«COMPRENDRE LES EFFETS PHYSIOLOGIQUES DES INTERVENTIONS DE RÉHABILITATION»

réanimation 2025
PARIS 11-13 JUIN

URICE
Unité de recherche et d'innovation Condorcet Epicura

SKR
Société de Kinésithérapie de Réanimation

EpiCURA
mon hôpital

Laboratoire de l'effort & du mouvement
TOURNAI-BELGIUM

Province de HAINAUT
HAUTE ÉCOLE CONDORCET

Cheryl HICKMANN
Kinésithérapeute, PhD
Centre Hospitalier EpiCURA Hornu
HEPH-Condorcet à Tournai

Conflit d'intérêt

Pas de conflit d'intérêt à déclarer

Le problème?

Lors du séjour en réa


Jupiler

Altérations

réanimation 2025
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10.3389/fphys.2023.1170429

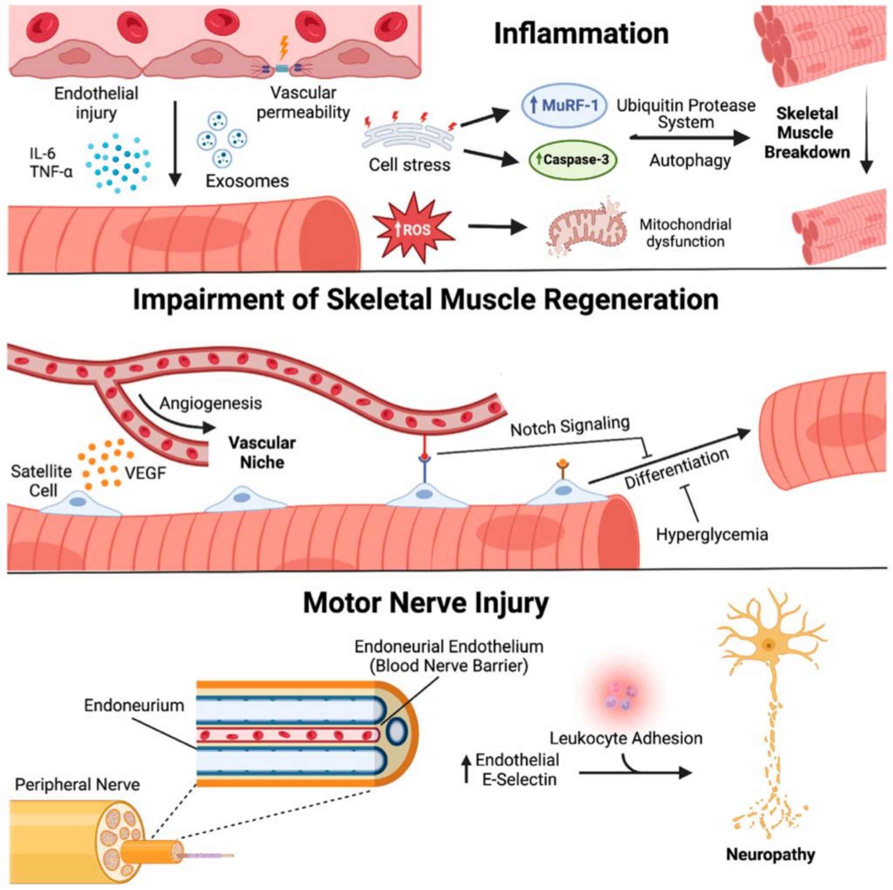
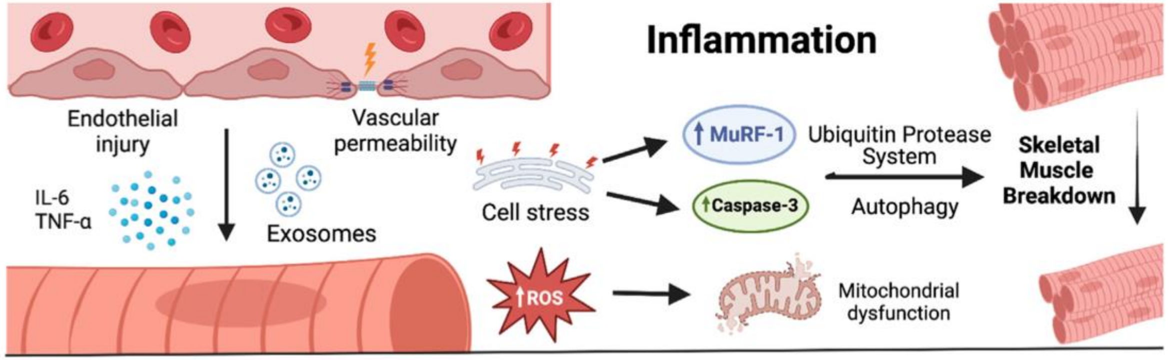
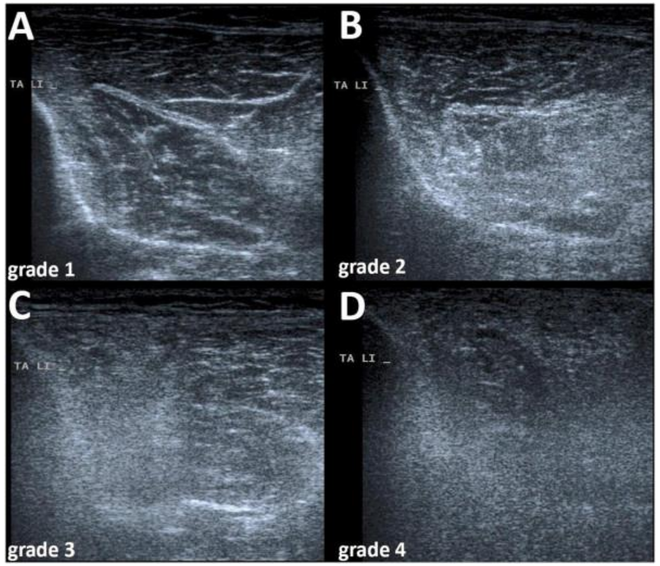


FIGURE 1
Endothelial biology and pathogenesis of ICU-acquired weakness. Endothelial cells (EC) engage in molecular crosstalk with myocytes and peripheral nerves in skeletal muscle. Activated ECs secrete mediators of inflammation that lead to atrophy and oxidative stress within adjacent myocytes; disruption of the vascular niche affects satellite cell function and capacity for muscle regeneration and repair; damage to the blood-nerve-barrier promotes leukocyte adhesion and development of critical illness polyneuropathy. *Created with BioRender.com.*

Cheryl Hickmann O. - PT, PhD

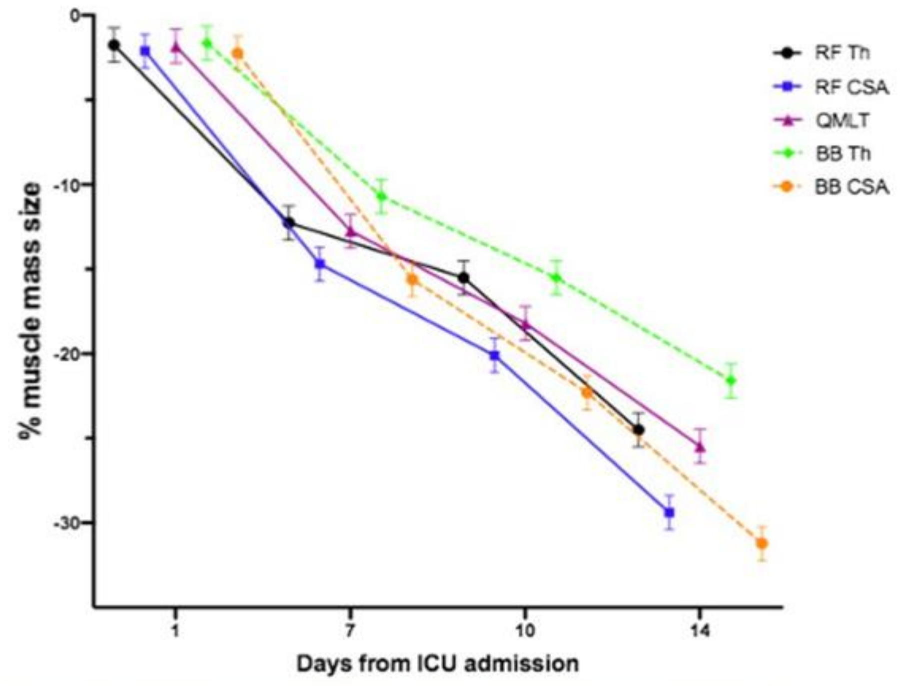
Catabolisme accru





Crit Care Med 2015; 43:1603–1611

Figure 1 Ultrasonic cross-sections through the tibialis anterior muscles showing different grades in echogenicity as defined by the Heckmatt score [23]. (A) Normal echo intensity with starry-night aspect with distinct bone echo in a healthy control. **(B)** Increased echo intensity with normal bone echo in a septic patient at day 4. **(C)** Increased echo intensity with reduced bone signal in a septic patient at day 14. **(D)** Increased echo intensity and loss of bone signal in a septic patient at day 14.

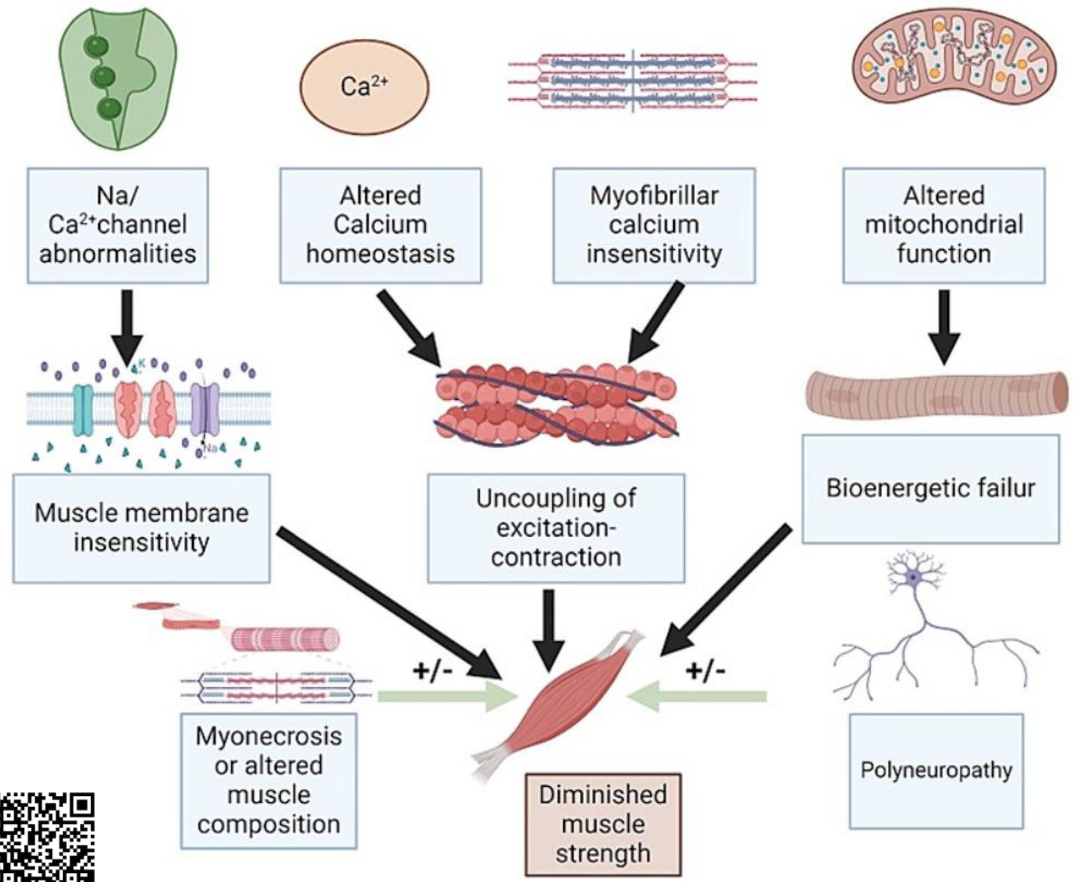


% RF th	-1.75	-12.25	-15.5	-24.5
% RF CSA	-2.10	-14.7	-20.1	-29.4
% QMLT	-1.82	-12.74	-18.2	-25.48
% BB Th	-1.64	-10.7	-15.5	-21.6
% BB CSA	-2.23	-15.61	-22.30	-31.22

Fig. 2 Loss in muscle mass from day 1 to day 14 of ICU admission. Abbreviations: percentage, %; rectus femoris: RF; cross-sectional area: CSA, thickness: Th, quadriceps muscle layer thickness: QMLT; biceps brachii: BB

Fazzini *et al. Critical Care (2023)*

Fonction altérée



Proposed mechanism of intensive care unit-acquired weakness.

Image credits: Tejbir Singh Monga

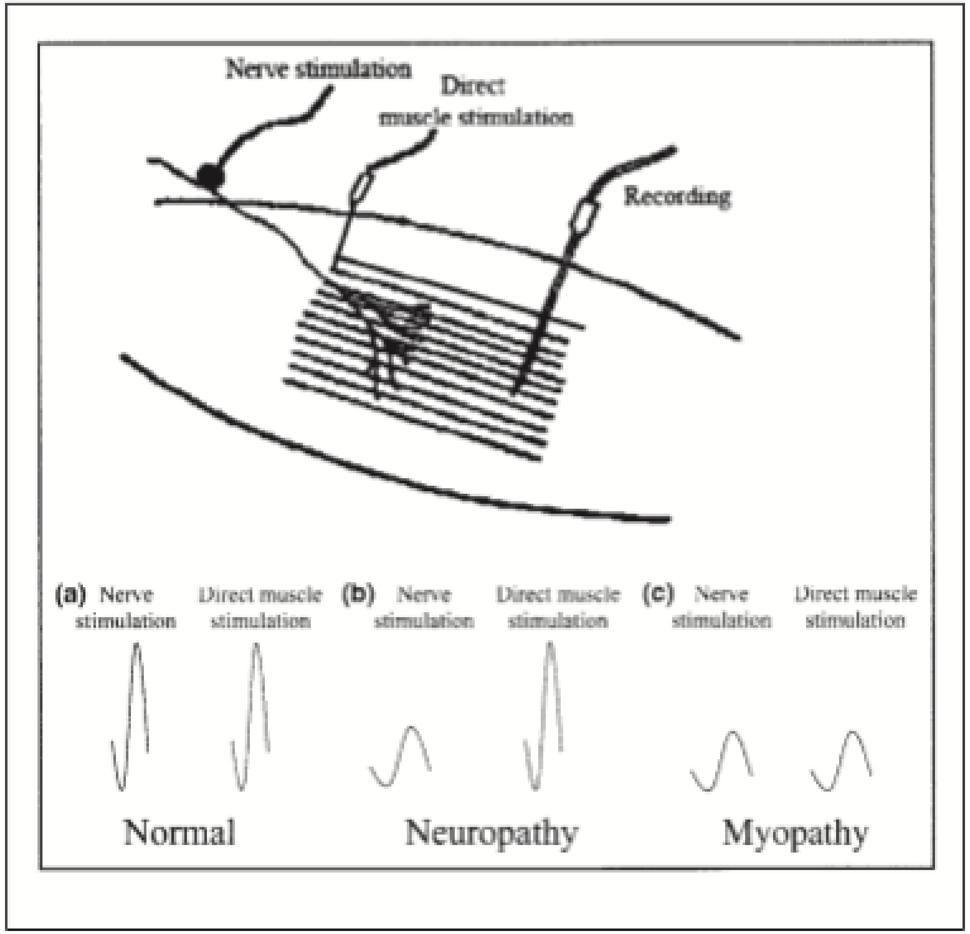
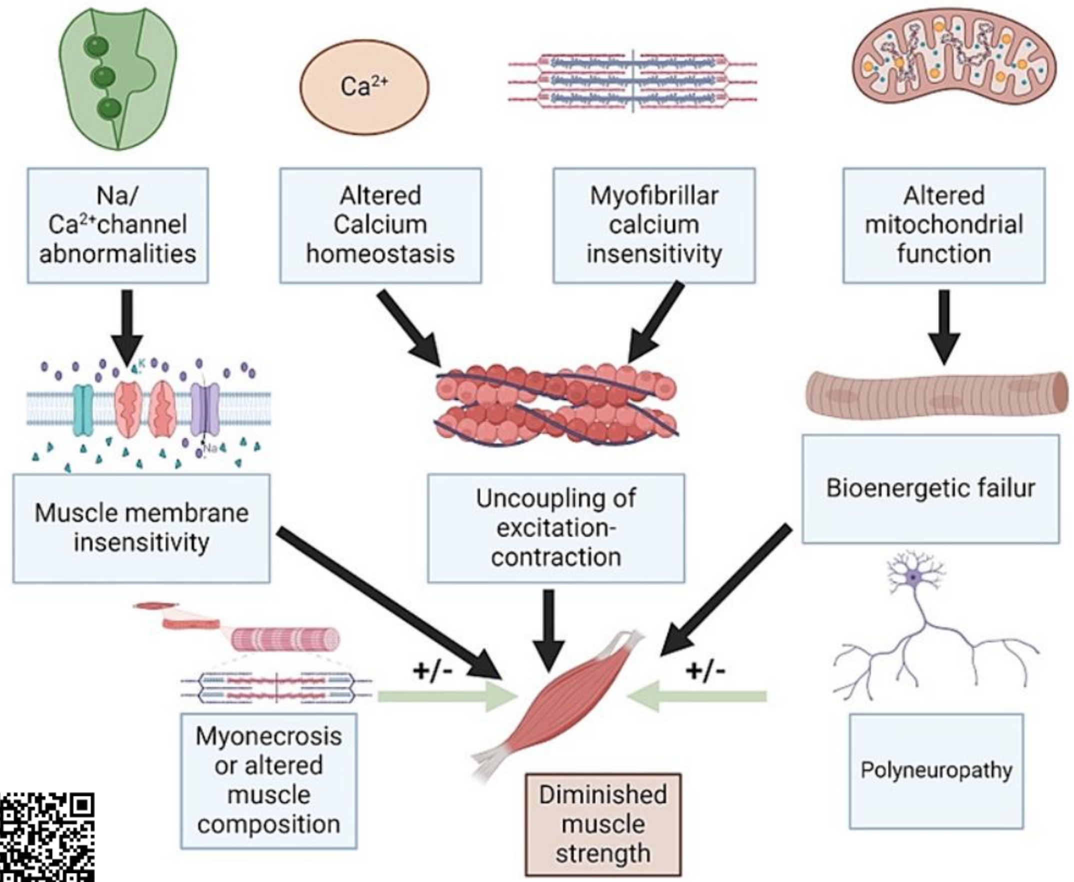


Fig. 4.—Estimulación mixta, nerviosa y muscular directa

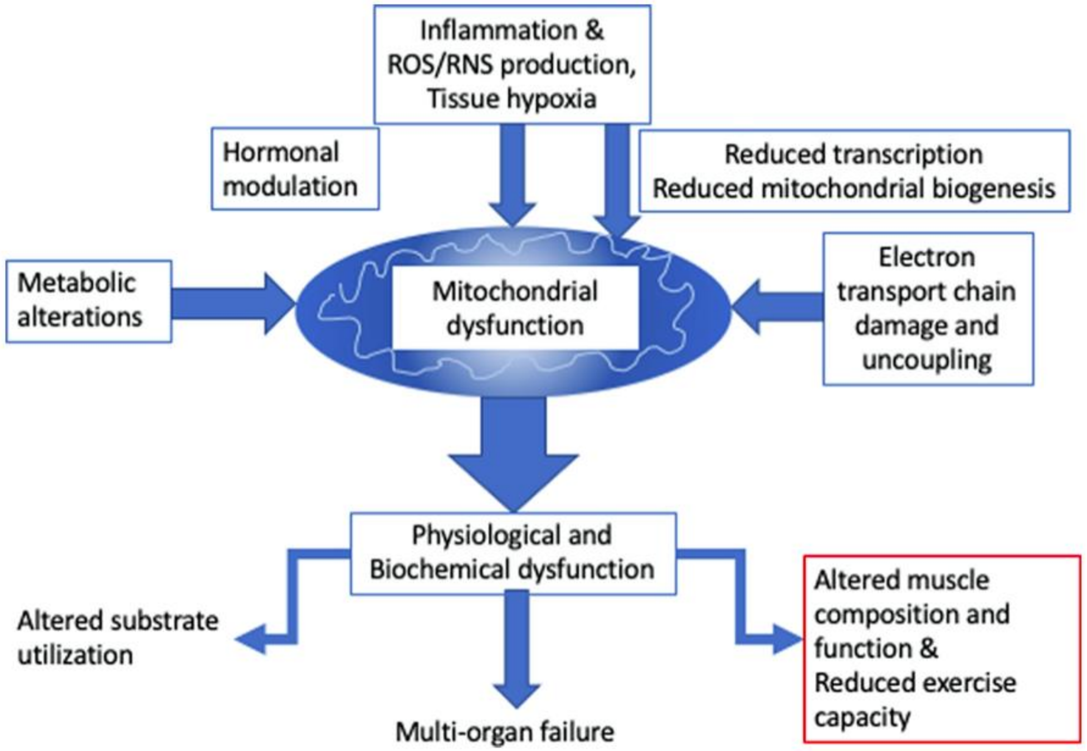
A. Mesejo y cols.
Nutr. Hosp. (2006)

Fonction mitochondriale altérée



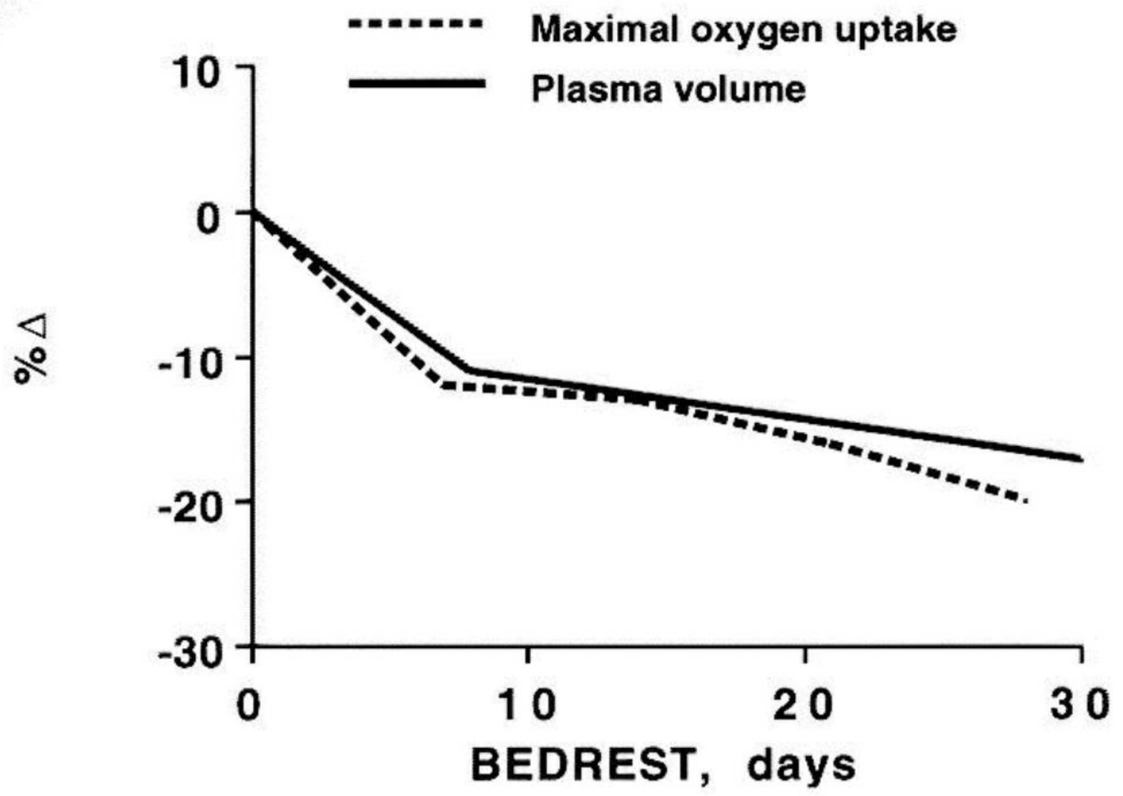
Proposed mechanism of intensive care unit-acquired weakness.

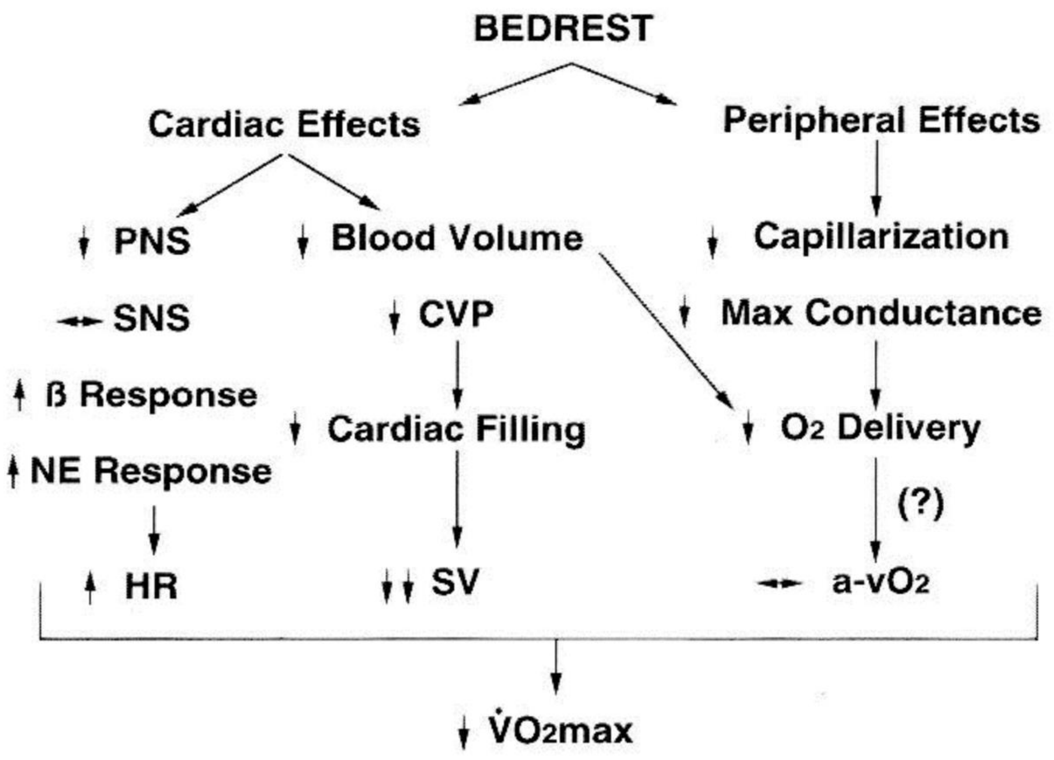
Image credits: Tejbir Singh Monga



Molinger J. Curr Opin Crit Care. 2021

Micro et macro adaptations



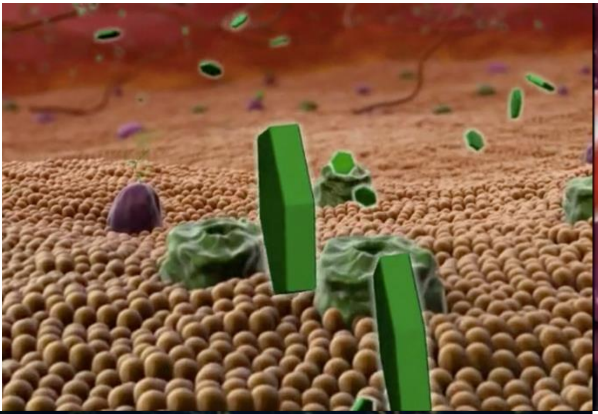


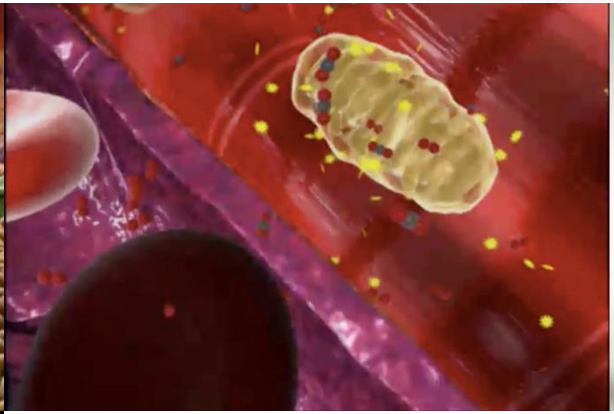
Convertino V.A. Medicine & Science in Sports & Exercise 1997

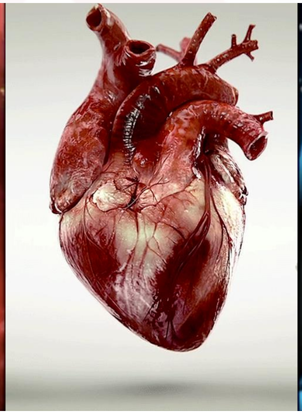
Les effets

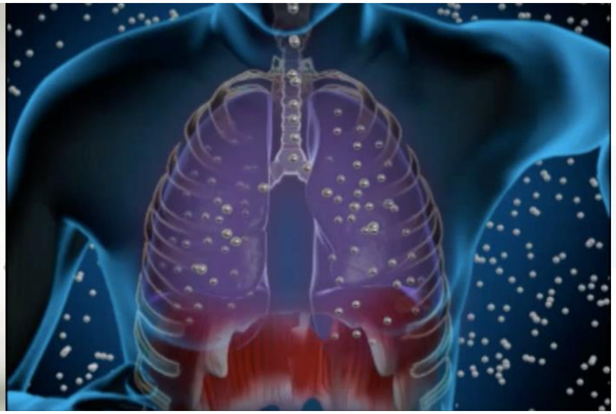
De l'exercice physique?

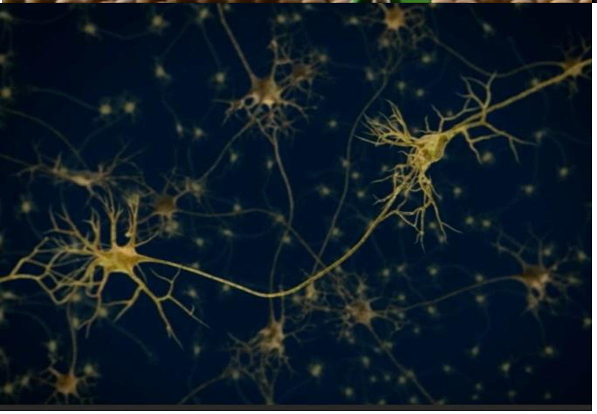
Micro et macro adaptations











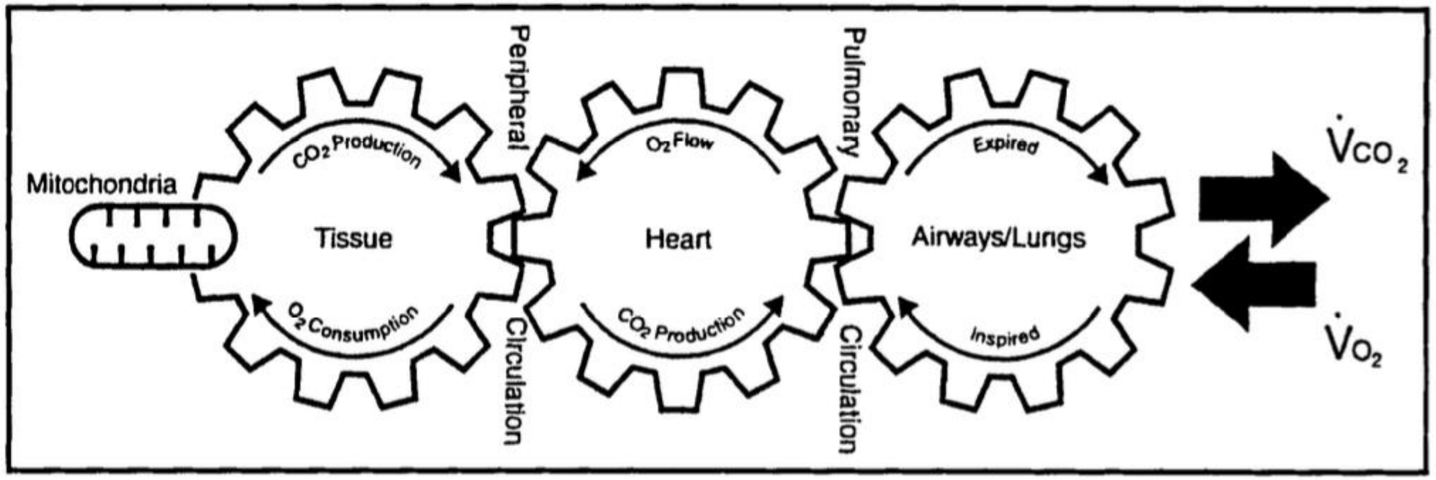


Figure.
The oxygen transport pathway, showing pulmonary-cardiovascular-metabolic coupling that affects cellular respiration. O_2=oxygen, CO_2=carbon dioxide, $\dot{V}O_2$=O_2 uptake from the alveoli, $\dot{V}CO_2$=CO_2 output from the alveoli. (Modified from Wasserman K, Hansen JE, Sue DY, Whipp BJ. *Principles of Exercise Testing and Interpretation.* Philadelphia, Pa: Lea & Febiger; 1987.)

ROS in exercise

reactive oxygen species

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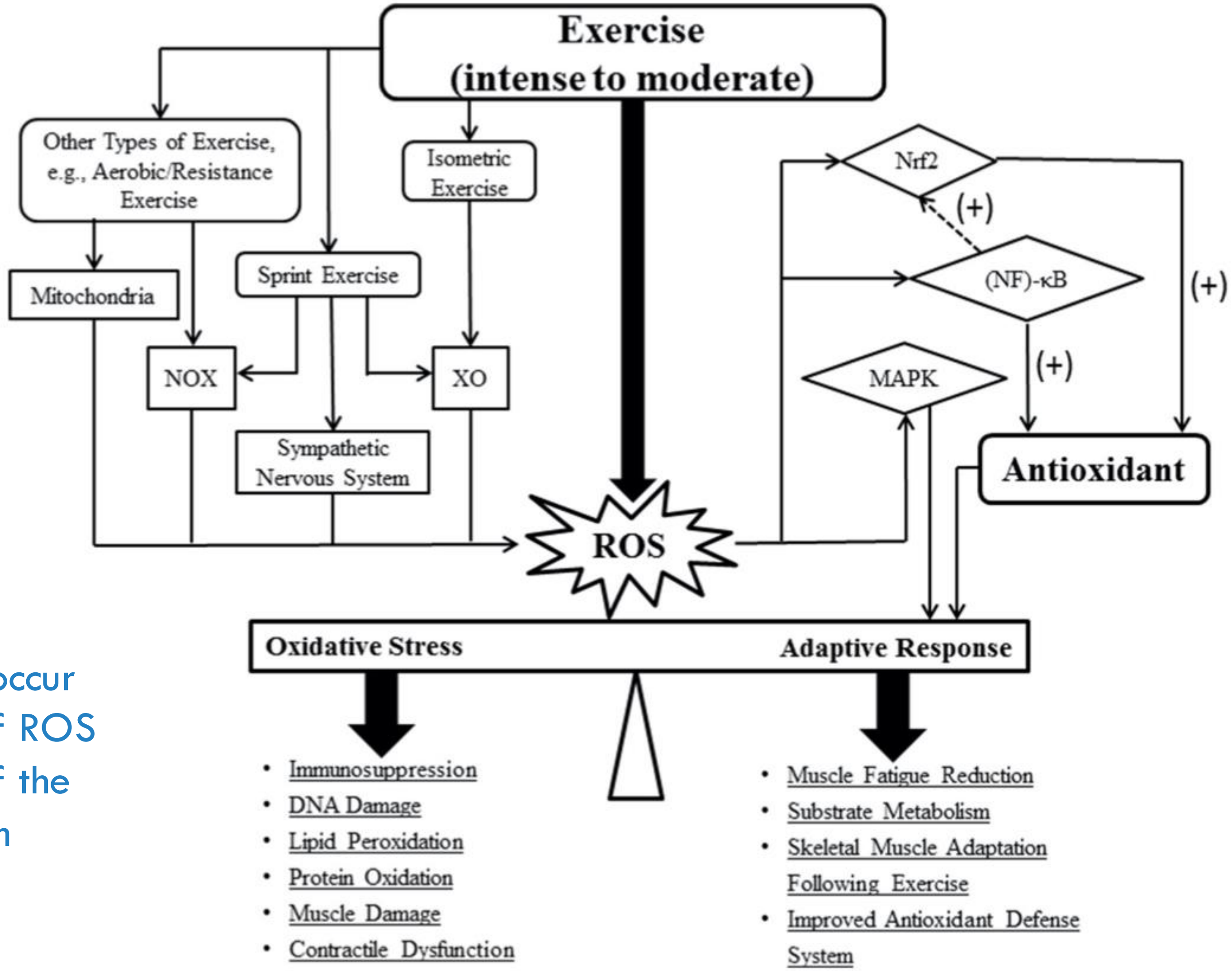
He F. et al 2016
Frontiers in physiology



Oxidative stress can occur when the generation of ROS exceeds the ability of the antioxidant system

Moderate exposure to ROS is necessary to induce adaptive antioxidant defense mechanisms

Myokines et ses effets globaux

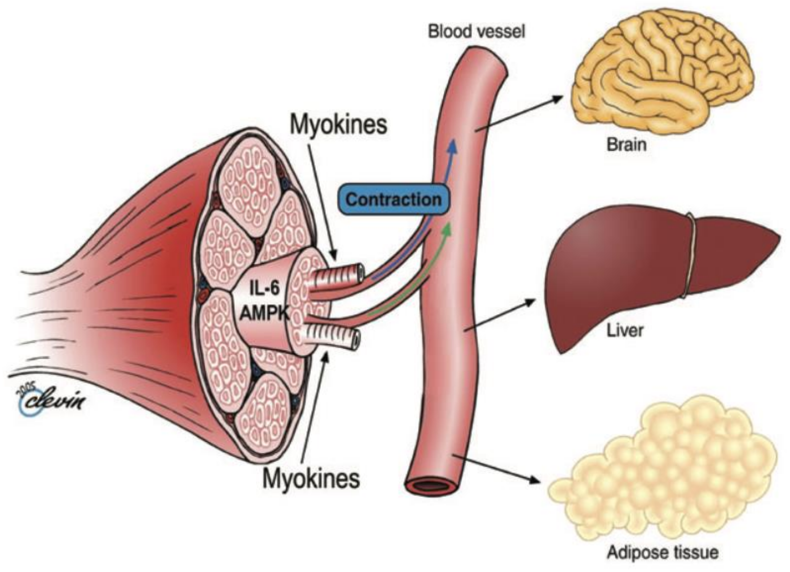
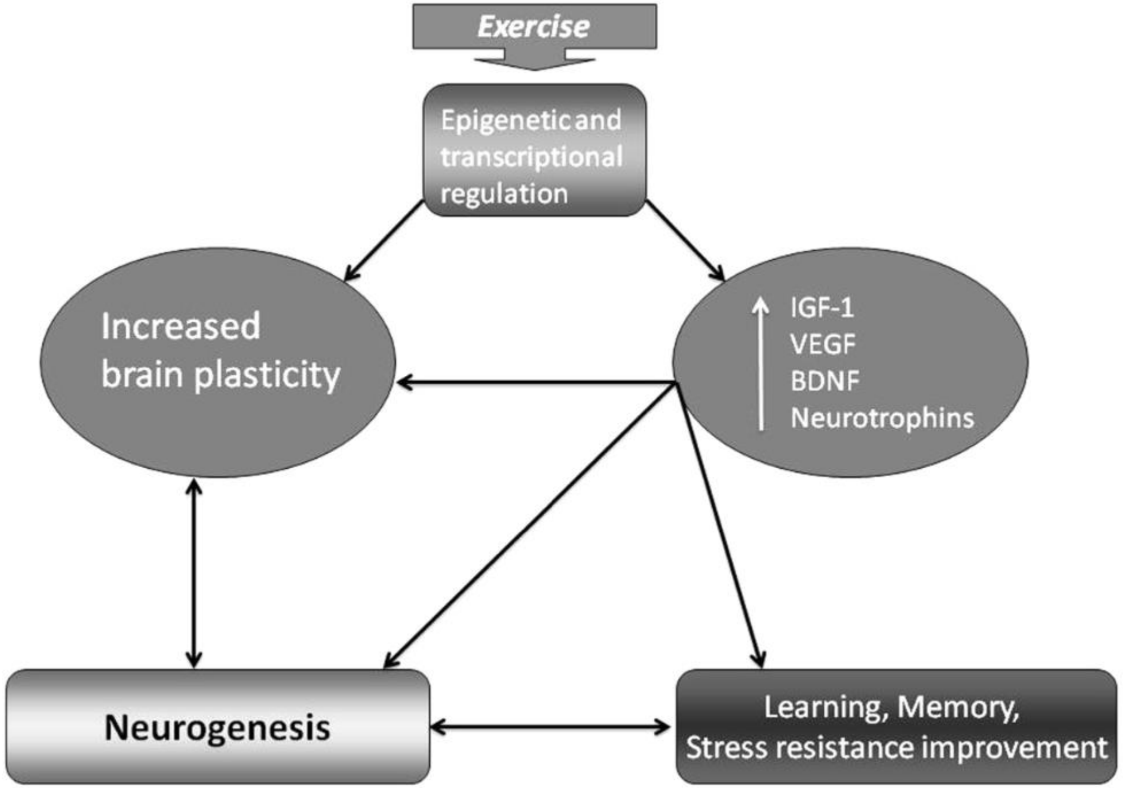


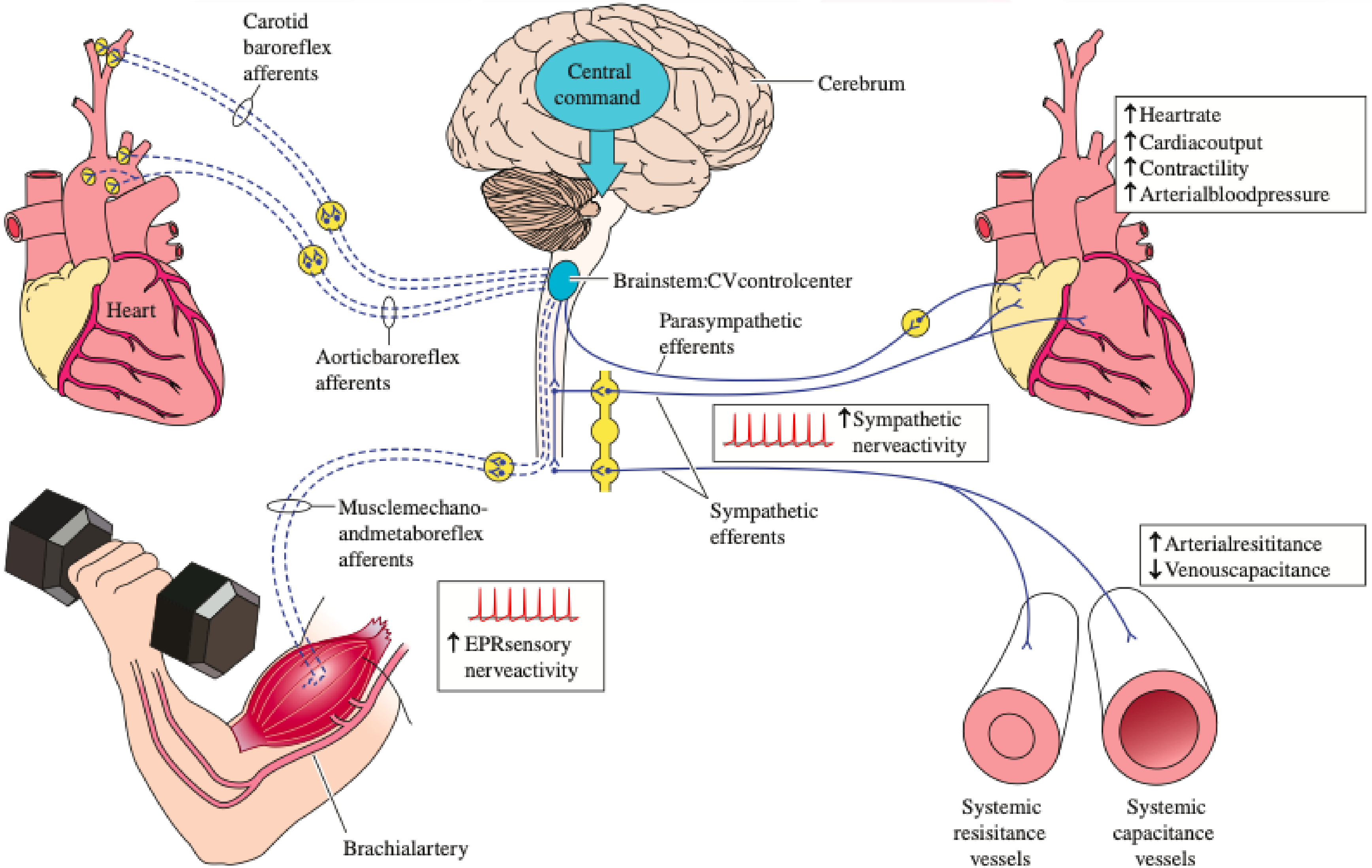
Fig. 4. Biological role of contraction-induced IL-6. Skeletal muscle expresses and releases myokines into the circulation. In response to muscle contractions, both type I and type II muscle fibres express the myokine IL-6, which subsequently exerts its effects both locally within the muscle (e.g. through activation of AMP-activated protein kinase, AMPK) and – when released into the circulation – peripherally in several organs in a hormone-like fashion. Figure reproduced in modified form, with permission (Pedersen and Fischer, 2007).

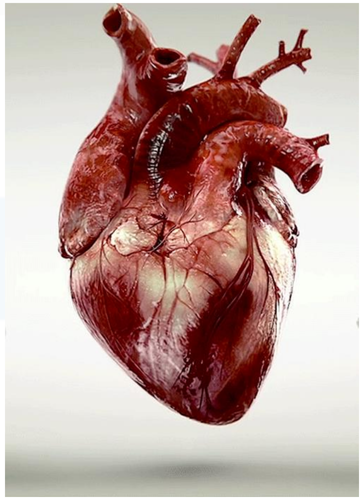
Pedersen B.K.
The Journal of Experimental Biology 2010



J. Ntanasis-Stathopoulos
Journal of musculoskeletal & neuronal interactions 2013

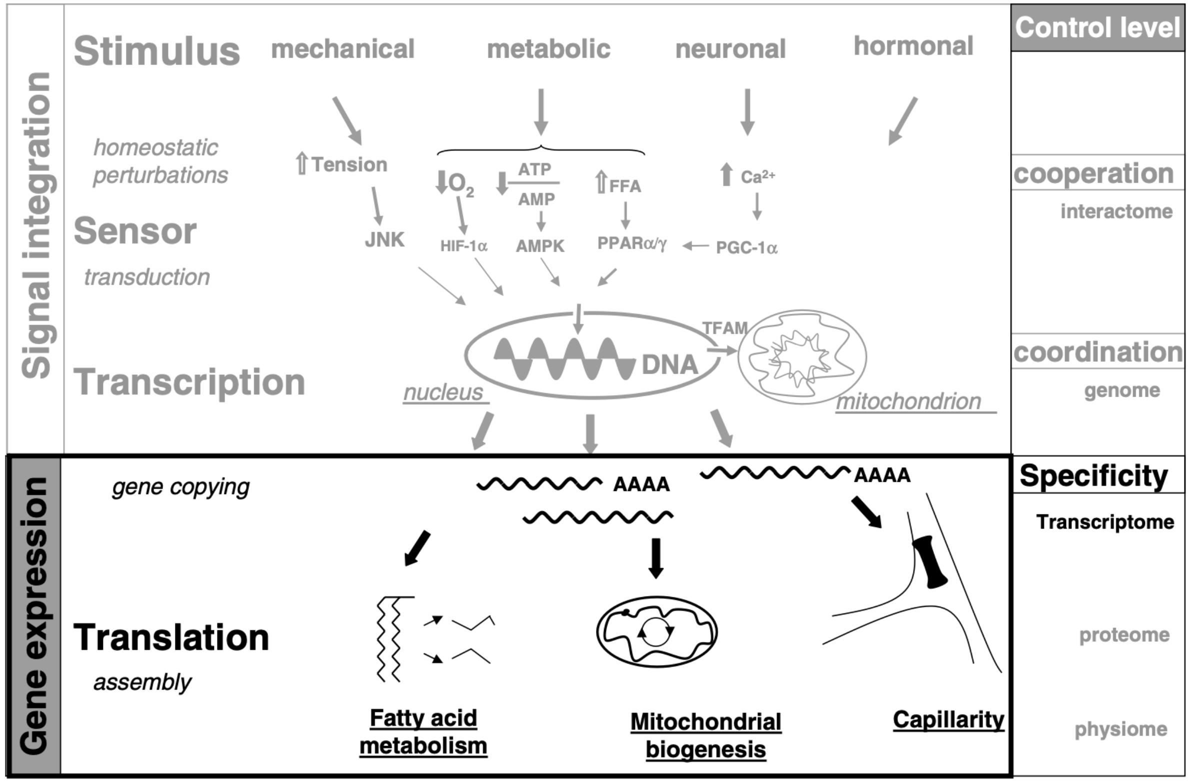
Adaptations cardiovasculaires

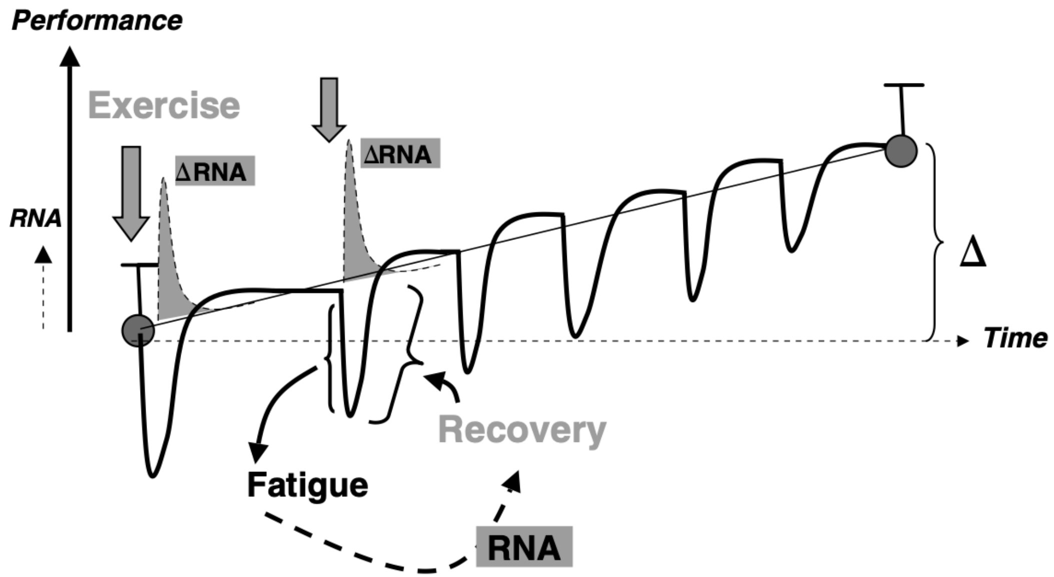




Spranger MD
2015 *Am J
Physiol Heart
Circ Physiol*

Adaptations à l'exercice





Flück M.
The Journal of Experimental Biology 2006

Effet de l'entraînement

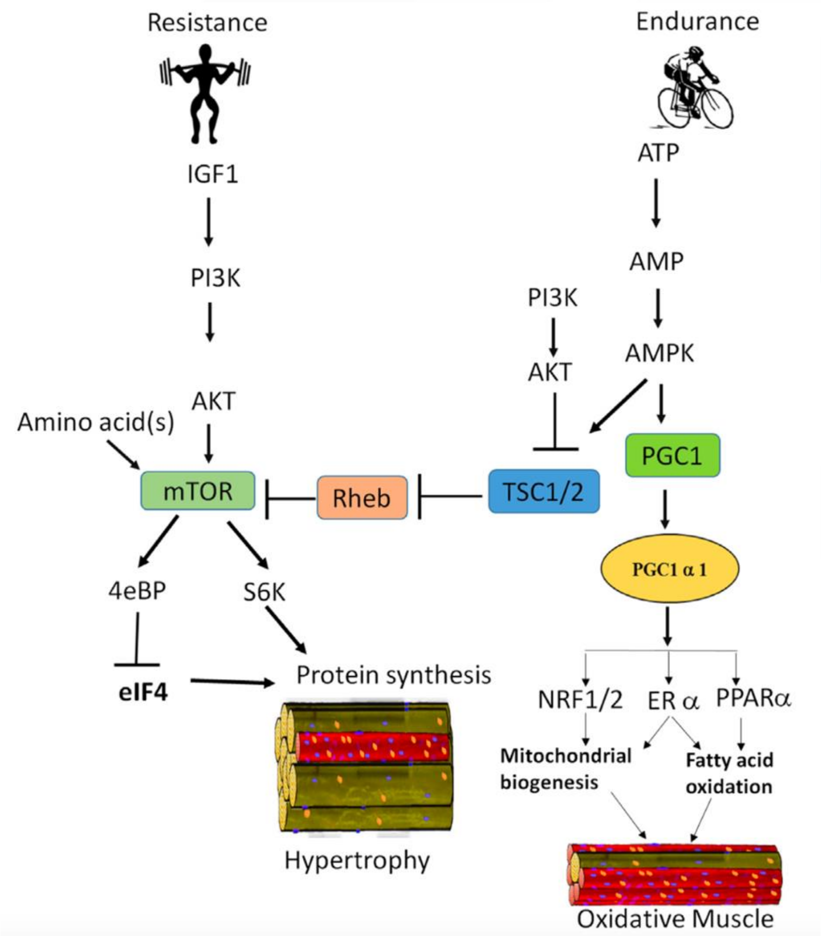
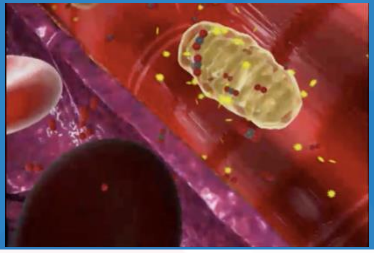


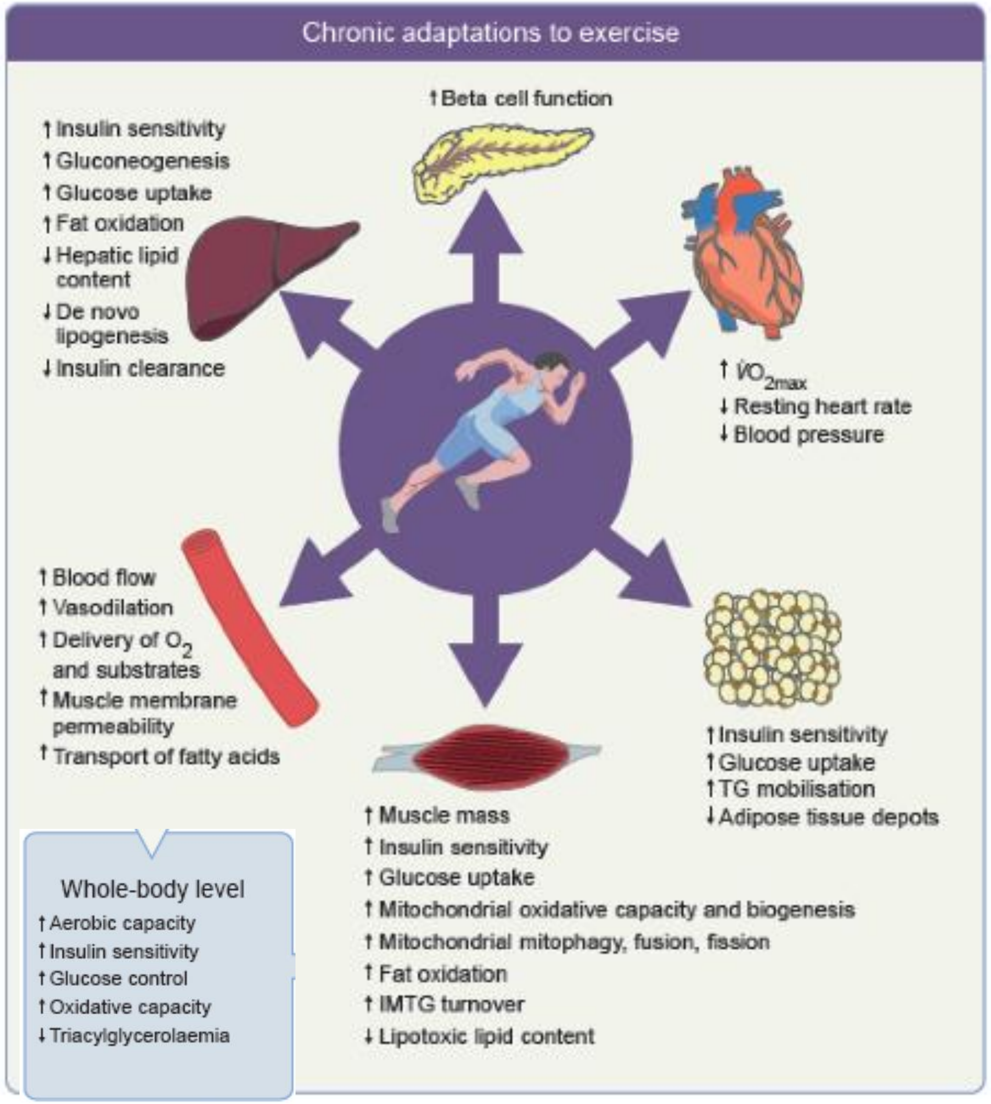
Table 1
Skeletal muscle adaptive response to endurance and resistant exercises. ↔, No change; ↔↑ no change or small effect; ↑, small effect; ↑↑, large effect.

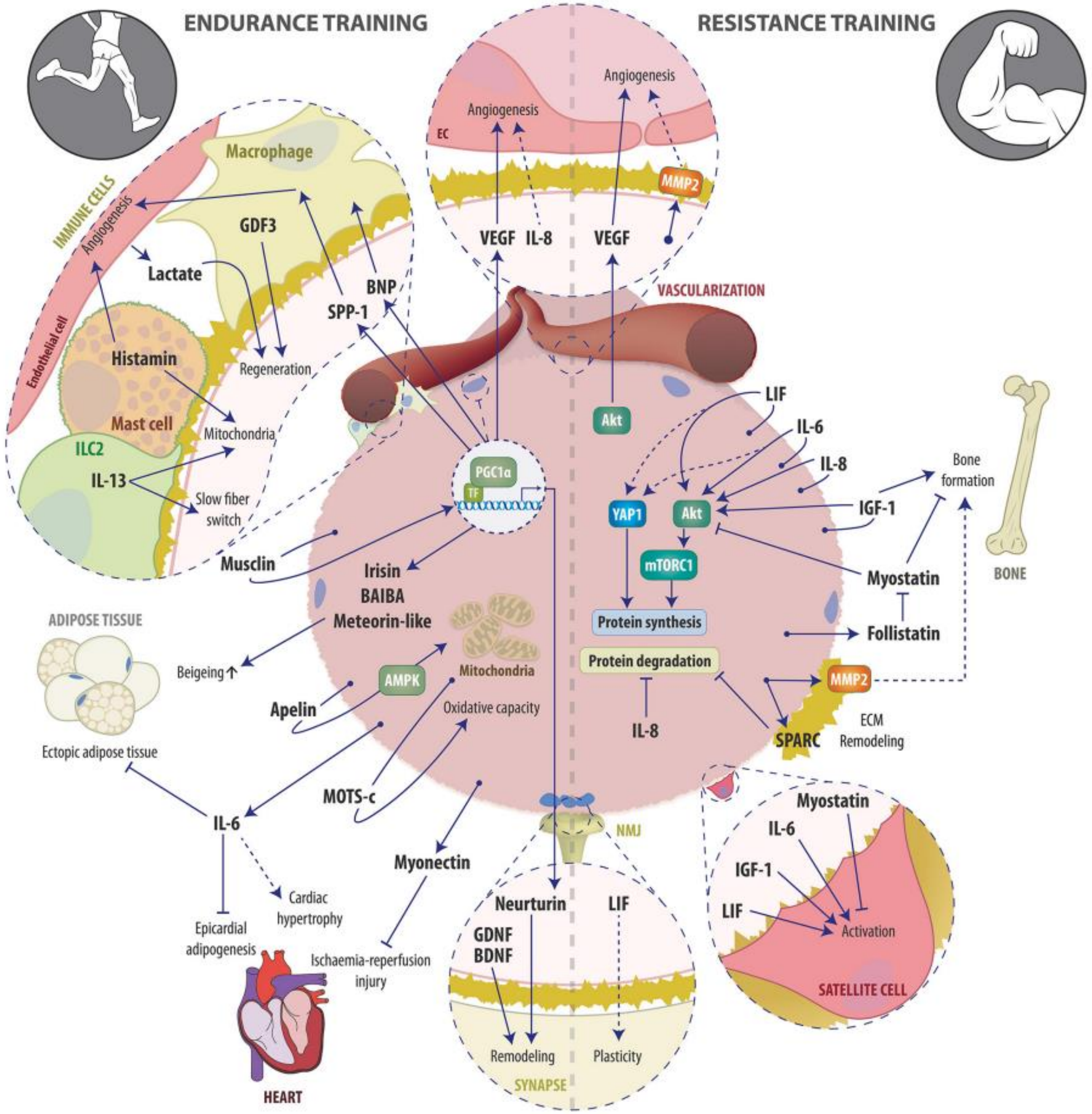
	Endurance exercise	Resistance exercise
Muscle hypertrophy	↔	↑↑
Muscle strength	↔	↑↑
Muscle fiber size	↔↑	↑↑
Myofibriller protein synthesis	↑	↑↑
Satellite cells count	↑	↑↑
Myonuclei count	↔↑	↑↑
Lactate tolerance	↑↑	↔↑
Glycolytic function	↑	↑↑
Mitochondrial volume	↑↑	↑
Mitochondrial protein synthesis	↑↑	↔↑
Capillary density	↑↑	↔
Oxidative function	↑↑	↔↑
Endurance capacity	↑↑	↔↑

Qaisar R. Free Radical Biology and Medicine 98 (2016)

Effets multiples

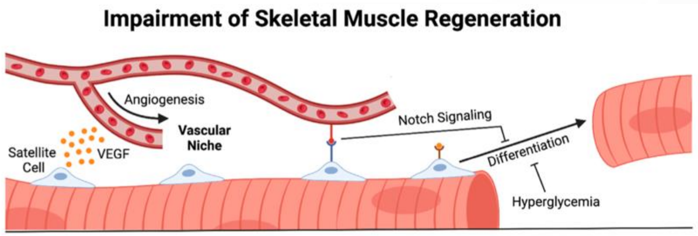






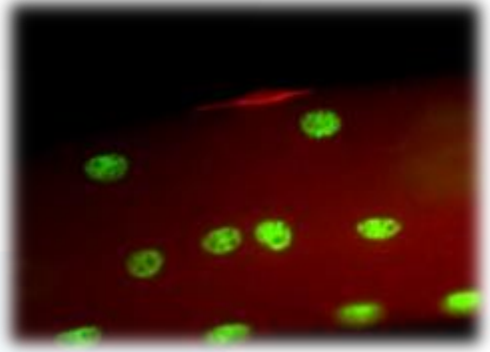
Thyfault JP Diabetologia. 2020

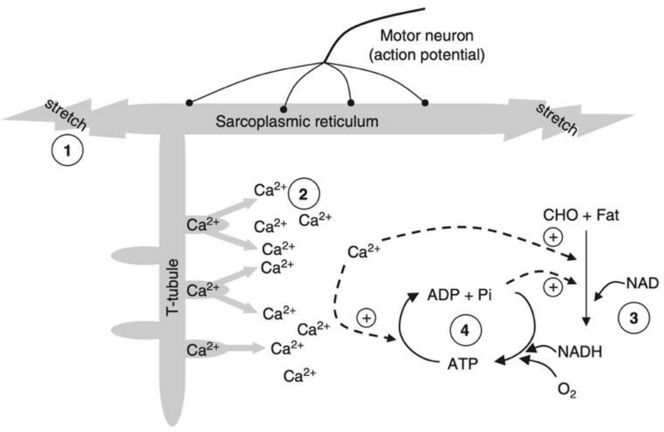
In other populations PROM:



Promote muscle regeneration by activating satellite cells

Relaix F, Zammit PS (2012) Satellite cells are essential for skeletal muscle regeneration: the cell on the edge returns centre stage. Development 139:2845–2856





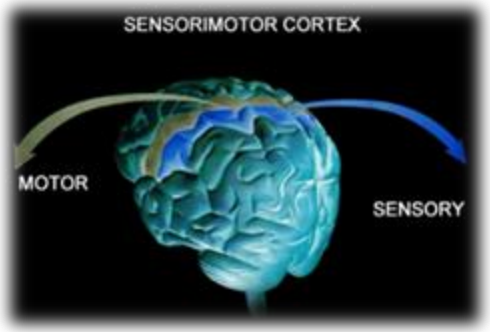
Coffey VG. Sports Med 2007

Induce a reorganization of sensorimotor representation

Carel C, Loubinoux I, Boulanouar K, Manelfe C, Rascol O, Celsis P, Chollet F (2000) Neural substrate for the efects of passive training on sensorimotor cortical representation: a study with functional magnetic resonance imaging in healthy subjects. J Cereb Blood Flow Metab 20:478–484 39.

Infuence the excitability of the corticomotor pathway

Edwards DJ, Thickbroom GW, Byrnes ML, Ghosh S, Mastaglia FL (2002) Reduced corticomotor excitability with cyclic passive movement: a study using transcranial magnetic stimulation. Hum Mov Sci 21:533–540



Les effets

De l'exercice physique, **mais en REA?**

Effects of Bilateral Passive Range of Motion Exercise on the Function of Upper Extremities and Activities of Daily Living in Patients with Acute Stroke

Acute stroke patients:
Control (n=18) → PROM from week 2
Intervention (n=19) → <72h PROM 15-minute
twice a day, 5 times a week, for 4 weeks

Table 3. Comparison of range of motion of affected shoulder between experimental and control groups

Variables		Baseline		After 2 wks		After 4 wks
				Mean±SD		
Flexion (°)	Exp (n=19)	114.1±13.0[a]	↗	116.7±12.8[b]	↗	119.0±12.6[c]
	Cont (n=18)	109.1±20.2[a]	→	109.8±20.7	↗	111.1±21.1[b]
Extension (°)	Exp (n=19)	25.2±5.2[a]	↗	27.1±4.9[b]	↗	29.5±5.3[c]
	Cont (n=18)	31.2±4.7	→	31.3±4.7	→	31.9±4.8
Abduction (°)	Exp (n=19)	94.2±12.0[a]	↗	96.3±12.1[b]	↗	98.4±12.5[c]
	Cont (n=18)	92.7±13.0[a]	→	93.0±13.1	→	94.2±13.4[b]
Internal rotation (°)	Exp (n=19)	51.3±19.8[a]	↗	53.8±19.5[b]	↗	55.6±19.6[c]
	Cont (n=18)	57.7±14.8[a]	→	58.3±14.8[b]	→	58.8±15.2[c]
External rotation (°)	Exp (n=19)	44.8±24.9[a]	↗	46.7±25.3[b]	↗	48.6±25.5[c]
	Cont (n=18)	35.0±18.2[a]	→	35.4±18.3	→	36.0±18.3[b]

Exp=Experimental group, Cont=Control group, [a,b,c] =Bonferroni test

↑ ROM upper limbs
↓ Level of edema at 2 and 4 weeks
↑ The self-care skills (eating and dressing)

Kim HJ, J Phys Ther Sci 2014

Continuous passive motion

9 ±1 days (start 1.7 ± 0.9 days)
n =7 fully sedated and MV patients
2,5h X4j

Ultrasound measurements of tibialis anterior cross-sectional area.

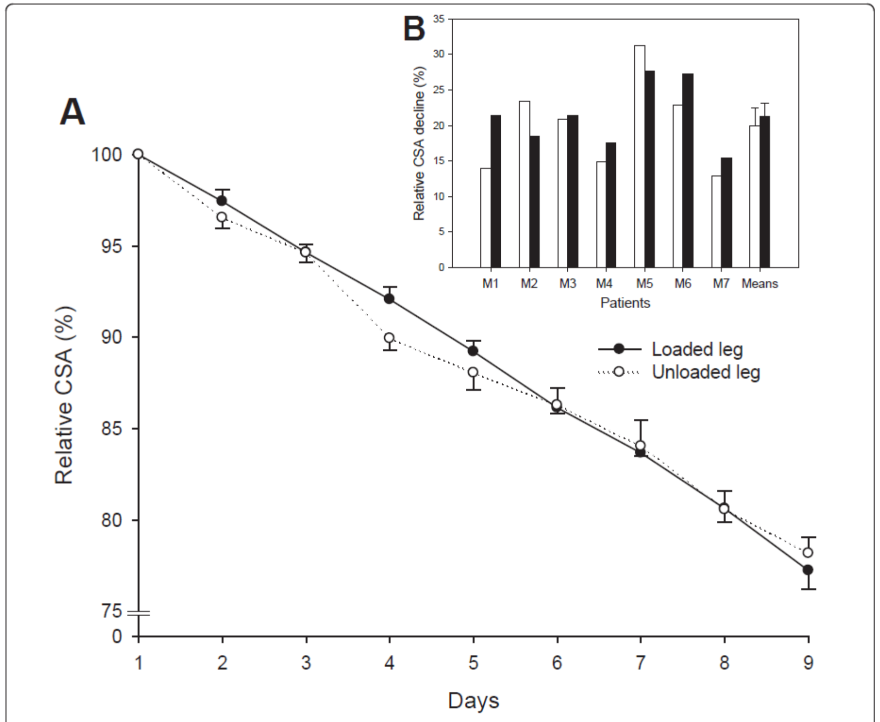


Figure 1 Ultrasound measurements of tibialis anterior cross-sectional area. (A) Relative cross-sectional area (CSA) during the intervention period (9 ± 1 days). Solid line, loaded side; dashed line, unloaded side. Values are mean ± standard error of the mean (SEM). The value at day 1 is equivalent to 100%. **(B)** Relative CSA decline in the loaded leg (black bars) and the unloaded leg (white bars) for each ICU patient on the final day of the intervention, and mean ± SEM for all patients.

Specific force in single muscle fibers.

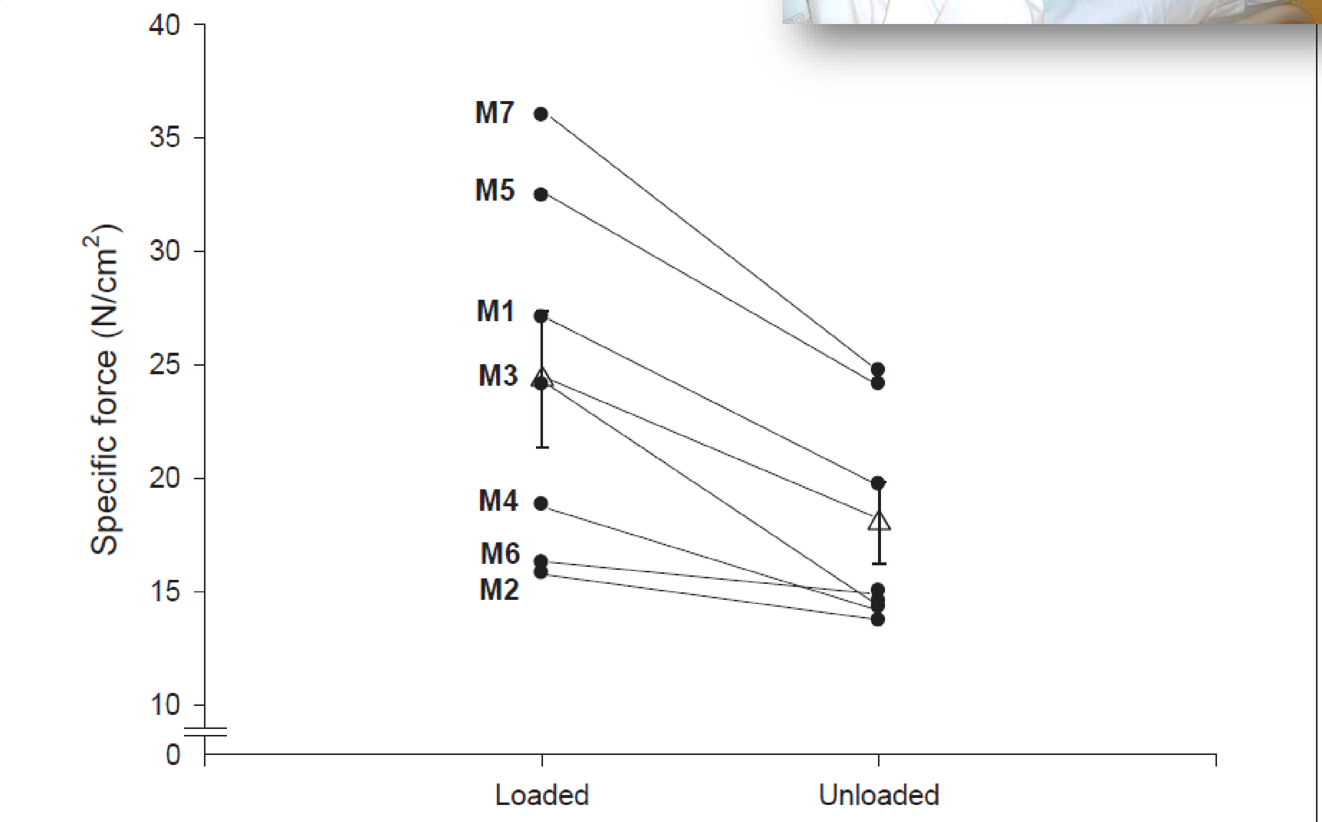


Figure 2 Specific force in single muscle fibers. Specific force in single muscle fibers expressing the type I myosin heavy chain isoform in the loaded and unloaded legs from patients exposed to unilateral loading and mechanical ventilation for 9 ± 1 days. Black circles, individual means; open triangles, average for all patients pooled together ± standard error of the mean.

Llano-Diez et al. Critical Care 2012

Very ealy exercice cycling

réanimation 2025
PARIS 11-13 JUIN

Hickmann CE. CCM 2019

Impact of Very Early Physical Therapy During Septic Shock on Skeletal Muscle: A Randomized Controlled Trial

Sans augmentation de l'inflammation déjà existante

n= 19 patients avec choc septique
initiation <72h du diagnostique
2X 30 min vélo sur 7j/7j

CCM_46_9_2018_06_12_HICKMANN_CCMED-D-18-0(

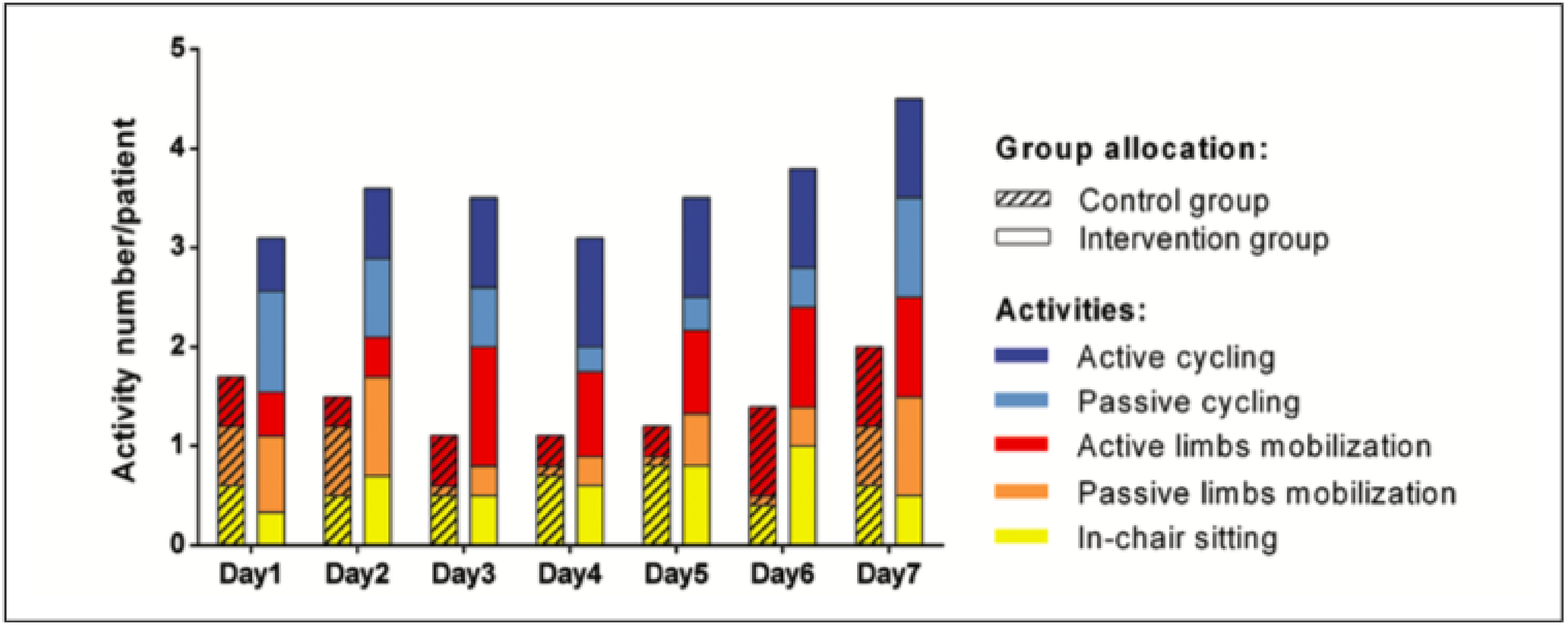


Figure 1. Amount of mobility activities performed per patient during the first week.

Very ealy exercice cycling

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Impact of Very Early Physical Therapy During Septic Shock on Skeletal Muscle: A Randomized Controlled Trial

Plus d'activités ont été réalisés, le maintient de la masse musculaire était plus important.

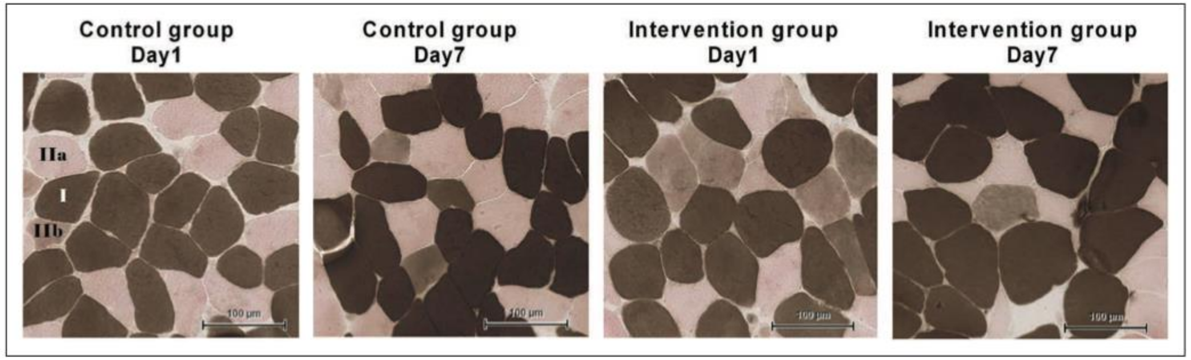
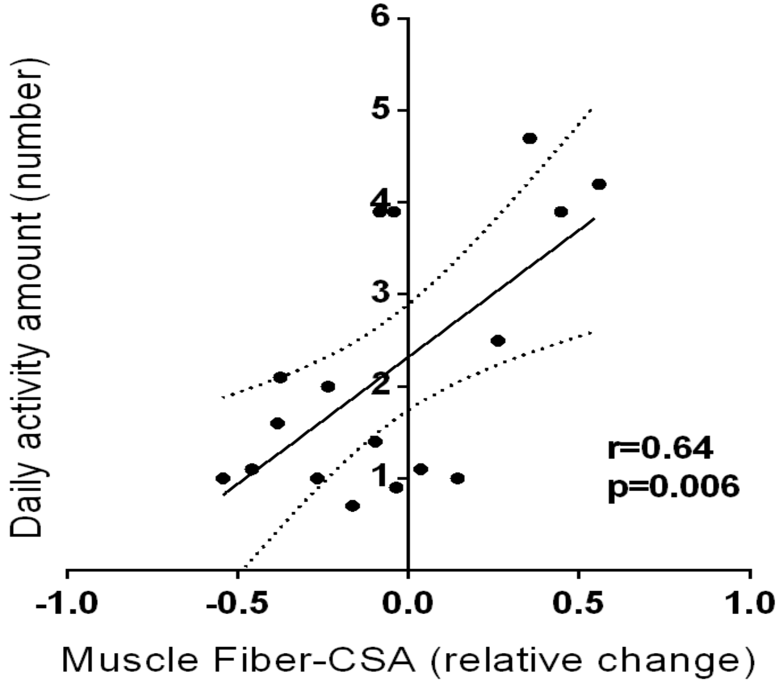


Figure 3. Muscle fiber cross-sectional area changes by group. Skeletal muscle sections stained with adenosine triphosphatase pH 4.50; *black* fibers correspond to type-I fibers; *gray* fibers are type-IIb fibers and; *pink* fibers correspond to type-IIa.

TABLE 2. Changes in Cross-Sectional Area by Groups

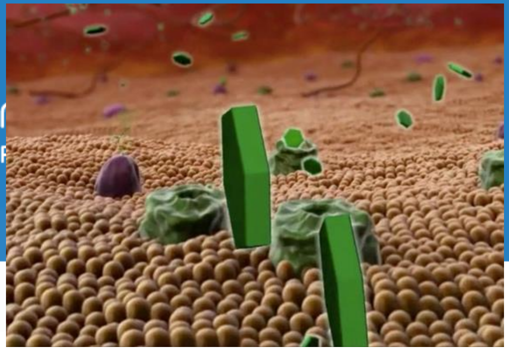
	Control Group ($n = 9$), Mean ± SD		Intervention Group ($n = 8$), Mean ± SD		
Fiber Type	Day 1	Day 7	Day 1	Day 7	p[b]
All fibers types (μm²)	3,603 ± 1,284	2,629 ± 1,174[a]	3,448 ± 1,993	3,770 ± 1,473	0.01
Type I fibers (μm²)	4,236 ± 1,379	3,135 ± 1,103[a]	4,250 ± 1,977	4,678 ± 1,189	0.02
Type-IIa fibers (μm²)	3,949 ± 1,447	2,744 ± 1,260[a]	2,574 ± 856	2,920 ± 745	0.003
Type-IIb fibers (μm²)	2,624 ± 1,243	2,006 ± 1,286[a]	2,082 ± 1,083	2,576 ± 948	0.04

[a]Different than day 1 ($p < 0.05$).
[b]p of the difference between groups changes, no differences were detected between groups at day 1 in any fibers type.



Hickmann CE, *Crit Care Med* 2019

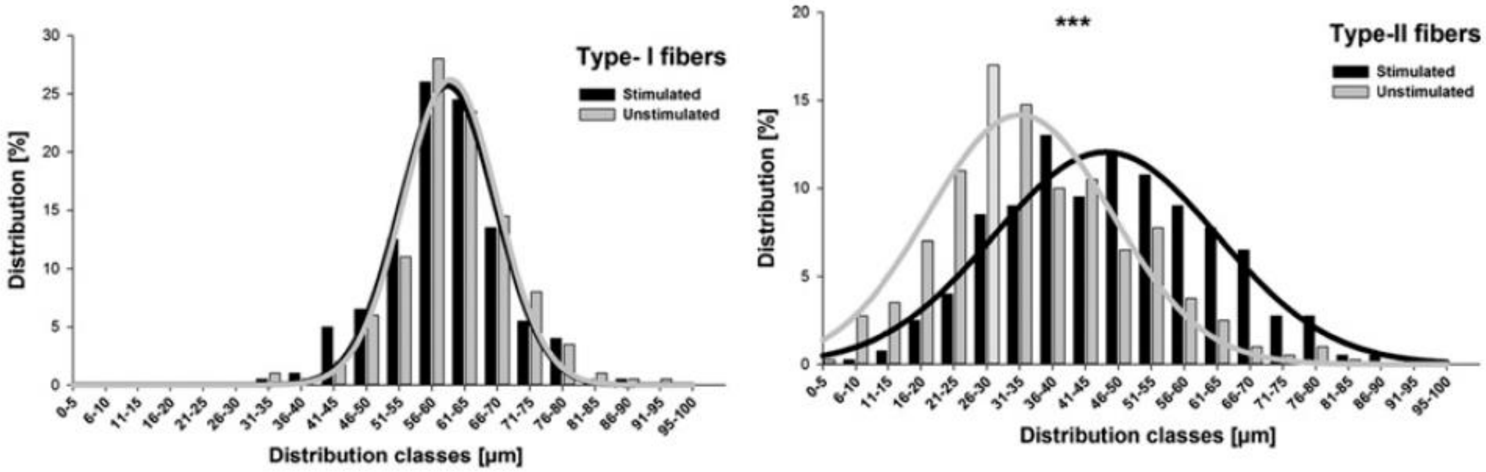
NMES

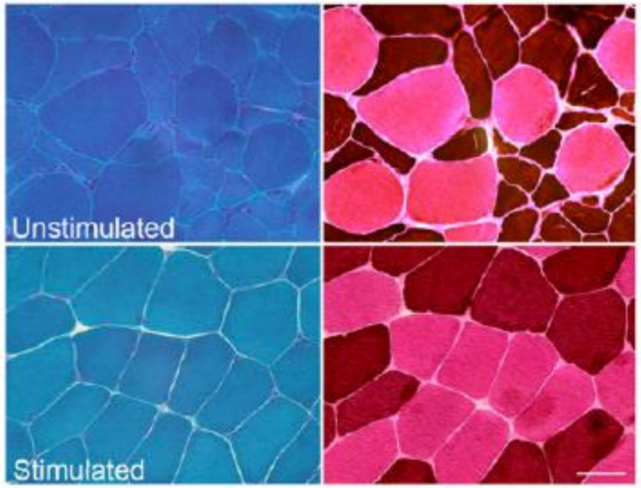


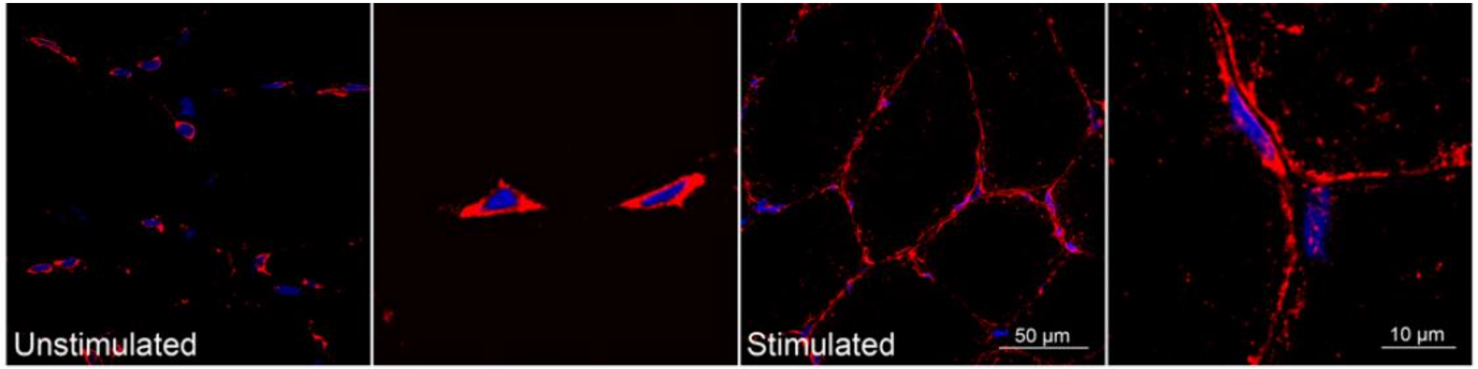
Critical Illness Myopathy and GLUT4

Significance of Insulin and Muscle Contraction

n=4, ARDS and sepsis







(GLUT4, red; nuclei, blue)

EMS may:

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

Weber-Carstens S, et al. AJRCCM 2013

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
FES = Functional electrical stimulation
FES + PCE

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*	

↓ TNF-α only after PCE

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

Resistance training + NMES

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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*

Neither NMES-RT nor PMT changed mitochondrial complex tissue levels; however, changes in peak VO2 were related to complex I in mitochondrie.

Gorgey AS, Appl Physiol (1985) 2021

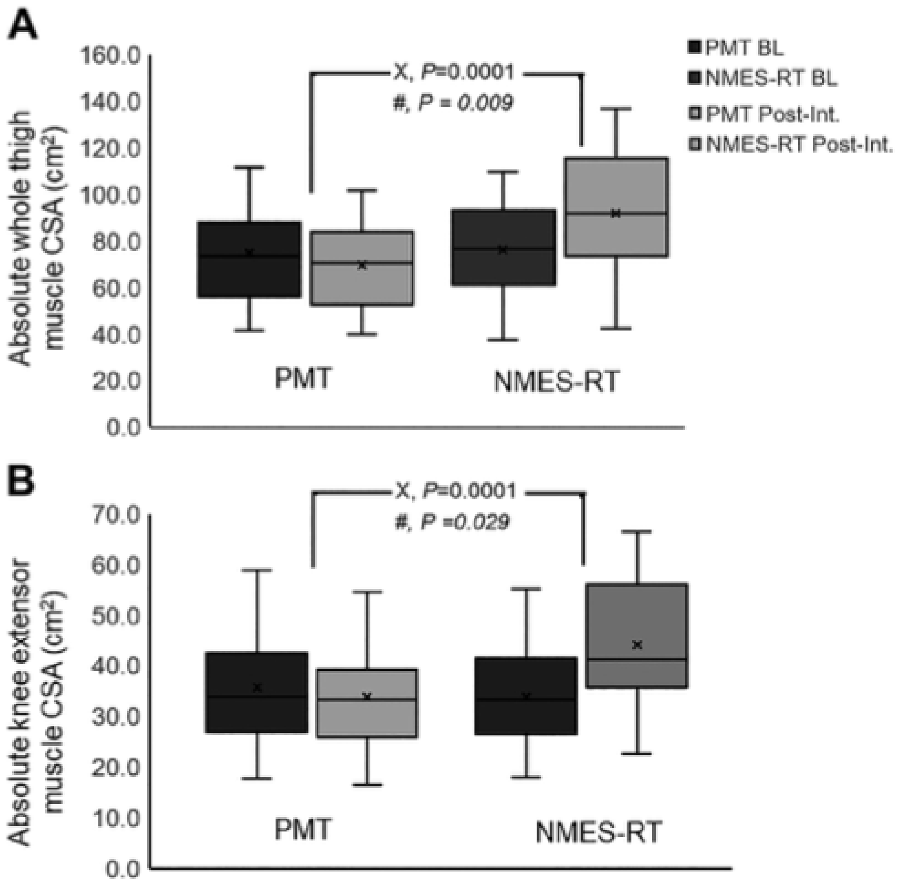
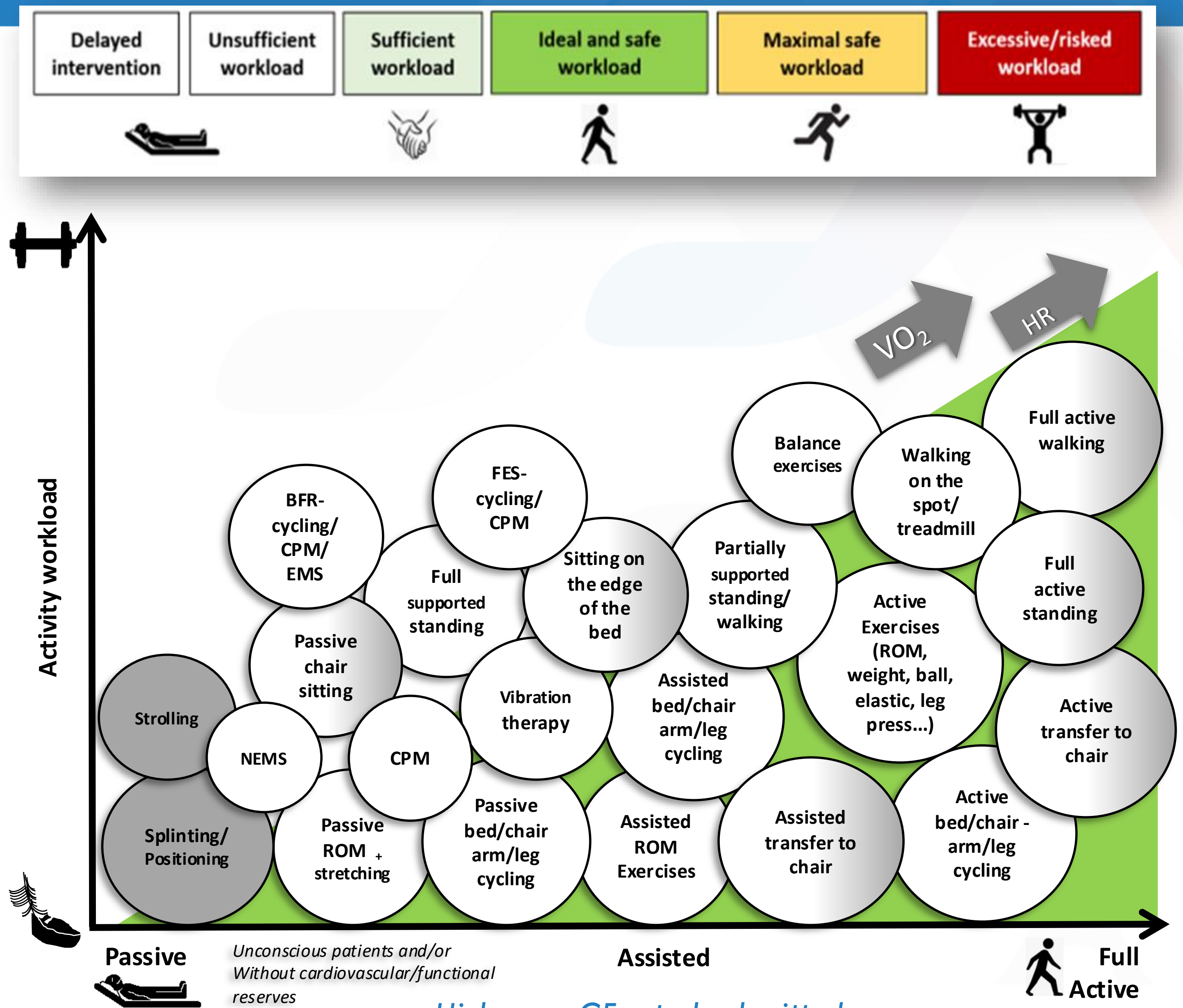
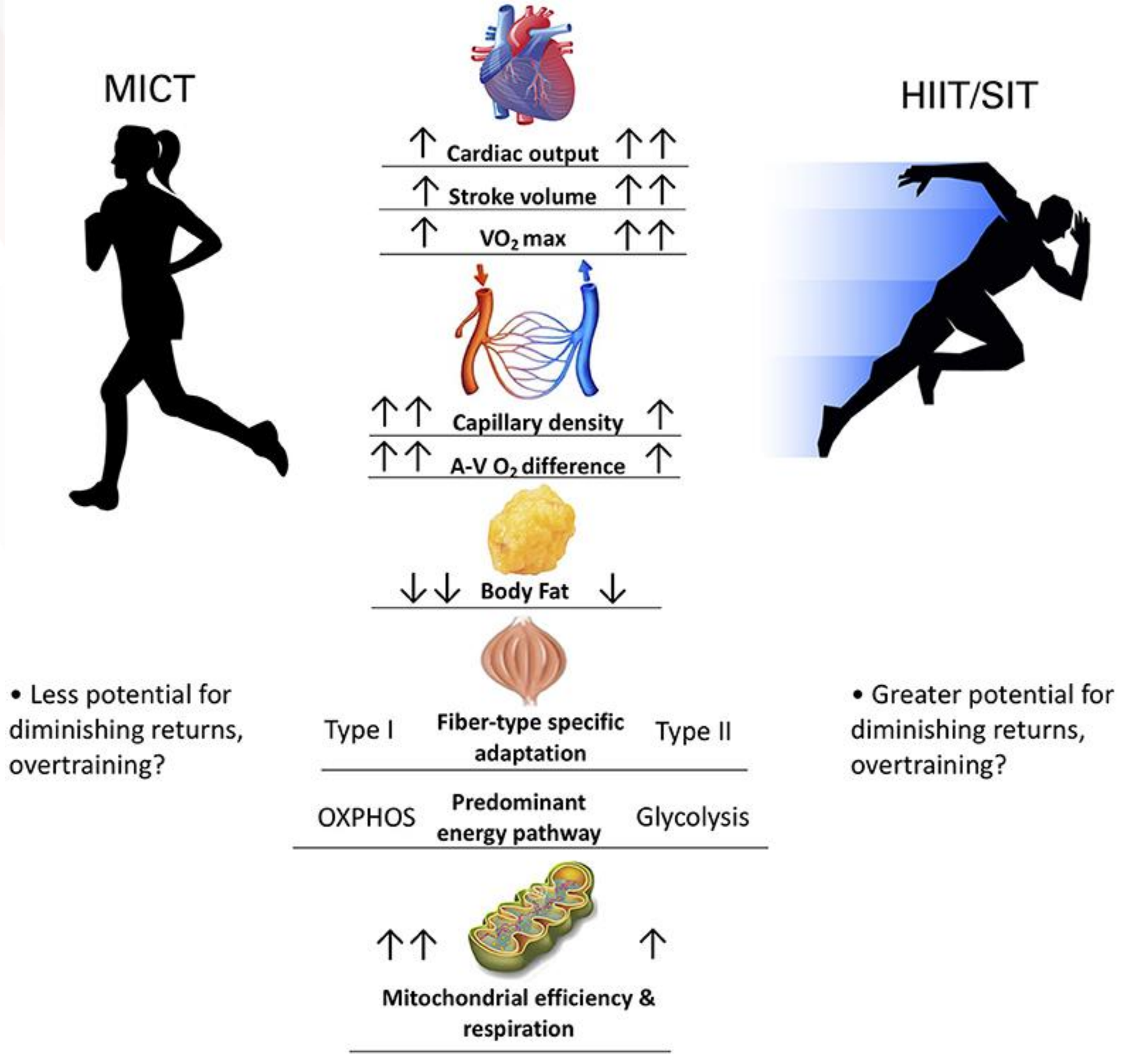


Figure 1. Distribution of muscle cross-sectional area (means ± SD) during baseline (BL) and postintervention (postint.) for both the PMT and NMES-RT groups for thigh muscle CSA (*A*) and knee extensor muscle CSA (*B*) in persons with SCI. CSA, cross-sectional area; NMES-RT, neuromuscular electrical stimulation-resistance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

Intensité idéale?

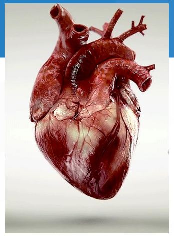


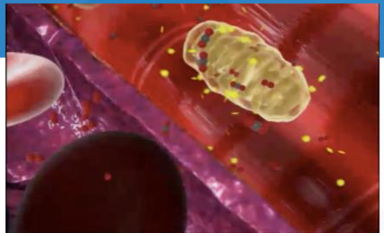
Hickmann CE, et al submitted

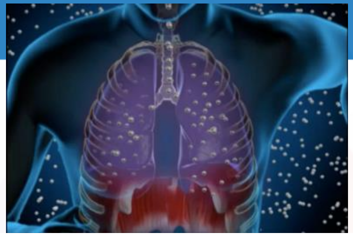


Clinical parameters

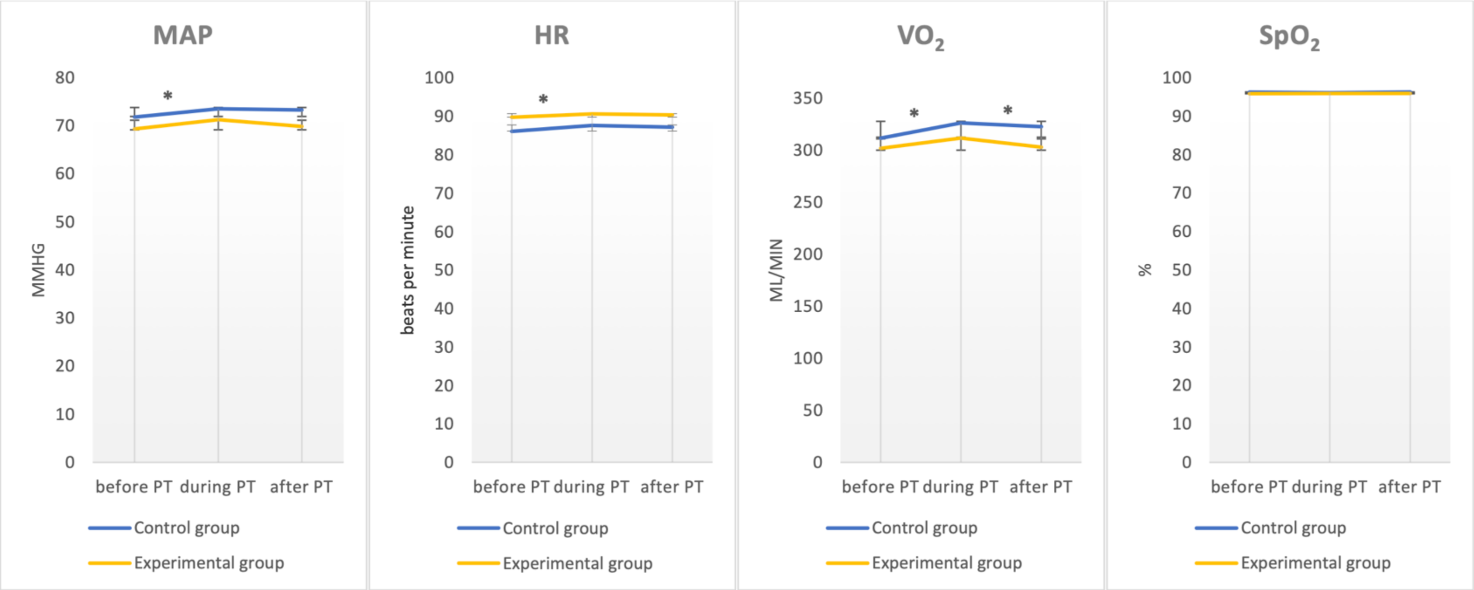
réanimation 2025
PARIS 11-13 JUIN







S2 Fig. Physiological parameters while on mechanical ventilation (with indirect calorimetry) for before, during and after physiotherapy.



* $p < 0.013$

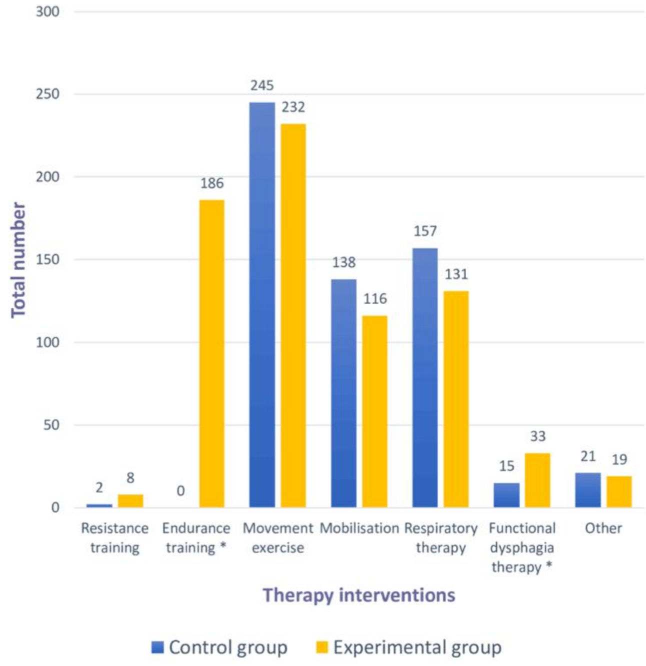
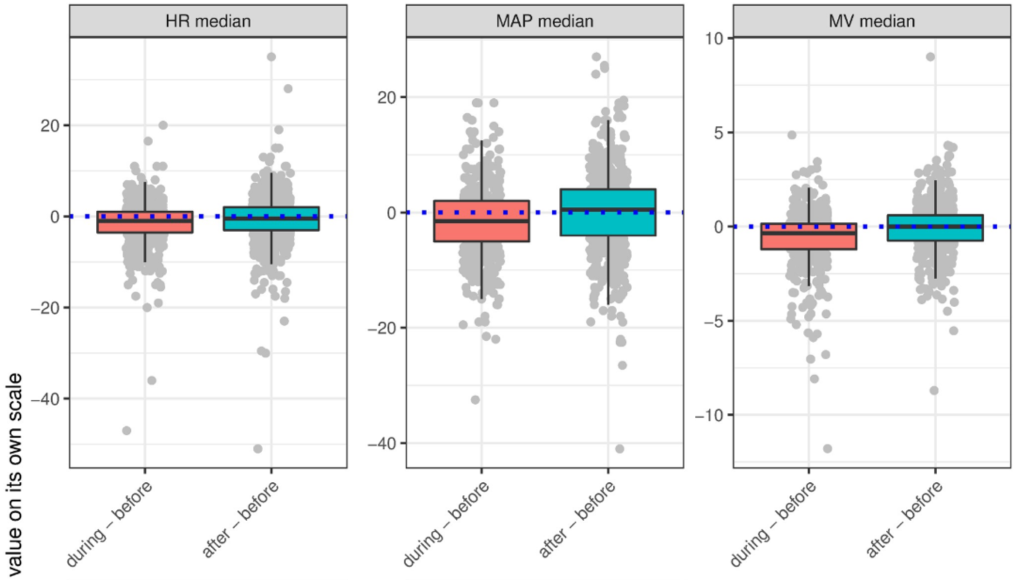


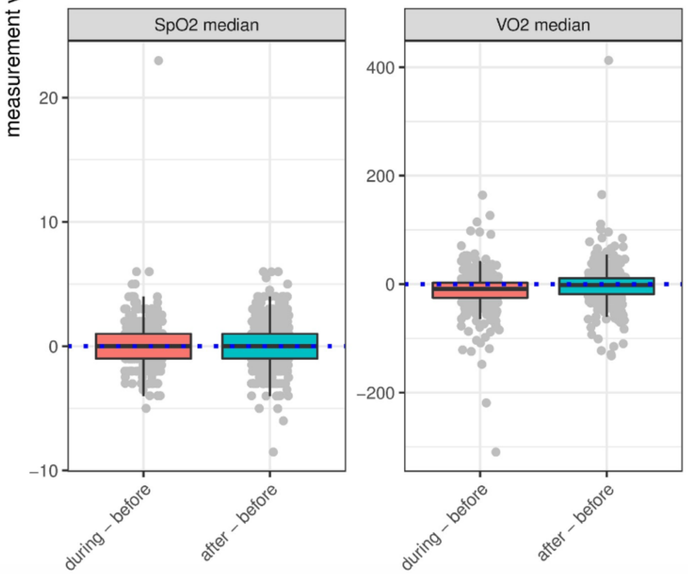
Figure 3.2. Overview of each physiotherapy intervention for the control and experimental groups. More than one therapy intervention per session (=single physiotherapy treatment) possible, total sessions: 407 (85% of study days) experimental and 377 (68%) control group. * p<0.003

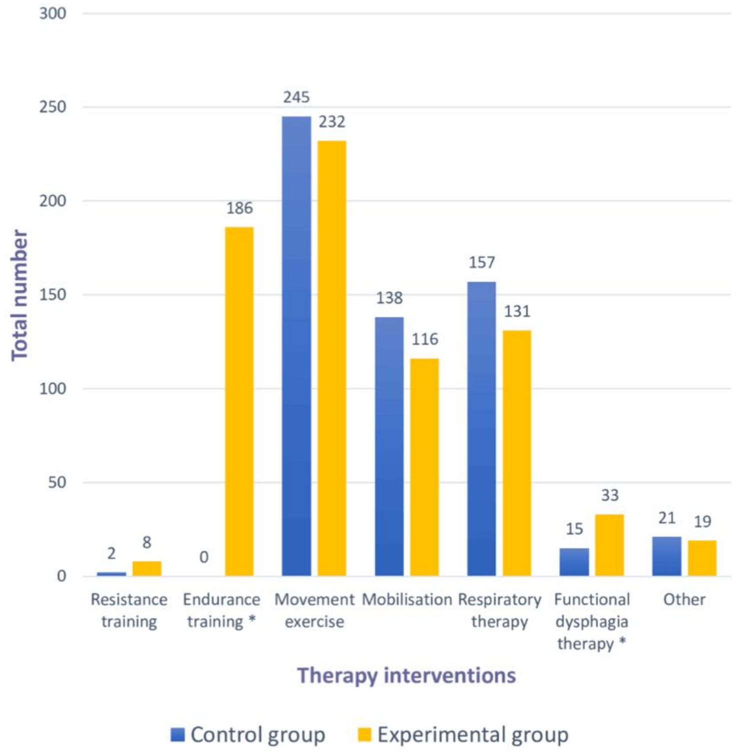
Only full data sets (from before to after physiotherapy) were included. Total sessions: MAP: experimental n=193, control n=214, HR: experimental n=195, control n=222, VO2: experimental n=166, control n=192, SpO2: experimental n=195, control n=221.

Eggmann S,
PLOS one 2018

Clinical parameters







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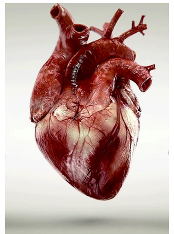
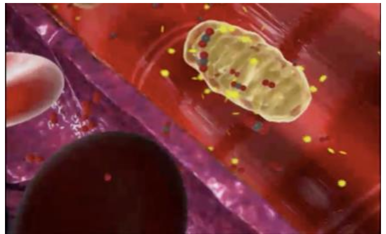
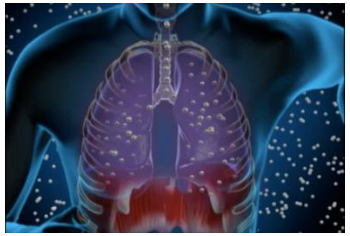


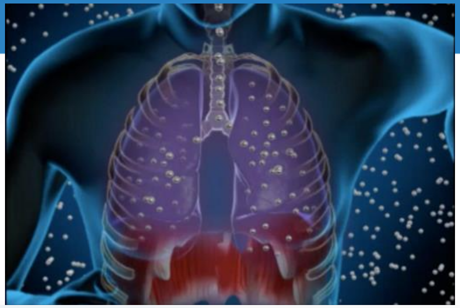




Eggmann S,
PLOS one 2022

Et sur oxygénation?

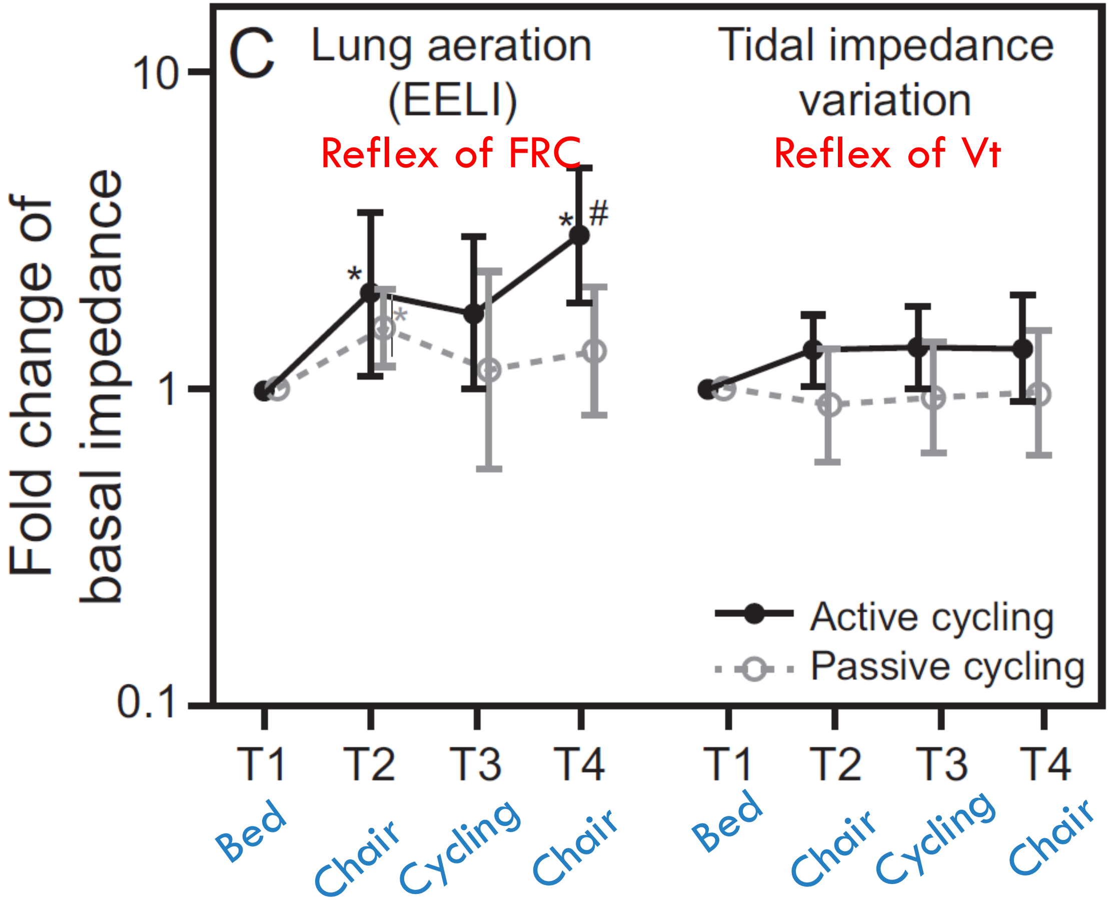
Acute Effects of Sitting Out of Bed and Exercise on Lung Aeration Oxygenation in Critically Ill Subjects



n=17 MV patients

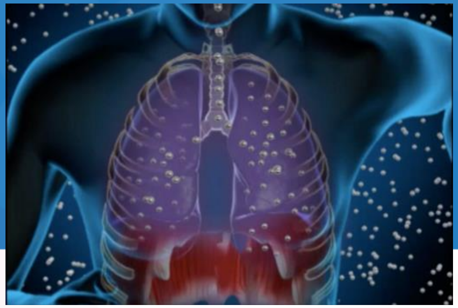
n= 6, active chair-cycling

n= 11 passive chair-cycling



Hickmann CE et al. Resp Care (2021)

MV parameters adaptation



réanimation 2025
PARIS 11-13 JUIN

Proportional ventilation during exercise results in **higher work efficiency** and **less increase in VO2** compared to ventilation with PSV.
These preliminary findings suggest that proportional ventilation could enhance the training effect and facilitate rehabilitation.

Fig. 1 Example of a patient ventilated with Neurally Adjusted Ventilator Assist (NAVA) while performing exercise with the cycle ergometer (MOTOmed Letto 2, RECK-Technik GmbH and Co. Betzenweiler, Germany). Oxygen consumption is measured through indirect calorimetry

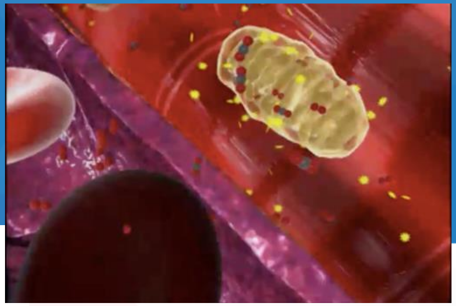
Table 1 Patient characteristics

Patient	Sex	Age (years)	Diagnosis	ICU (days)	MV (days)	APACHE II	PS	PEEP	FiO_2 (%)	Group
1	M	69	Sepsis-MOF	14	14	29	4	6	24	NAVA
2	M	53	Cardiac arrest	54	54	42	7	5	30	NAVA
3	F	53	CO intoxication	6	6	16	13	5	35	NAVA
4	M	66	Pneumonia	14	14	20	5	5	30	NAVA
5	M	54	Esophageal cancer	7	2	25	11	6	27	PAV+
6	M	72	Polytrauma	19	19	13	9	8	28	PAV+
7	M	61	ARF	32	32	22	16	7	21	PAV+
8	F	55	AECOPD	16	16	28	8	5	34	PAV+
9	F	55	Sepsis–cirrhosis	12	12	13	9	5	30	PAV+
10	M	48	Pneumonia	14	14	18	7	6	35	PAV+
Median		55		14	14	21				
IQR		53–65		12.5–18.3	12.5–18.3	16.5–27.3				

M male, *F* female, *ARF* acute respiratory failure, *MOF* multiple organ failure, *CO* carbon monoxide, *AECOPD* acute exacerbation of chronic obstructive pulmonary disease, *ICU* intensive care unit, *MV (days)* duration of mechanical ventilation (in days) at first study day, *APACHE II* simplified acute physiology score II, *PS* ventilator assistance during baseline ventilation, *PEEP* positive end expiratory pressure, *PAV+* Proportional Assist Ventilation with load-adjustable gain factors, *NAVA* neurally adjusted ventilator assist, *IQR* interquartile range

Akoumianaki *et al. Ann. Intensive Care* (2017)

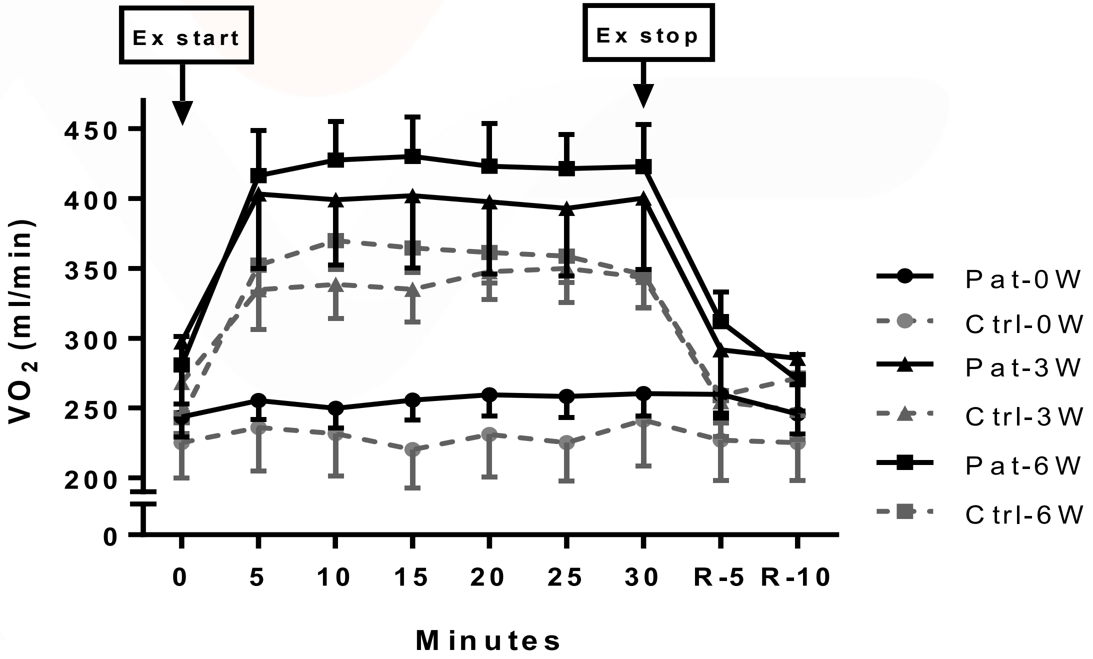
Consommation d'oxygène



réanimation 2025
PARIS 11-13 JUIN

Energy expenditure in the critically ill performing early physical therapy

Hickmann CE.
ICM 2014



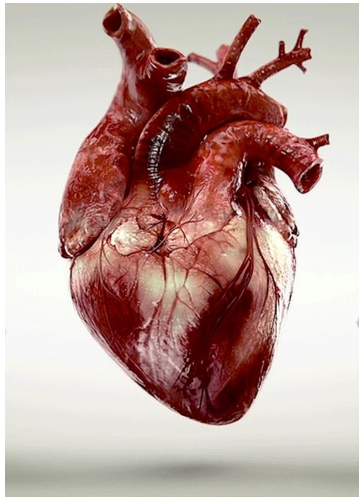
Pat-6W (n = 17)
Pat-3W (n = 7)
Pat-0W (n = 15) → 13 MV patients
14 patients with sepsis/septic shock

Continuous Indirect Calorimetry

Rest	Exercise	Rest
15 min	30 min	15 min

Débit cardiaque

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



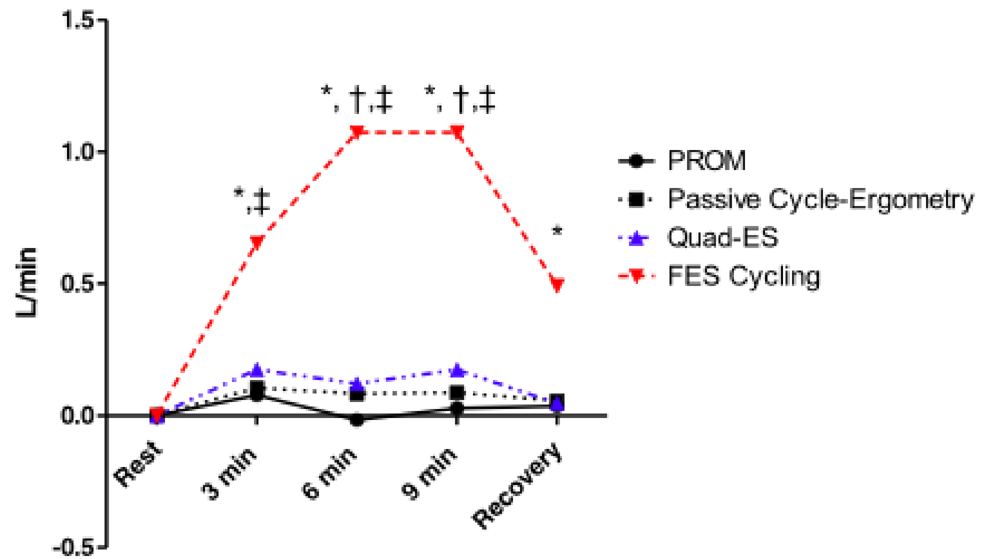
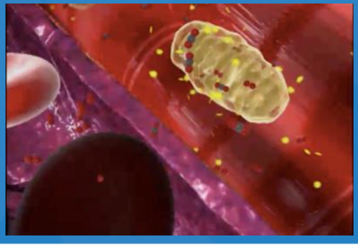


Fig. 2 Cardiac output over time for each exercise. Black circles represent passive range of leg movement (PROM); black squares represent passive cycle-ergometry; blue triangles represent quadriceps electrical stimulation; red triangles represent functional electrical stimulation cycling (FES-Cycling). *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.
Annals of Int Care 2018

Whole-body Vibrations



réanimation 2025
PARIS 11-13 JUIN

Mechanical stretch and reflex mechanism by the peripheral nerve.
Leads to much more than 1000 muscle contractions per minute
Leading to increased muscle strength and mass, seen as muscle hypertrophy in other populations

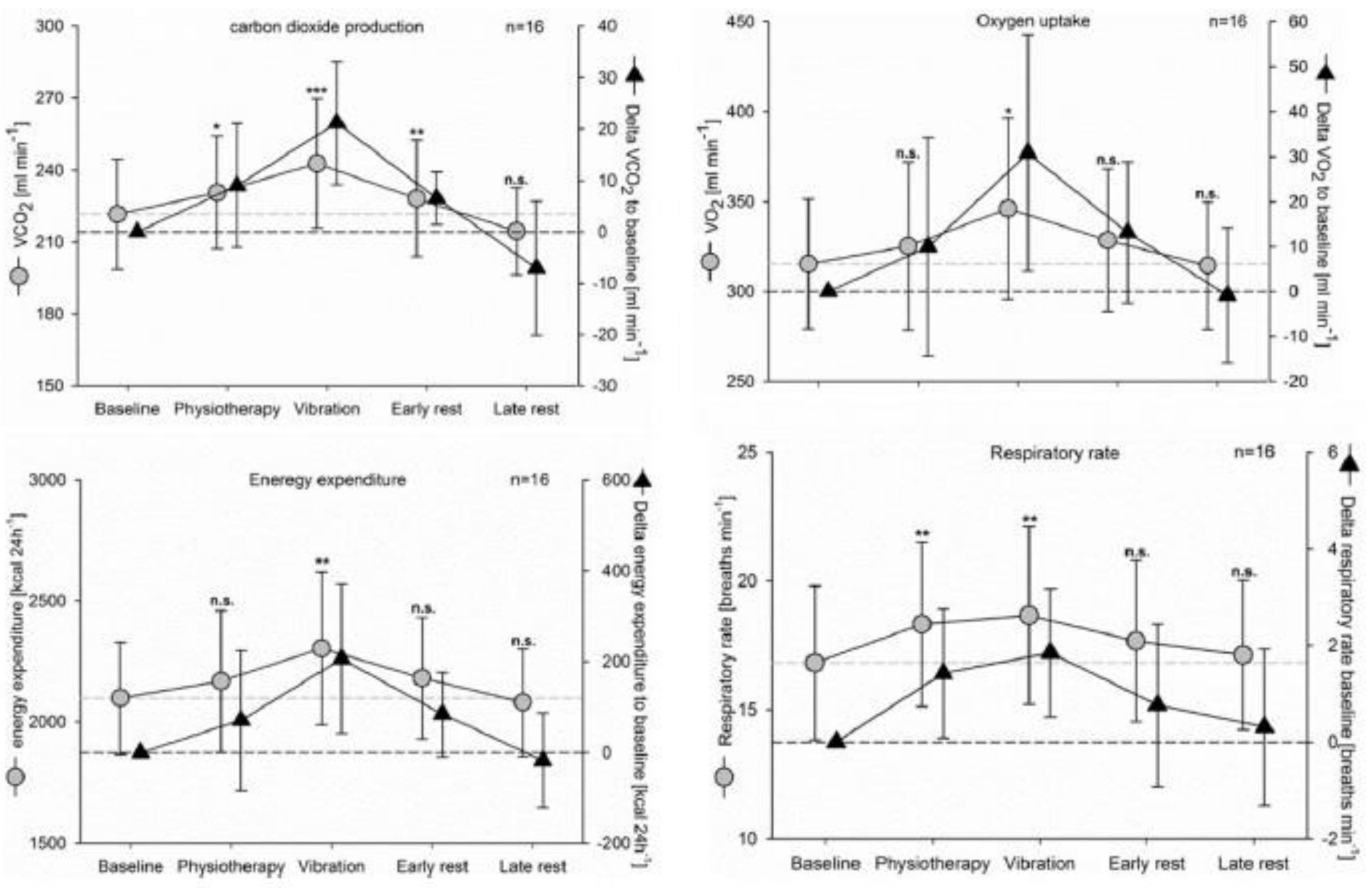
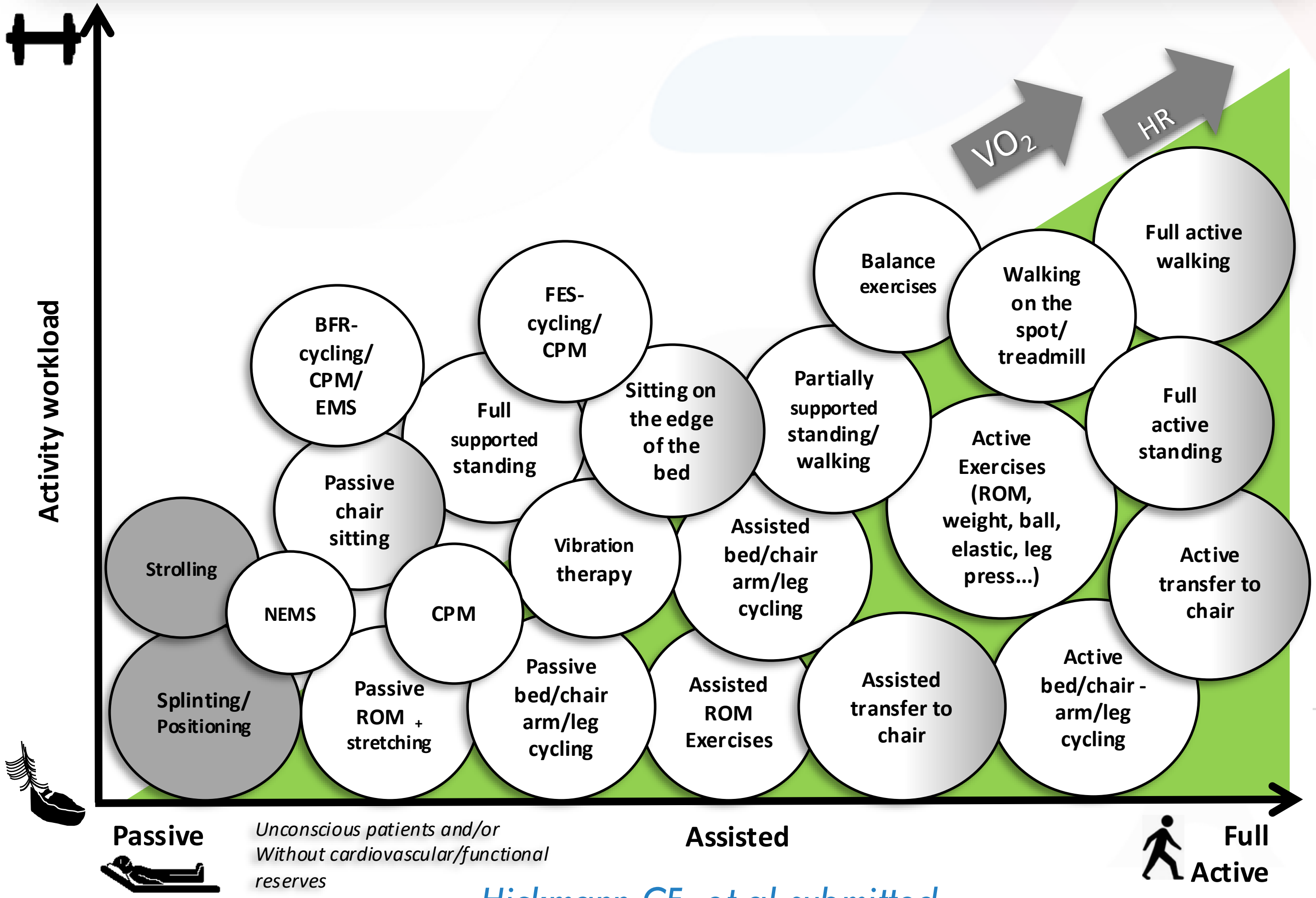


Fig. 4 Energy metabolism measurements for longitudinal observation.

Wollersheim et al. Critical Care (2017)

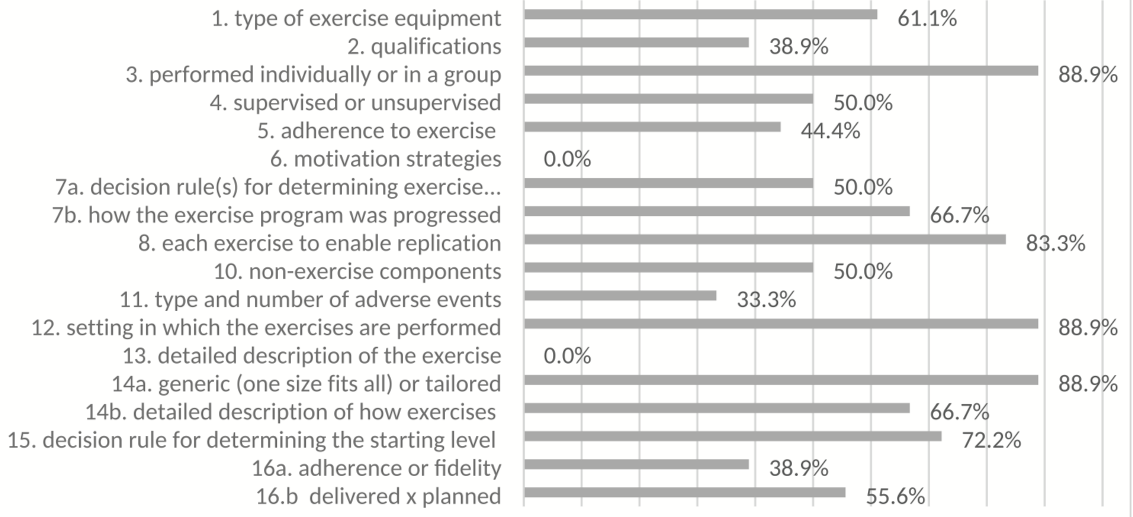
Intensité idéale?



Hickmann CE, et al submitted

Manque de description des activités by CERT

R.S. de Queiroz et al. / Heart & Lung (2018)



Evaluation of the description of active mobilisation protocols for mechanically ventilated patients in the intensive care unit: A systematic review of randomized controlled trials.

de Queiroz RS, et al. Heart Lung. 2018. PMID: 29609834 Review.

Intensité

BED CYCLING EXERCISE

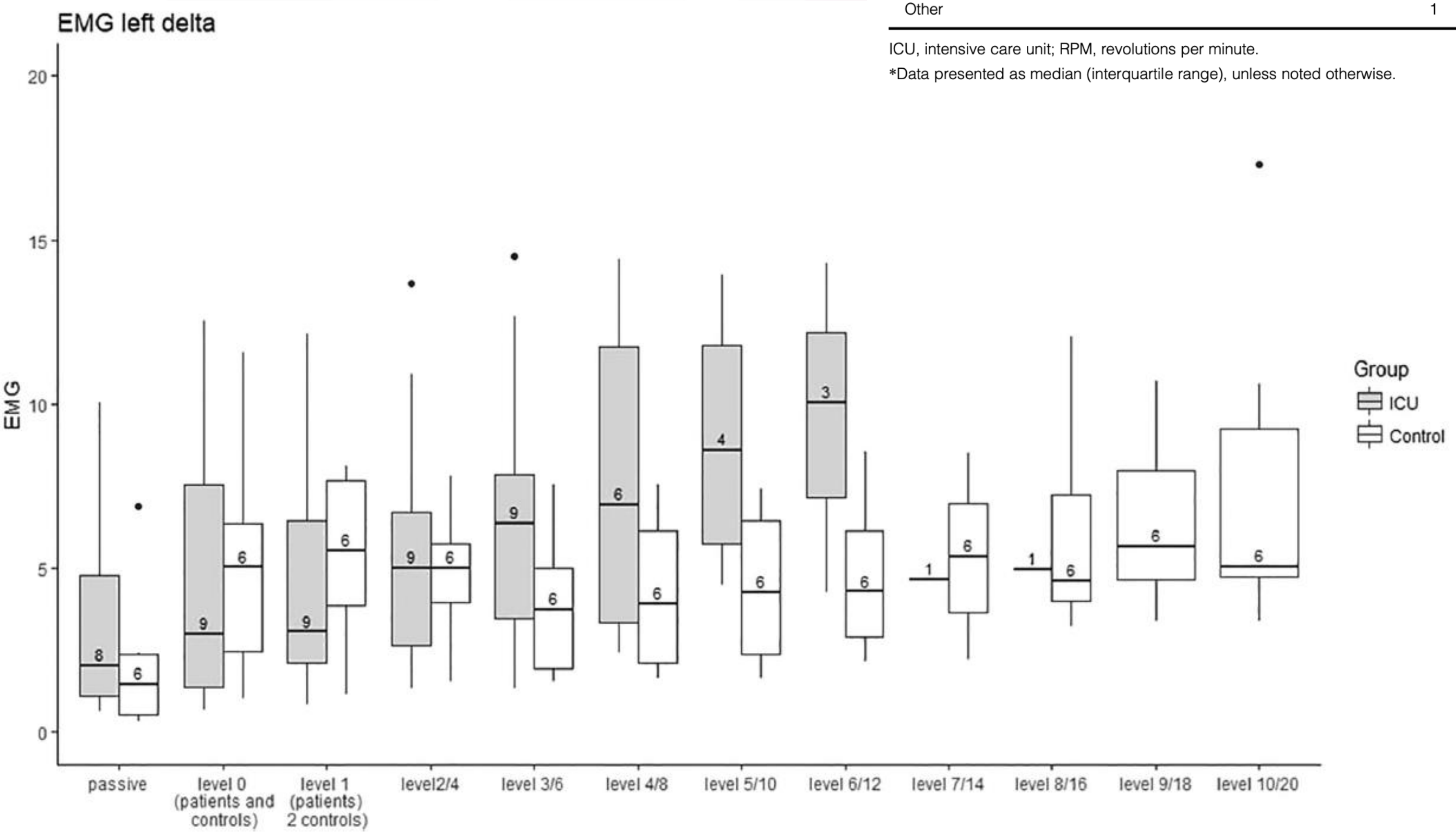


Table 2. Results of bed cycling.*

	ICU patients (*n* = 9)	Healthy persons (*n* = 6)
Duration of the test (min:s)	5:3 (4:6–8:2)	12:0 (12:0–12:0)
Maximal workload (W)	3 (2.5–5)	34.5 (32.5–54.5)
RPM	33.5 (26–38.3)	60 (53.3–73.8)
Maximum steps	4 (4–5)	20 (20–20)
Borg score	13 (12–15)	13 (9–13)
Reason to stop (*n*)		
Muscle fatigue	7	
Dyspnea	1	
Other	1	6 (end of program)

ICU, intensive care unit; RPM, revolutions per minute.

*Data presented as median (interquartile range), unless noted otherwise.

ICU patients

5 min
~3W
33 rpm
Borg ~13

Control

12 min
~35W
60 rpm
Borg ~13

Sommers J. Muscle & Nerve 2018

Intensité de l'exercice

TABLE 5. Classification of exercise intensity: relative and absolute exercise intensity for cardiorespiratory endurance and resistance exercise.

	Cardiorespiratory Endurance Exercise											Resistance Exercise
	Relative Intensity				Intensity ($\%\dot{V}O_{2max}$) Relative to Maximal Exercise Capacity in METs			Absolute Intensity	Absolute Intensity (MET) by Age			Relative Intensity
Intensity	%HRR or $\%\dot{V}O_2R$	$\%HR_{max}$	$\%\dot{V}O_{2max}$	Perceived Exertion (Rating on 6–20 RPE Scale)	20 METs $\%\dot{V}O_{2max}$	10 METs $\%\dot{V}O_{2max}$	5 METs $\%\dot{V}O_{2max}$	METs	Young (20–39 yr)	Middle-aged (40–64 yr)	Older (≥65 yr)	% 1RM
Very light	<30	<57	<37	<Very light (RPE < 9)	<34	<37	<44	<2	<2.4	<2.0	<1.6	<30
Light	30–39	57–63	37–45	Very light–fairly light (RPE 9–11)	34–42	37–45	44–51	2.0–2.9	2.4–4.7	2.0–3.9	1.6–3.1	30–49
Moderate	40–59	64–76	46–63	Fairly light to somewhat hard (RPE 12–13)	43–61	46–63	52–67	3.0 to 5.9	4.8–7.1	4.0–5.9	3.2–4.7	50–69
Vigorous	60–89	77–95	64–90	Somewhat hard to very hard (RPE 14–17)	62–90	64–90	68–91	6.0–8.7	7.2–10.1	6.0–8.4	4.8–6.7	70–84
Near–maximal to maximal	≥90	≥96	≥91	≥Very hard (RPE ≥ 18)	≥91	≥91	≥92	≥8.8	≥10.2	≥8.5	≥6.8	≥85

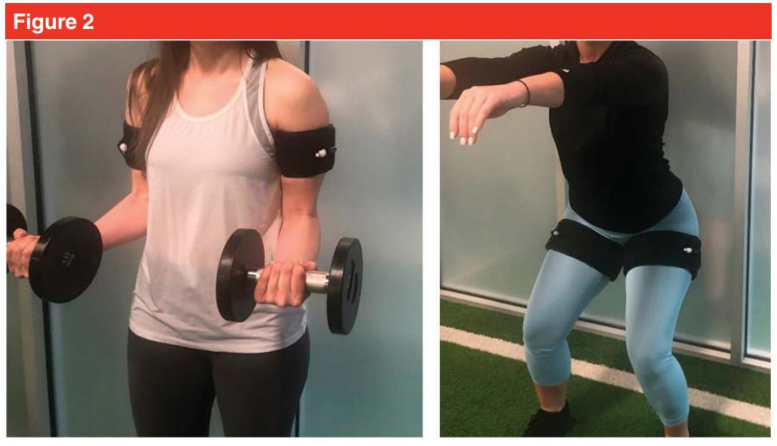
Table adapted from the American College of Sports Medicine (14), Howley (173), Swain and Franklin (344), Swain and Leutholtz (346), Swain et al. (347), and the US Department of Health and Human Services (370).
HR_{max}, maximal HR; $\%HR_{max}$, percent of maximal HR; HRR, HR reserve; $\dot{V}O_{2max}$, maximal oxygen uptake; $\%\dot{V}O_{2max}$, percent of maximal oxygen uptake; $\dot{V}O_2R$, oxygen uptake reserve; RPE, ratings of perceived exertion (48).

Medicine & Science in Sports & Exercise 43(7):p 1334-1359, July 2011

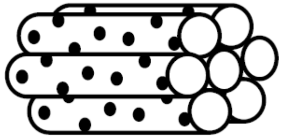
Hypoxia in skeletal muscle

Normobaric Hypoxic chamber (FiO2: 12-16%)

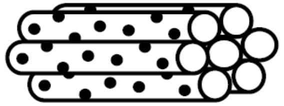
Blood flow restriction training



Skeletal muscle



Chronic hypoxia



Increase in:

- Protein turnover (degradation>synthesis)
- Inflammation

Decrease in:

- Physical activity
- Sleep
- Appetite

High Altitude (Hypobaric Hypoxia)

Critical illness + immobilization

COPD

Deldicque L. 2013 *Cell and Molec Ex Phy*

Blood flow restriction (BFR) training

It was originally developed in Japan in the late 1970s termed as KAATSU training.

Wider tourniquet:

Lower pressure

More effective

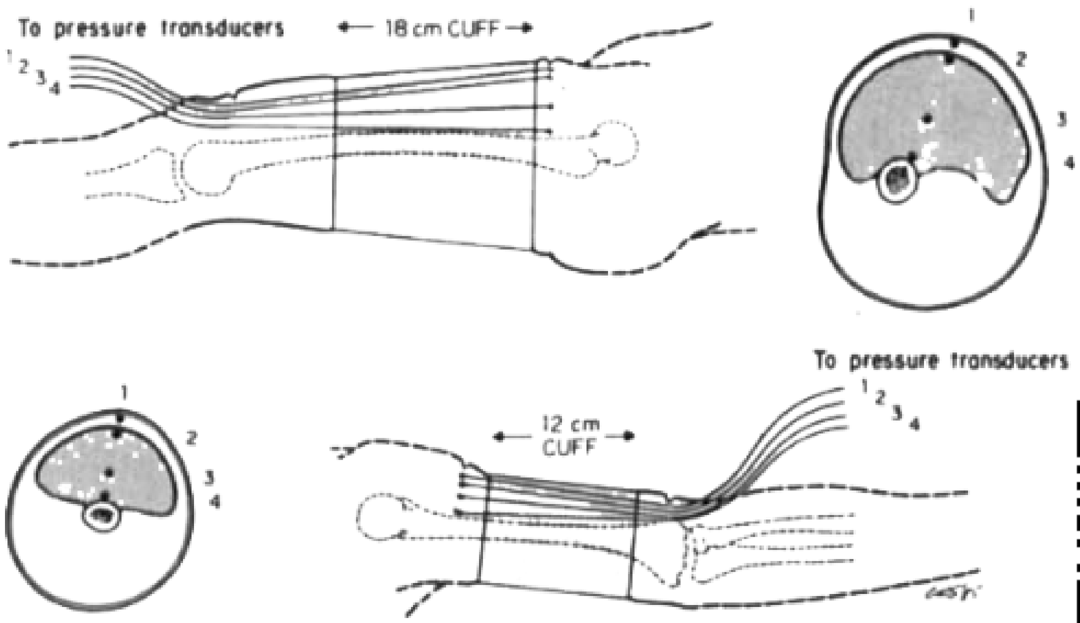
↓ Pain

Occlusive pressure

First : 200 mmHg

Currently: 50 mmHg

40–80% of the Arterial occlusion pressure (AOP).



Crenshaw AG.
1988 Acta orthop scand

BFRT

Metabolic Stress +Mechanical Tension
- Hypoxia
- Cellular Swelling
- Metabolites (Lactic Acid, ROS)

↓

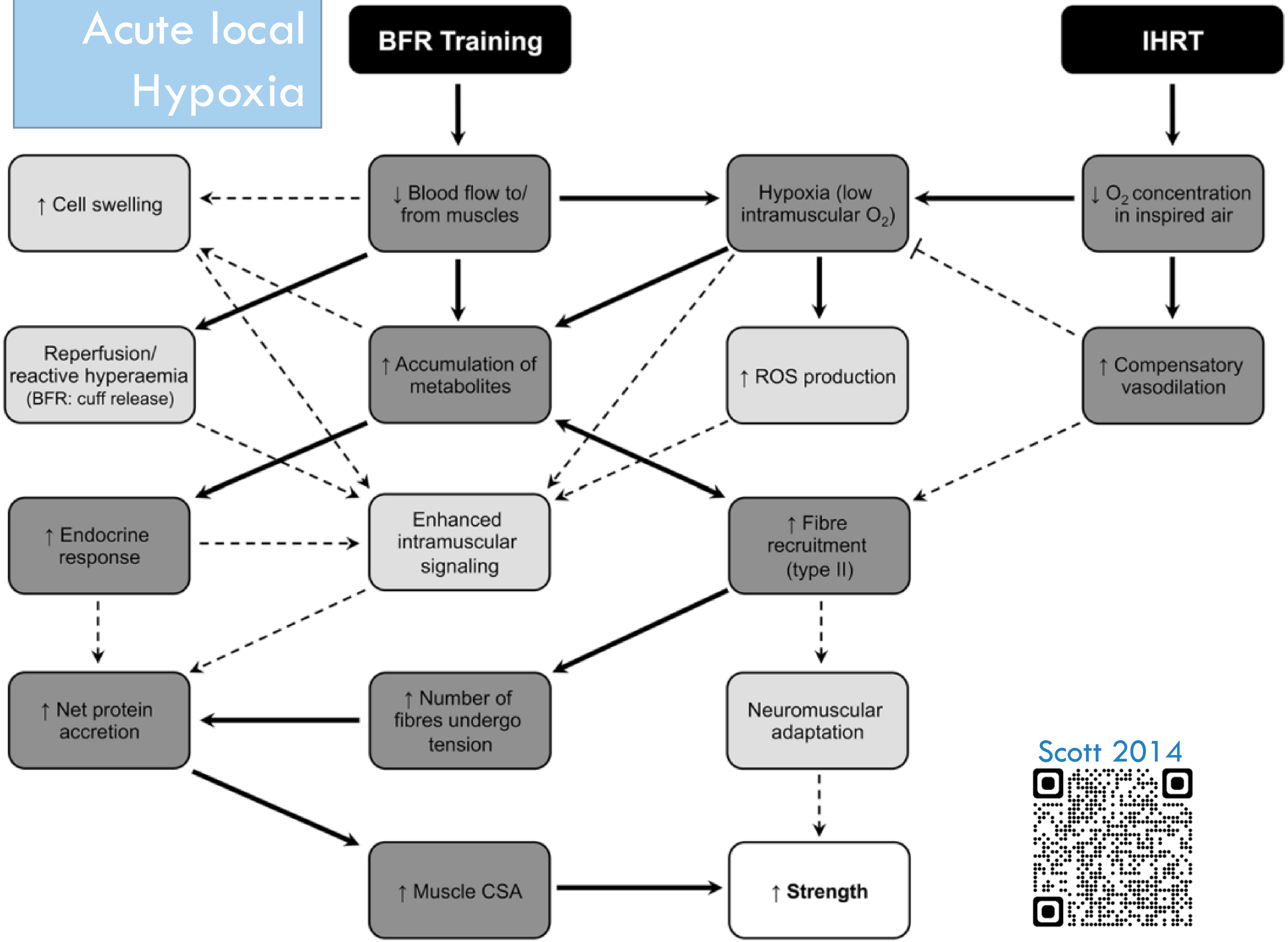
- ↑ Protein Synthesis
- ↑ Type 2 Muscle Fibers
- ↑ Local/Systemic Hormones
- ↑ Myogenic Stem Cells

↓

- ↑ Muscle Strength
- ↑ Hypertrophy
- ↑ Angiogenesis

Acute local Hypoxia

Intermitent Hypoxia environment



Factors Influencing the Response to BFR Training and IHRT

Individual factors:
- Age
- Sex
- Training history

Training factors:
- Intensity
- Volume
- Inter-set rest
- Frequency and program duration
- Exercise to failure or to a pre-determined amount of repetitions
- Hypoxic dose
  - BFR: Cuff type, dimensions and pressure, and duration of BFR
  - IHRT: F_IO_2 and exposure duration

Scott 2014

Passive BFR

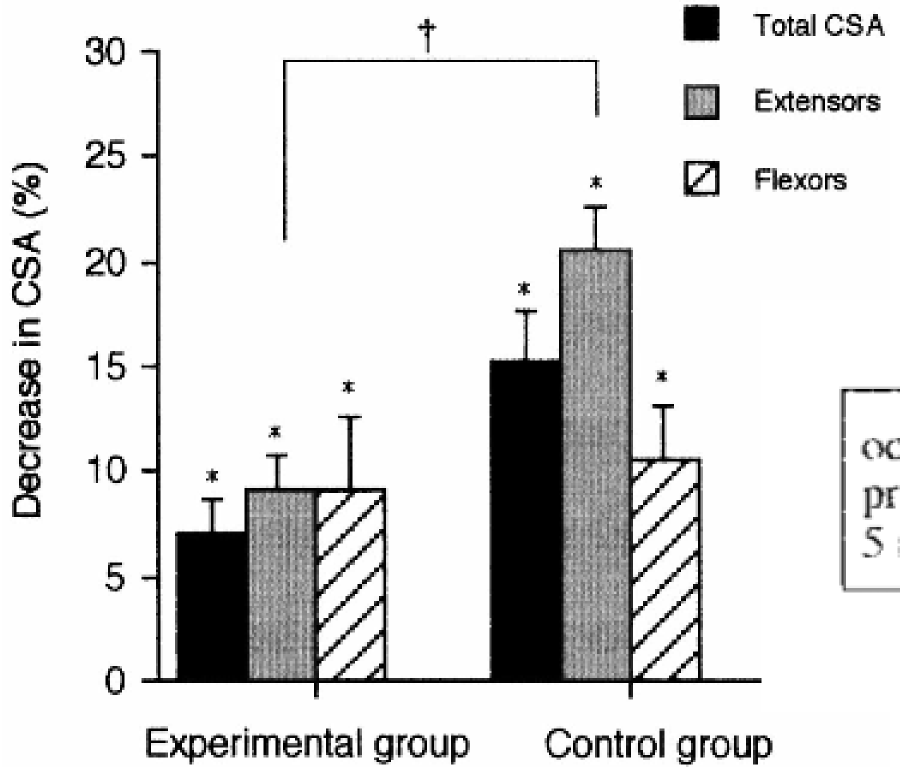
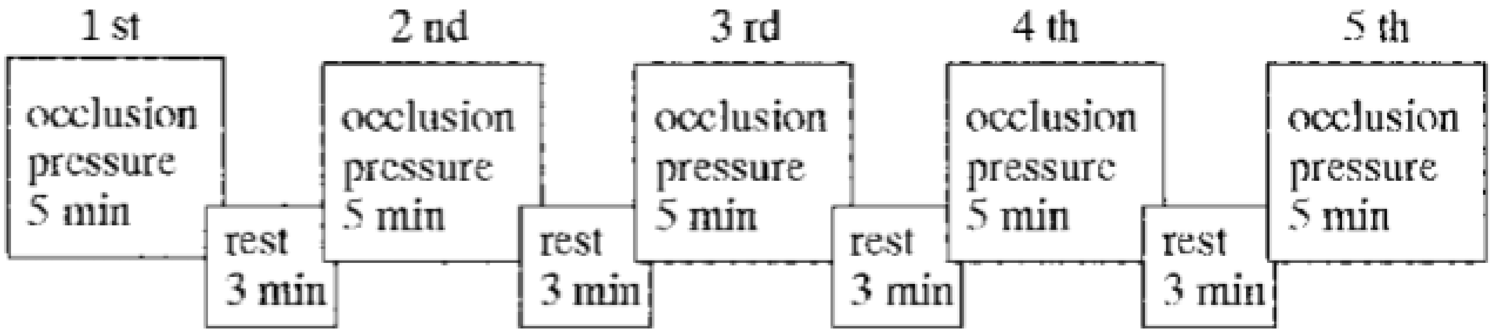


Figure 2—Relative decreases in muscular cross-sectional area during the period between 3rd and 14th days after the operation. Symbols just above the columns denote statistically significant changes from CSAs measured on the 3rd day after the operation (* $P < 0.05$ Wilcoxon signed-ranks test), whereas † denotes significant difference between control and experimental groups ($P < 0.05$, Mann-Whitney U-test).

Surgical reconstruction of the anterior cruciate ligament (ACL)
Day 3 to 14
180 – 260 mmHg

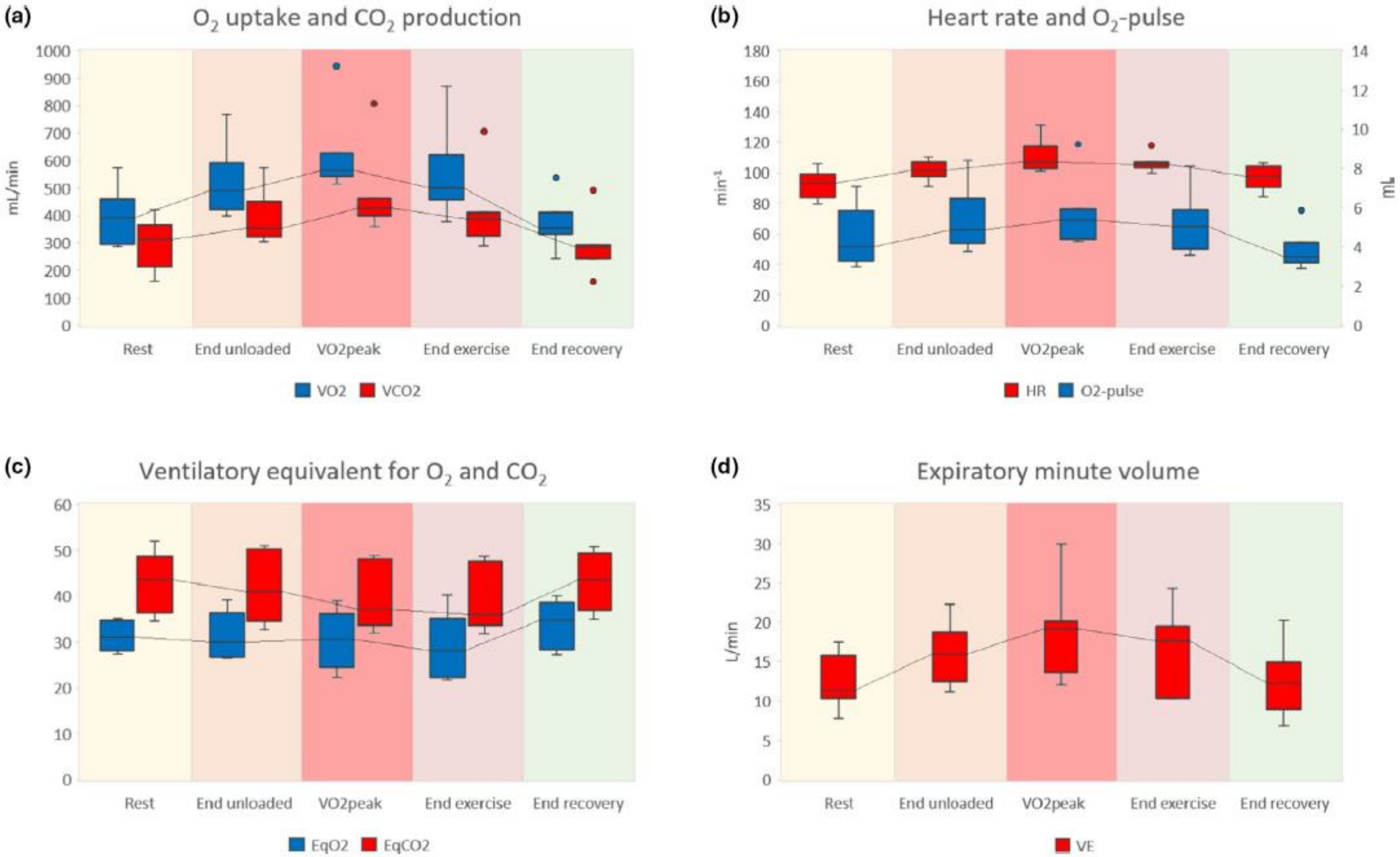


Takarada J. 2000
Medicine and Science in Sports and Exercise

Cardiopulmonary exercise testing (CPET)

réanimation 2025
PARIS 11-13 JUIN

MV patients mobilizing actively on an in-bed cycle ergometer, while recovering from critical illness



N=7

Van den Oever HLA,
Physiological Reports 2022

Cardiopulmonary exercise testing (CPET)

réanimation 2025
PARIS 11-13 JUIN

All patients had reduced exercise tolerance, because of:

- an insufficient gas exchange
- Cardiovascular limitations and/or
- Ventilatory restriction.

Van den Oever HLA, Physiological Reports 2022

Endurance testing for ICU patients

réanimation 2025
PARIS 11-13 JUIN

knee extension (40 BPM, 60 repetitions) and ankle dorsiflexion (80 BPM, 120 repetitions) at a constant pace using a metronome for 3 min and counts the number of repetitions.

Kim SH, et al *Healthcare* **2023**

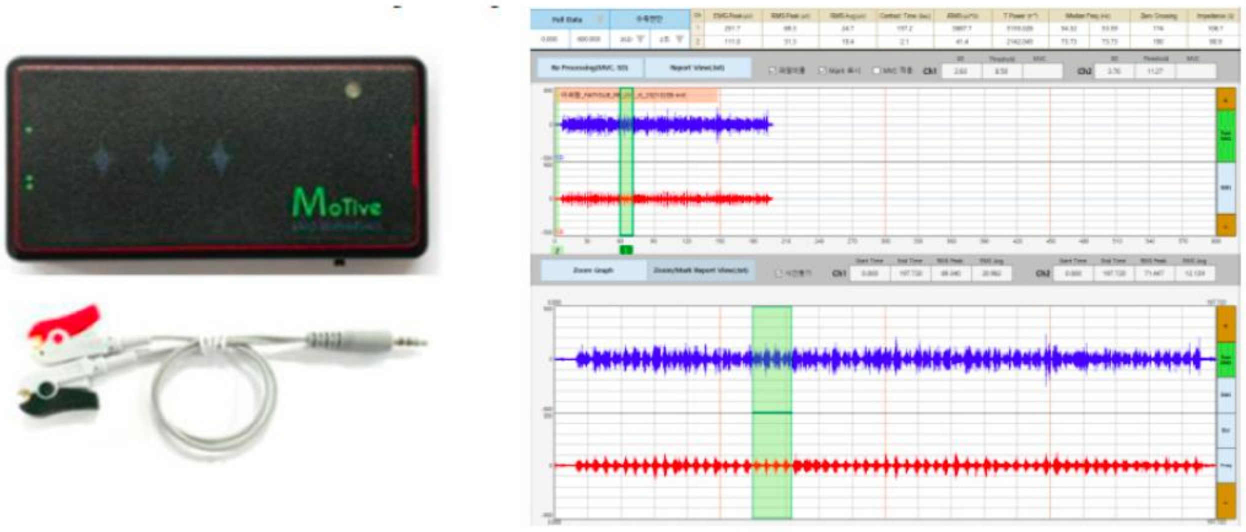


Figure 2. (**a**) Bluetooth surface electromyography device (MOT10; PhysioLab Co., Busan, Republic of Korea); (**b**) user interface of surface electromyography software (MoTive-Rs v1.0).

Figure 1. Modified FI2 endurance task using surface electromyography in the ICU patient.

Cardiopulmonary exercise testing (CPET)

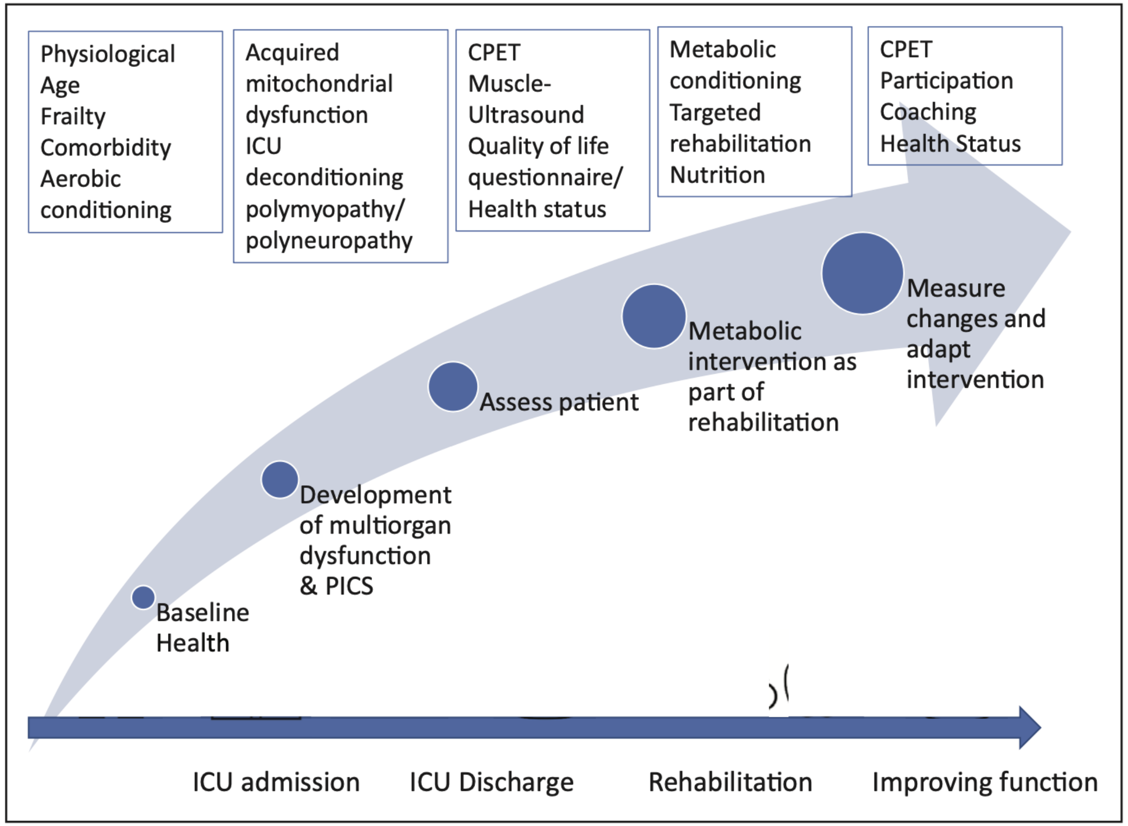


FIGURE 4. The continuum of loss of function, metabolic assessment and rehabilitation: suggested time-points for incorporation of cardiopulmonary exercise testing into a rehabilitation program.

Whittle J.
Curr Opin Crit Care 2021

Nous avons encore du travail !

from 26 to 27 September 2026 in Paris

10thn European Congress on Weaning and Rehabilitation in Critically-ill Patients

Early Bird saves 15%