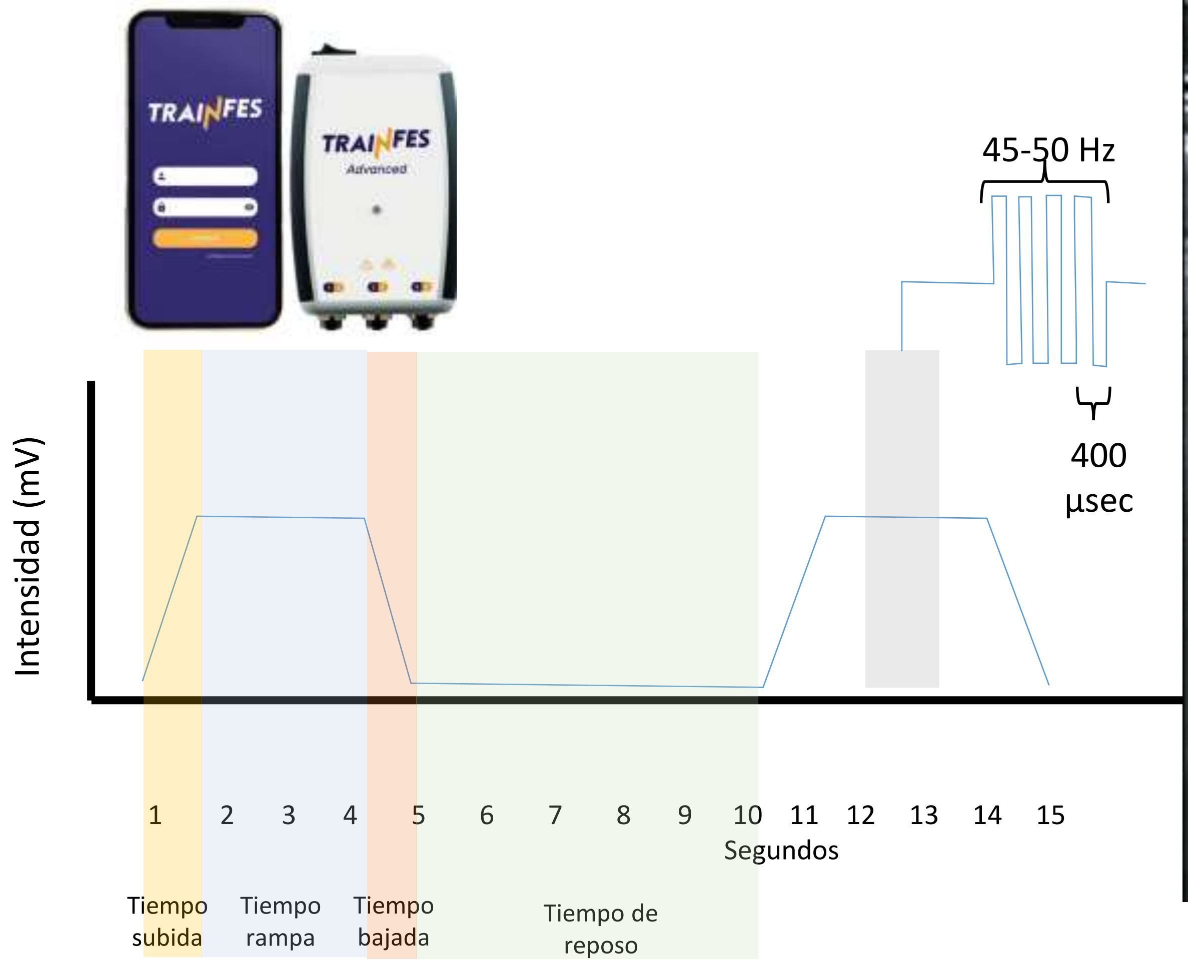
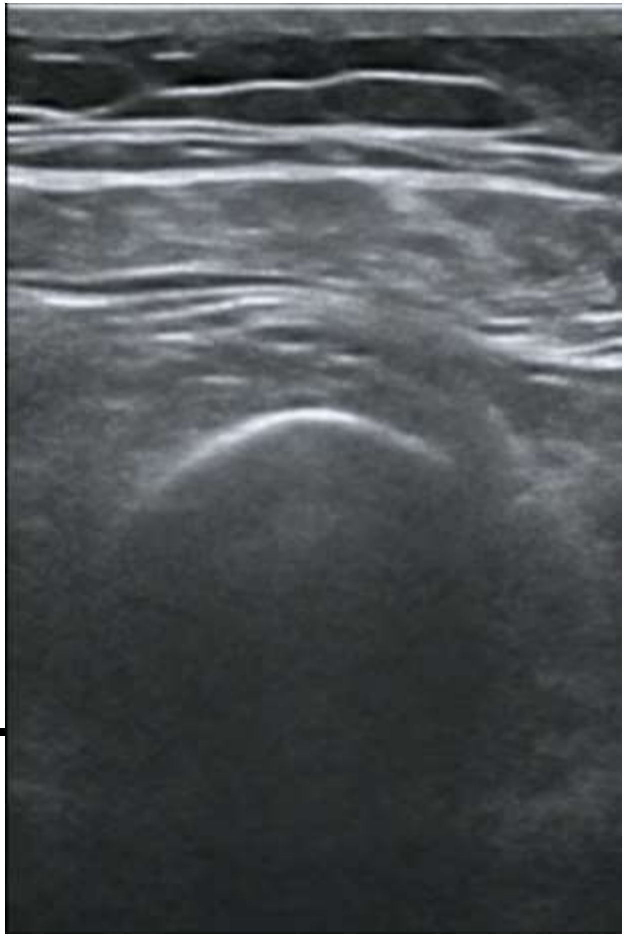
Protocole d'étude





ClinicalTrials.gov Identifier: NCT05536531

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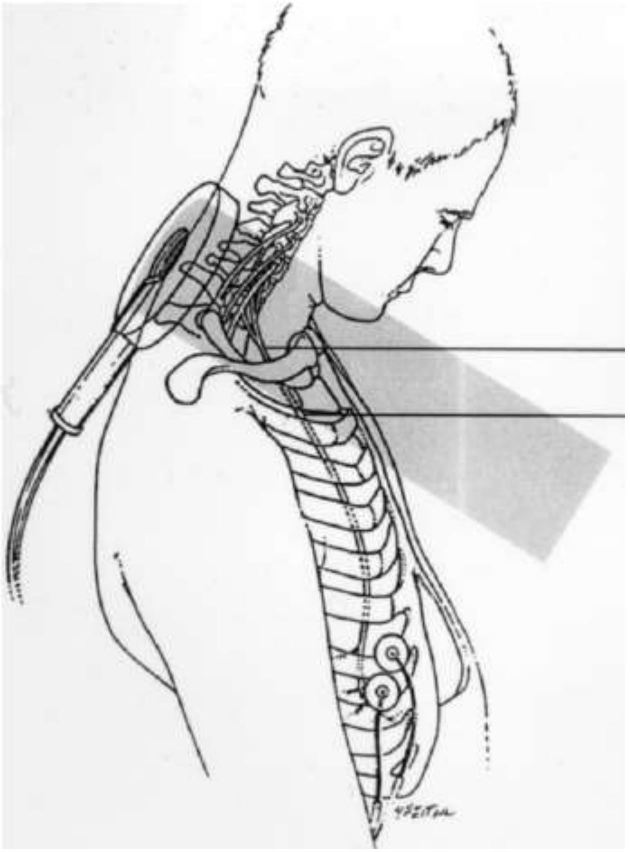
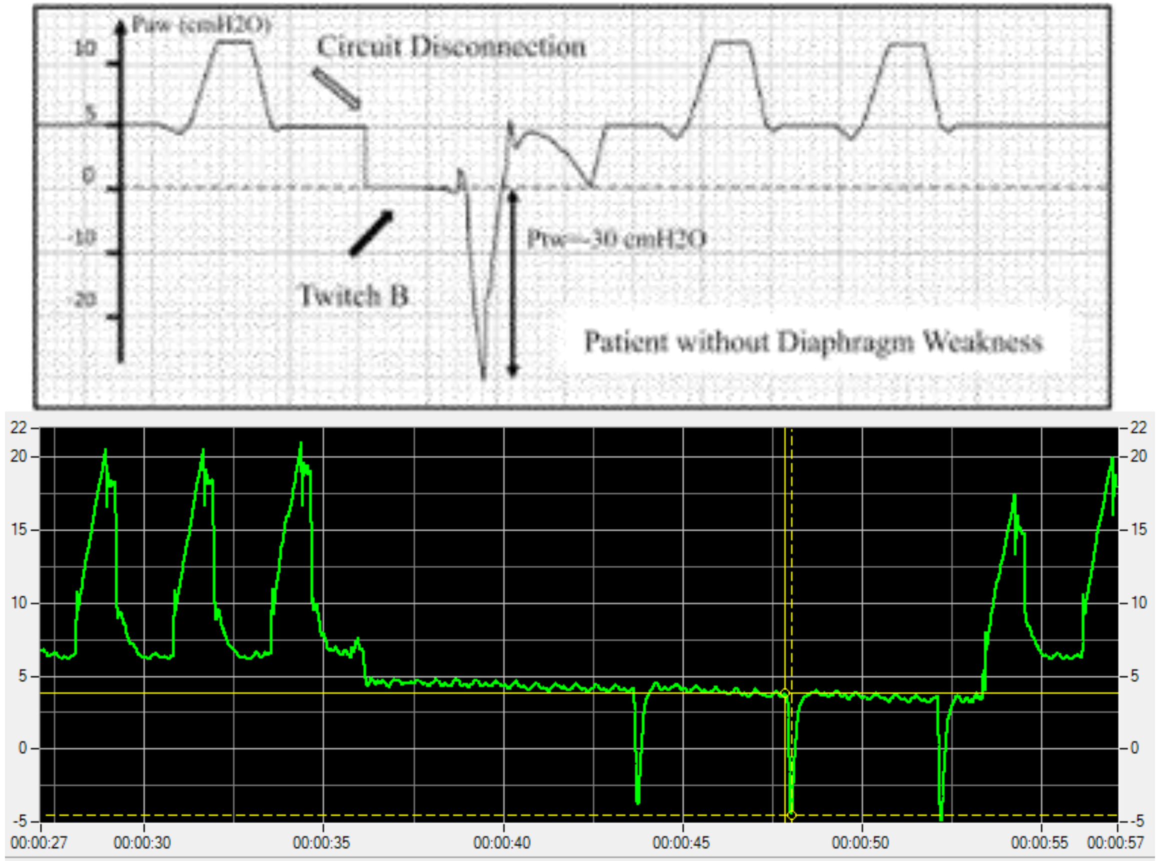
Protocole d'étude



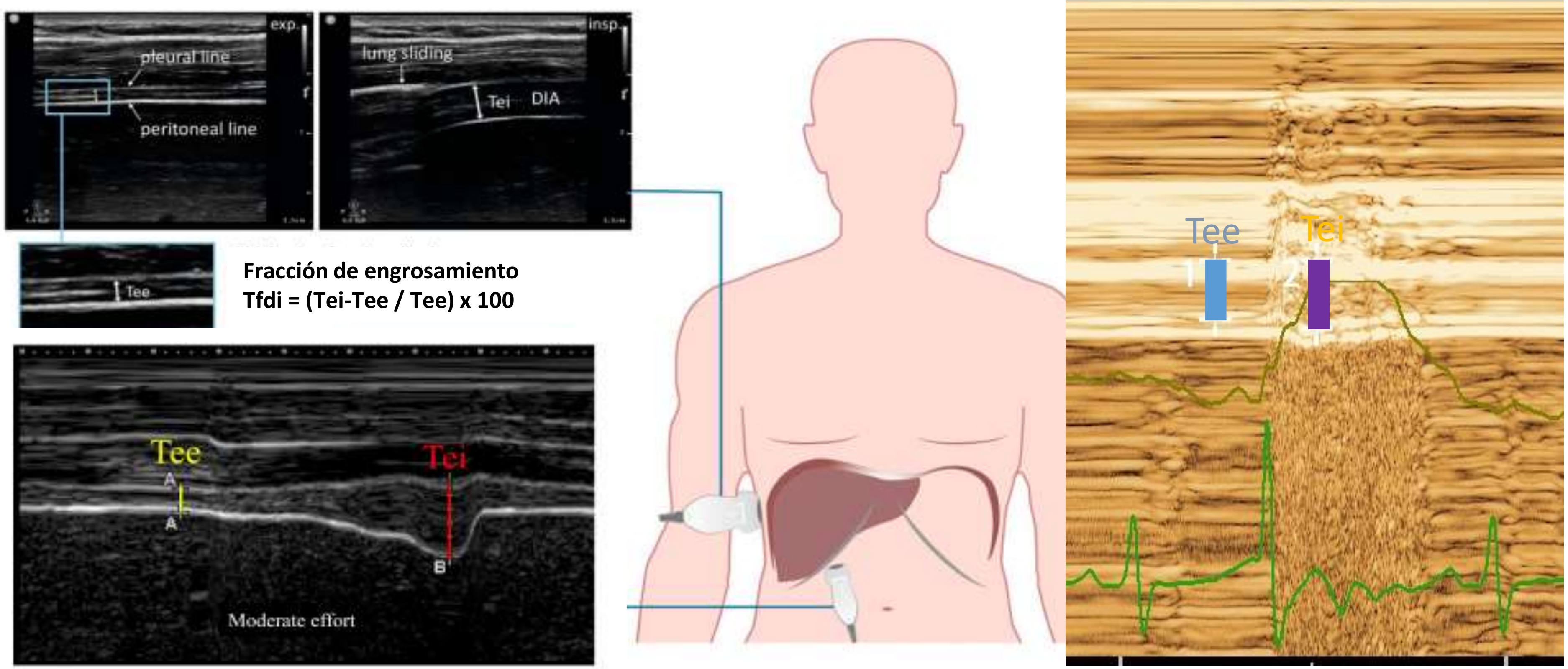
Medición de Presión traqueal (Ptr,tw).



ClinicalTrials.gov Identifier: NCT05536531

Protocole d'étude

Medición de la fracción de engrosamiento diafragmático twitch (Tfdi).



Fracción de engrosamiento
Tfdi = (Tei-Tee / Tee) x 100

Goligher EC,, et al. Measuring diaphragm thickness with ultrasound in mechanically ventilated patients: feasibility, reproducibility and validity. Intensive Care Med. 2015;41(4):642–9.

ClinicalTrials.gov Identifier: NCT05536531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