Associations between body composition and weakness and functional limitations

A cross-sectional study of bioelectrical impedance spectroscopy in mechanically ventilated adults

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Background

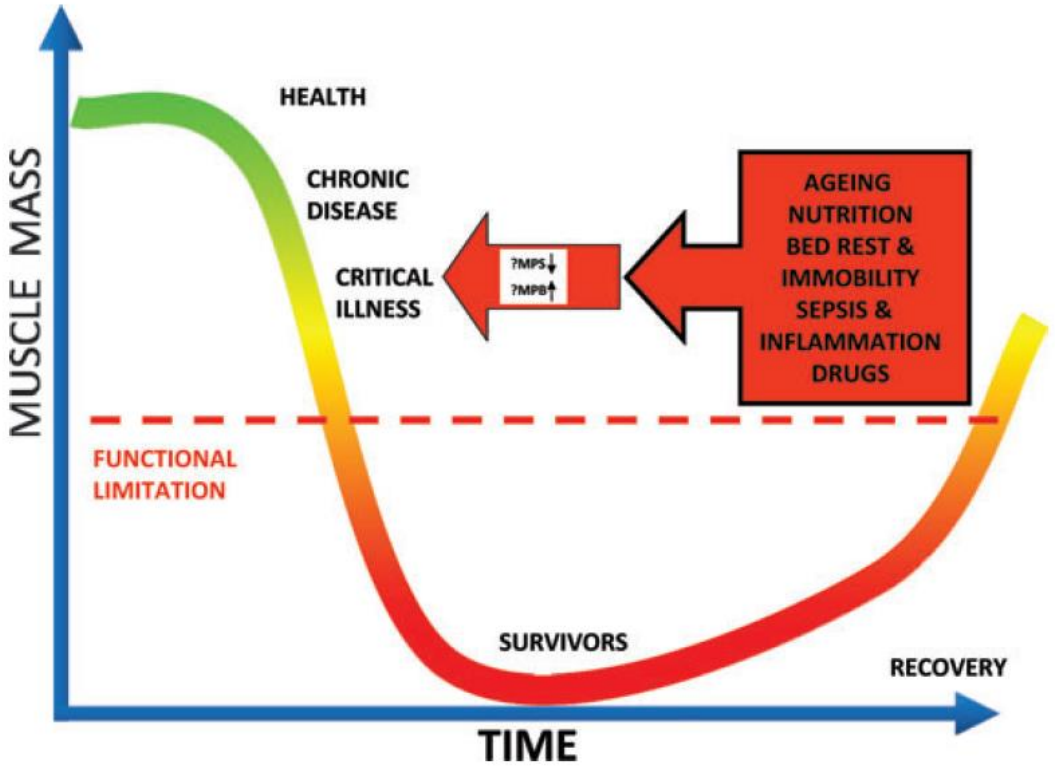


Figure 1. Schematic representation of the factors regulating muscle mass and function in critically ill patients
MPS, muscle protein synthesis; MPB, muscle protein breakdown

Puthucheary et al. *J Physiol* 2010;588:4641-4648

Bioelectrical impedance spectroscopy (BIS)

Fluid status
Yang 2017, Bihari 2013, Jones 2015, Chen 2015, Dewitte 2016

Nutrition assessment
Vermeulen 2016, Faisy 2000

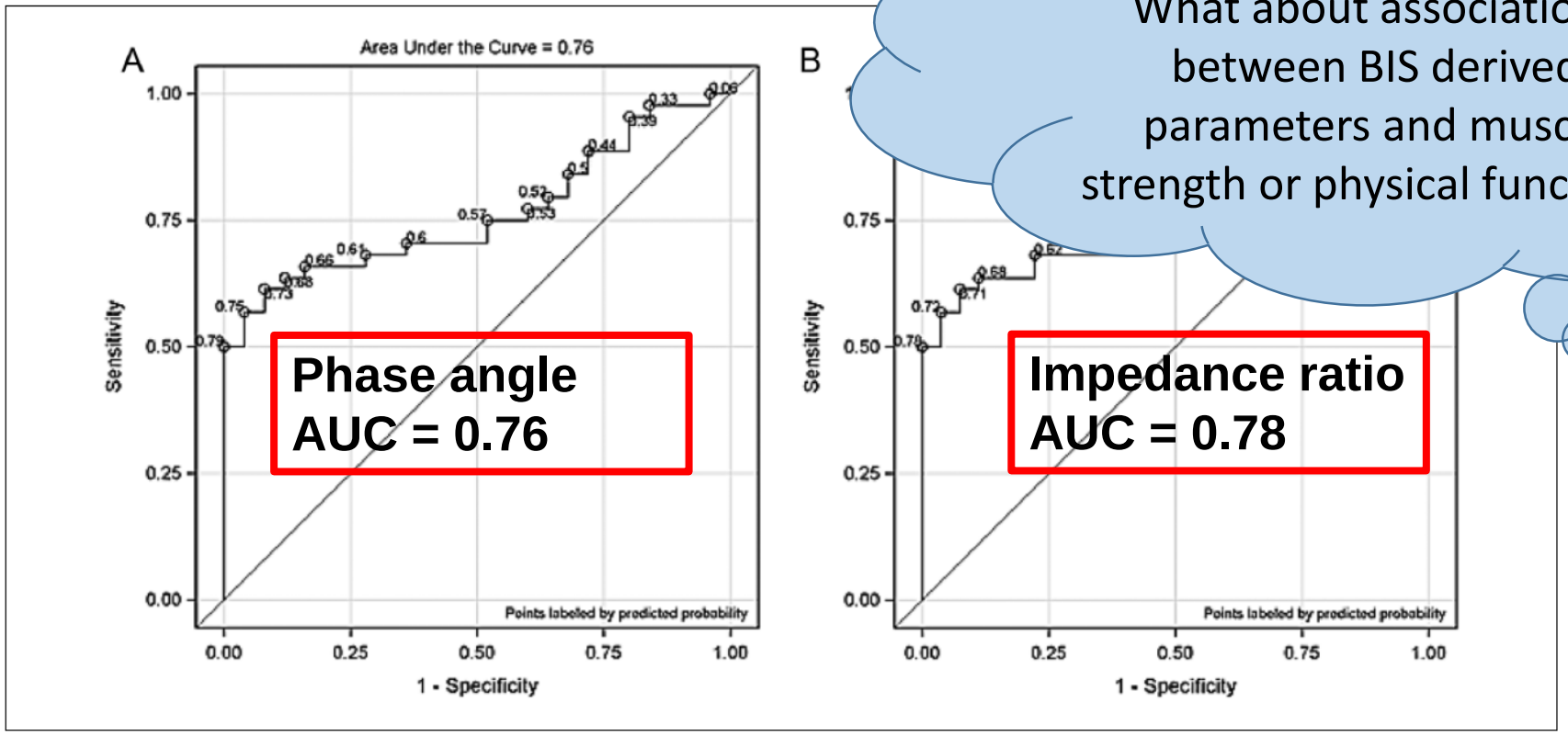
Length of stay
Vermeulen 2016

Illness severity
Vermeulen 2016, Thiabult 2016

Mortality
Thiabult 2016, Lee 2017

BIS derived parameters predicted low muscle cross-sectional area (on CT at L3)

Kuchina *JPEN* 2017;41:1131-8



What about associations between BIS derived parameters and muscle strength or physical function?

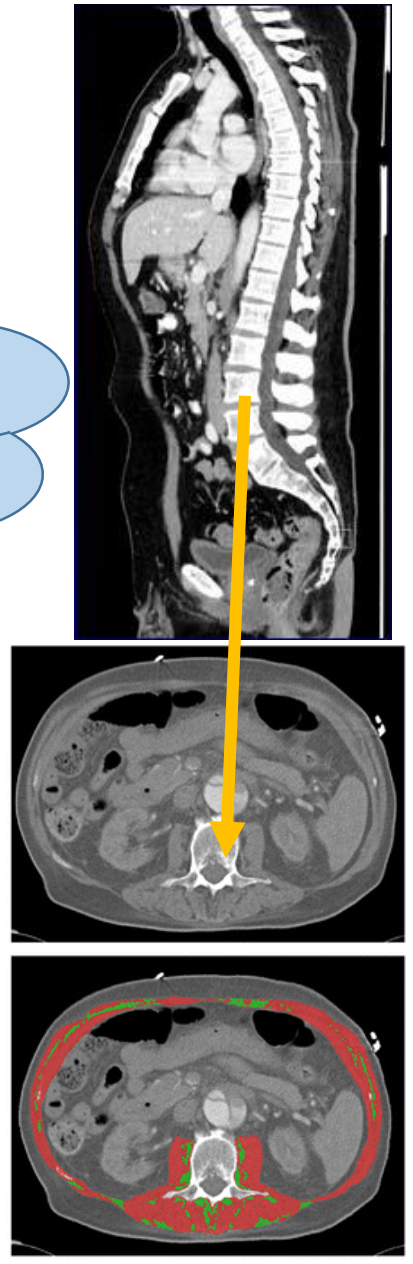


Figure 1. (A) Receiver operating characteristic curve for impedance ratio with covariates to predict low muscle area. (B) Receiver operating characteristic curve for phase angle with covariates to predict low muscle area. Receiver operating characteristic curve analysis is used to quantify how accurately medical diagnostic tests can discriminate between 2 patient states—in this case, low muscle mass or normal muscle mass. Area under the curve or c-index of 0.5 indicates no ability of the model to discriminate between low and normal muscle mass, while a c-index of 1 implies the ability to perfectly discriminate lower and normal muscle mass.[39]

Looijaard. *Crit Care* 2016;20:386

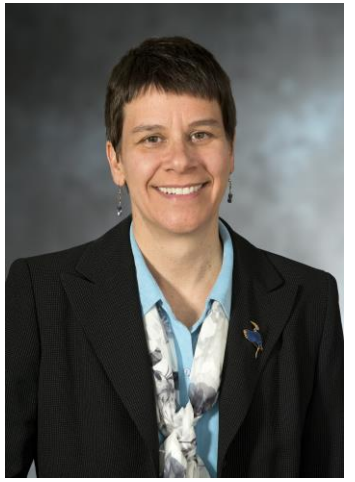
Best allied health paper?

✓ Yes

'the best allied health team'

Dr Claire Baldwin
Lecturer in Physiotherapy
Flinders Medical Centre

Kate Fetterplace
Clinical Lead and
Senior ICU Dietitian
Royal Melbourne Hospital



Prof Carrie Earthman
Professor of Nutrition
University of Minnesota
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Research Director
Senior Physiotherapist
National university hospital
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Dr Selina Parry
Senior lecturer and
NHMRC fellow
University of Melbourne

Lisa Beach
Senior ICU physiotherapist and
Cardiorespiratory Team Leader
Royal Melbourne Hospital

A/Prof Jenny Paratz
Academic and Research Centre Chair
Griffith University; University of Queensland

Aims

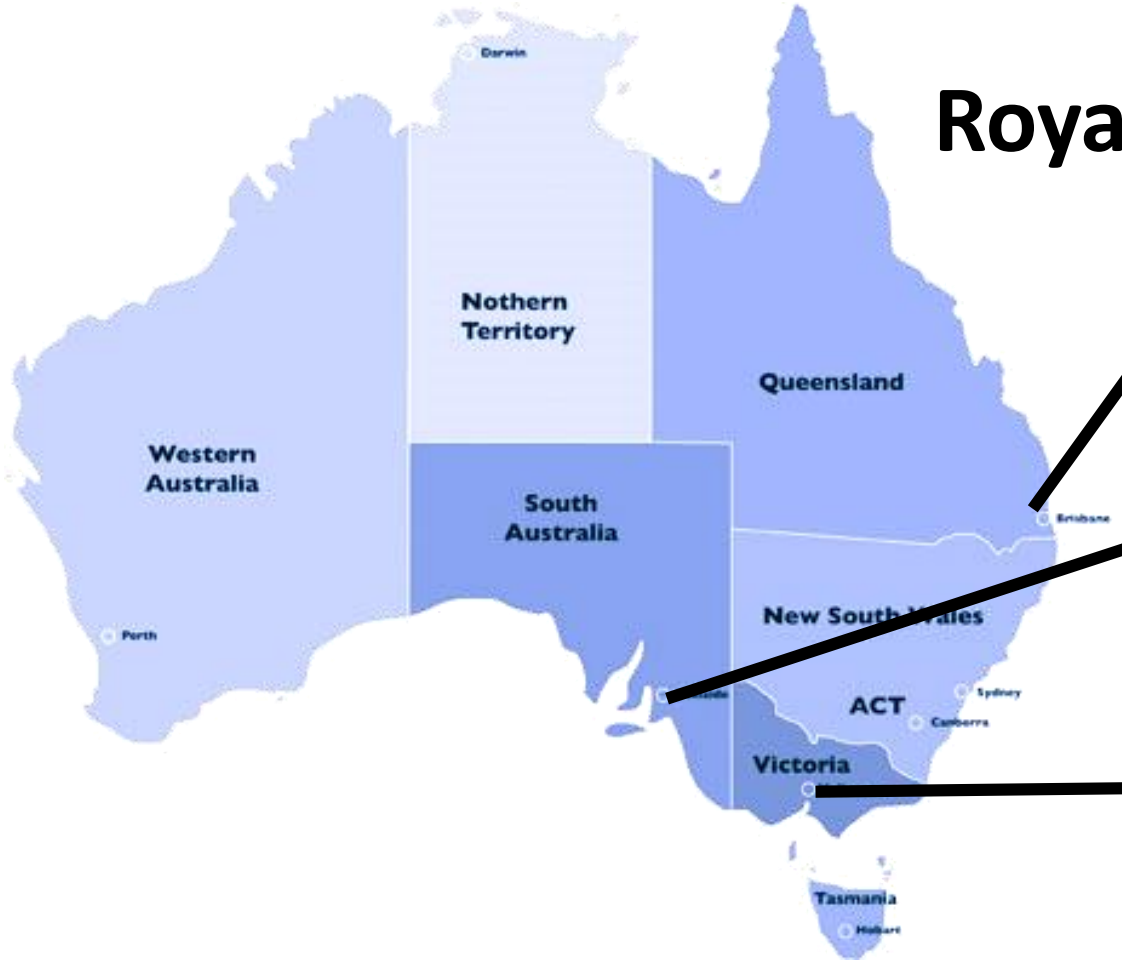
Retrospective analysis of prospectively collected data

1. To describe and **compare the body composition of critically ill patients who required mechanical ventilation,** across three Australian sites

2. To examine **relationships between bioimpedance data** and **muscle strength and physical function**

Methods

3 sites (all tertiary ICU's)



Royal Brisbane and Womens' Hospital

(Brisbane, QLD)

Flinders Medical Centre

(Adelaide, SA)

Royal Melbourne Hospital

(Melbourne, VIC)

VIC x1

Aug 2012 to Feb 2014
Cross-sectional

Measurement of physical activity levels in the Intensive Care Unit and functional outcomes: An observational study

Lisa J. Beach [a,*], Kate Fetterplace [b], Lara Edbrooke [c], Selina M. Parry [c], Rachel Curtis [a], Thomas Rechnitzer [d], Sue Berney [e], Linda Denehy [c]

J Critical Care 2017;40:89–196

SA x2

Nov 2009 to Mar 2010
Cross-sectional

Body Composition Analysis in Critically Ill Survivors: A Comparison of Bioelectrical Impedance Spectroscopy Devices

JPEN 2012;36(3):306-15

Claire E. Baldwin, BPhysio (Hons)[1,2]; Jennifer D. Paratz, PhD, FACP[3]; and Andrew D. Bersten, MD, FJFICM[1,2]

Nov 2010 to Dec 2011
Cross-sectional

Alterations in Respiratory and Limb Muscle Strength and Size in Patients With Sepsis Who Are Mechanically Ventilated

Claire E. Baldwin, Andrew D. Bersten

Phys Ther 2014;94(1):68-82

Sepsis

QLD x1

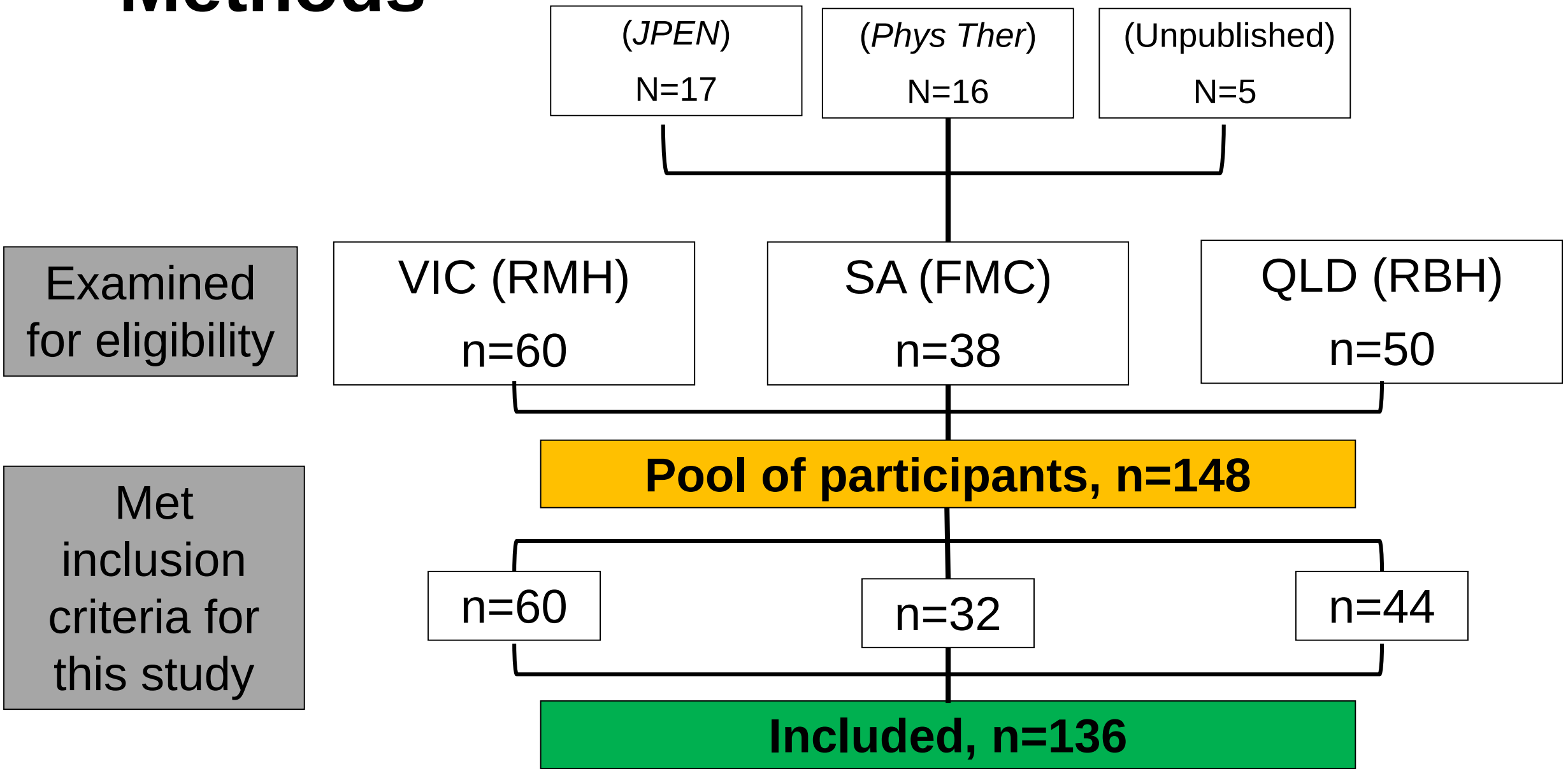
Double blinded RCT

Early physical rehabilitation in intensive care patients with sepsis syndromes: a pilot randomised controlled trial

Intensive Care Med 2015;41:865-874

Geetha Kayambu
Robert Boots
Jennifer Paratz

Methods

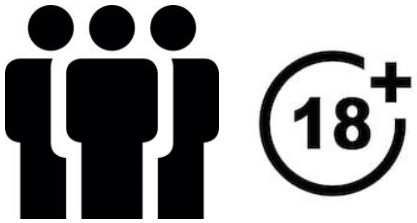

(*JPEN*)
N=17
(*Phys Ther*)
N=16
(Unpublished)
N=5
Examined for eligibility
VIC (RMH)
n=60
SA (FMC)
n=38
QLD (RBH)
n=50
Pool of participants, n=148
Met inclusion criteria for this study
n=60
n=32
n=44
Included, n=136

Participants

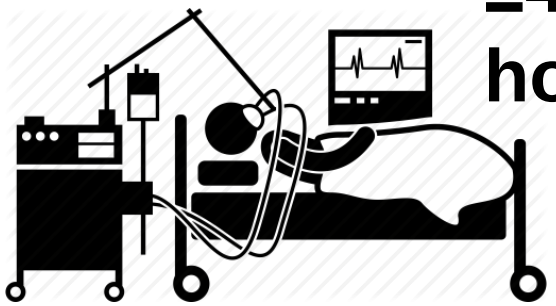
Inclusion criteria

n=136
Across studies

Adults

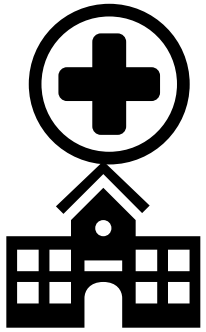


Mechanical ventilation



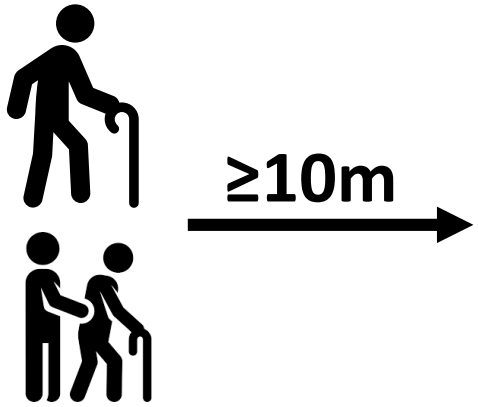
≥48 hours

ICU length of stay



≥5 days
Actual or anticipated

Able to walk ≥ 10 meters independently in last 3 months



Underwent body composition analysis with BIS

Cross-sectional timeline

VIC

SA

QLD

Body composition
✓ ***with BIS***

VIC	✓	✓ MRC-SS *(within 3 days)*	MRC-SS PFIT-s	
SA		✓ MRC-SS Handgrip *(same day)*	PFIT-s, DEMMI	PFIT-s, DEMMI
QLD	✓		MRC-SS PFIT-s	

Patient journey

ICU admission

Enrolment

≤ 48 hours of admission

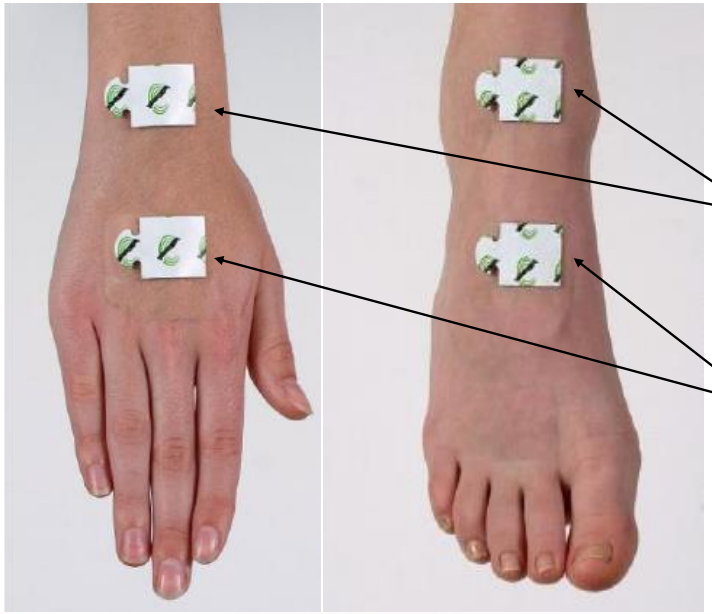
First awake

≤2 errors on Attention Screening Exam
Alert + calm (CAM-ICU)
OR
De Jonghe comprehension criteria
(JAMA 2002;288:2859-67)

ICU discharge

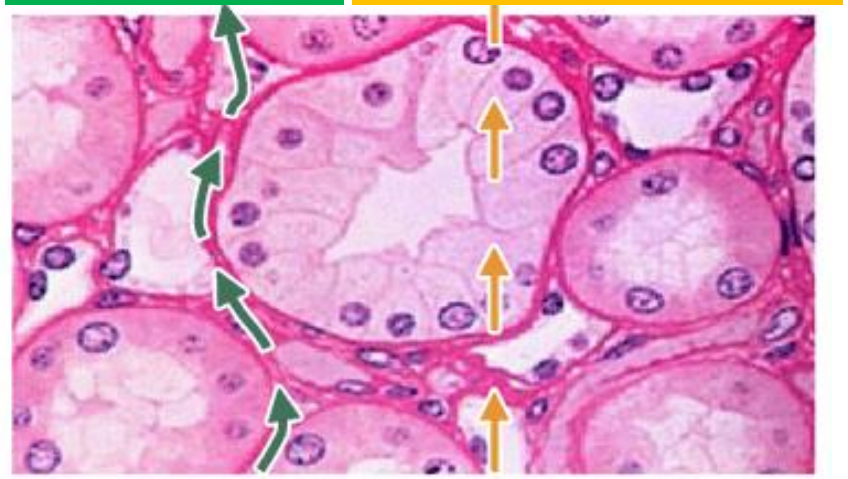
Hospital discharge

Body composition analysis with the SFB7
(Impedimed, AUS)



Typical set-up for measurement.

< 5 kHz | > 50 – 100 kHz and above



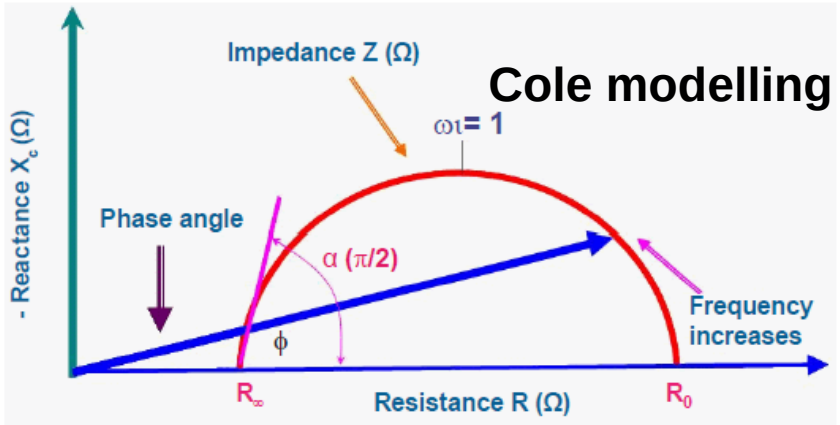


Figure 2: Cole plot in the impedance plane, derivation of the phase angle, resistance (R), reactance (Xc), impedance (Z) and the frequency of the applied current.

Tuorkey 2012 *J Biosens Bioelectron* 3:121

Bioelectrical impedance spectroscopy (BIS)
~250 measurements,

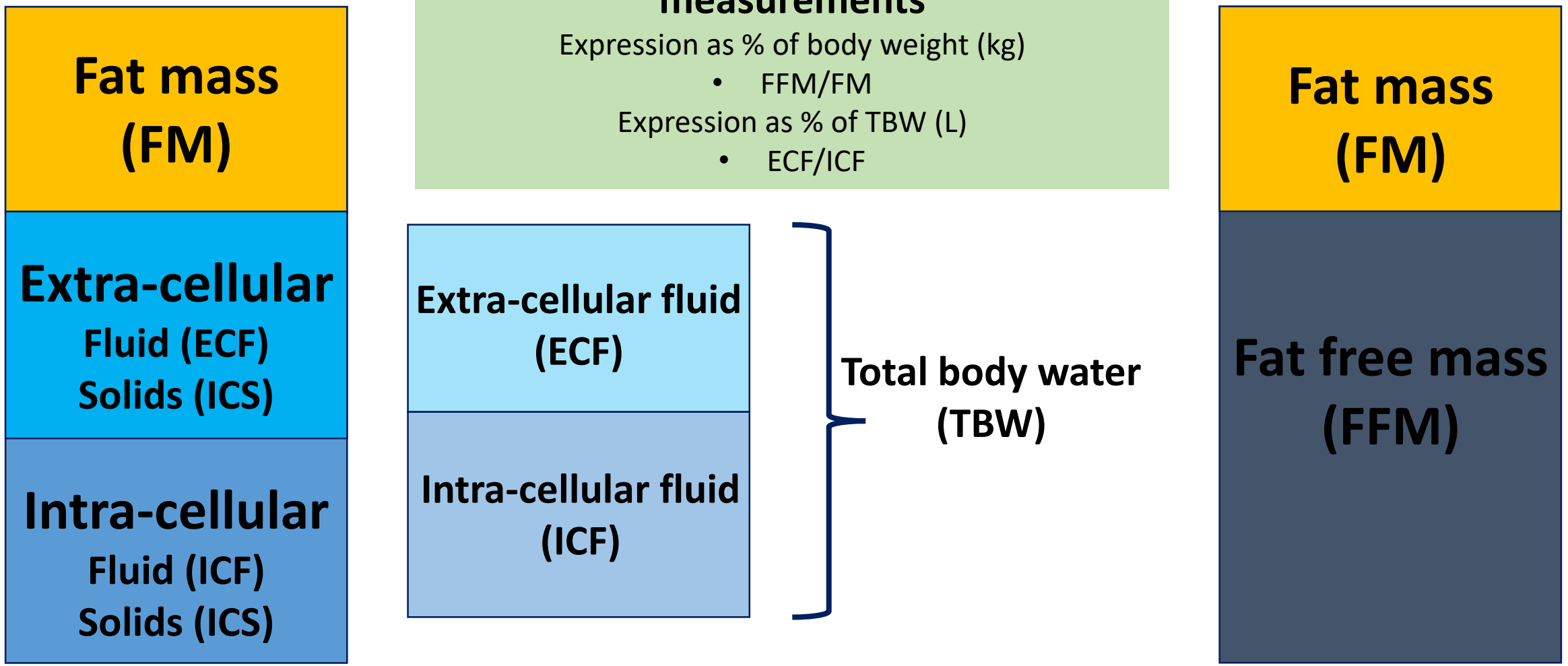
Requires accurate weight and height measurements

Expression as % of body weight (kg)

- FFM/FM

Expression as % of TBW (L)

- ECF/ICF



Muscle strength

Ciesla et al *J Vis Exp* 2011:50;e2632

Manual muscle testing: MRC-sum score (/60)

3 upper and 3 lower limb groups bilaterally

Grade each group /5

ICU acquired weakness: < 48/60

Physical function

Score	**0**	**1**	**2**	**3**
Sit to stand assistance	*Unable*	*Assist x2*	*Assist x1*	*No assist*
March on spot cadence (steps/min)	*Unable*	*> 0 – 49*	*50 - < 80*	*80+*
Shoulder flexion (grade)	*0, 1 or 2*	*3*	*4*	*5*
Knee extension (grade)	*0, 1 or 2*	*3*	*4*	*5*
Column total score (raw score)				

Raw score	0	1	2	3	4	5	6	7	8	9	10	11	12
PFIT score	**0**	**2.0**	**3.2**	**3.9**	**4.4**	**4.9**	**5.4**	**5.9**	**6.4**	**7.1**	**7.9**	**8.8**	**10**

Physical function in ICU test (PFIT-s)

Max score: /10

Minimal clinical important difference: 1.5 points

No difference in ICU-acquired weakness (MRC-ss <48) @ awakening (SA and VIC) (QLD not available)

Results *Median [1st-4th quartile], all p > 0.05*

Demographics	Illness severity (admission)	Mortality	Anthropometry	Nutrition
Age, years: 59 [50-69]	APACHE II score: 21 [17-27]	ICU, n(%): 14 (10)	Weight, kg: 80.0 [70.0-99.3]	EER for 25kcal/kg: 1875 [1700-2125]
Male n(%): 78 (57)	SOFA score: 10 [8-12]	Hospital, n(%): 22 (16)	BMI, kg/m^2: 27.8 [24.6-32.8]	NUTRIC score: 5 [4-6]

Results

Differences in cohorts between sites
Median [1st-4th quartile]

↑ duration of mechanical ventilation, p≤0.001

SA	>	QLD	>	VIC
12 [6-18]		7 [5-14]		4 [3-8]

↑ ICU length of stay, p≤0.001

SA	>	QLD	>	VIC
18 [9-23]		9 [7-19]		5 [3-12]

↓ PFIT-s @ ICU discharge, p=0.006

SA	>	QLD	>	VIC
4.9 [3.9-5.8]		5.2 [3.9-7.1]		5.9 [4.9-8.4]

Body composition @ enrolment

≤ 48 hours of ICU admission, VIC and QLD

Aim 1: comparison between sites

	Median [IQR] ICU day 2 [1-2]			
	All available n=104	VIC (RMH) n=60	QLD (RBH) n=44	p value
FM (% of body weight)	22.0 [11.6-29.6]	21.2 [13.8-28.2]	25.1 [10.9-33.0]	0.084
FFM (% of body weight)	76.9 [68.6-86.6]	78.8 [71.8-86.8]	72.2 [65.5-88.1]	0.569
TBW (% of body weight)	56.8 [50.0-65.0]	57.7 [52.6-63.5]	54.1 [48.0-66.2]	0.295
ICF (% of TBW)	48.8 [45.4-52.2]	47.4 [43.5-49.2]	52.2 [48.2-55.3]	≤0.001
ECF (% of TBW)	50.9 [47.5-53.3]	52.6 [50.8-56.5]	47.1 [43.6-50.5]	≤0.001
ECF:ECF[a]	1.03 [0.91-1.13]	1.09 [1.02-1.27]	0.91 [0.81-1.02]	≤0.001

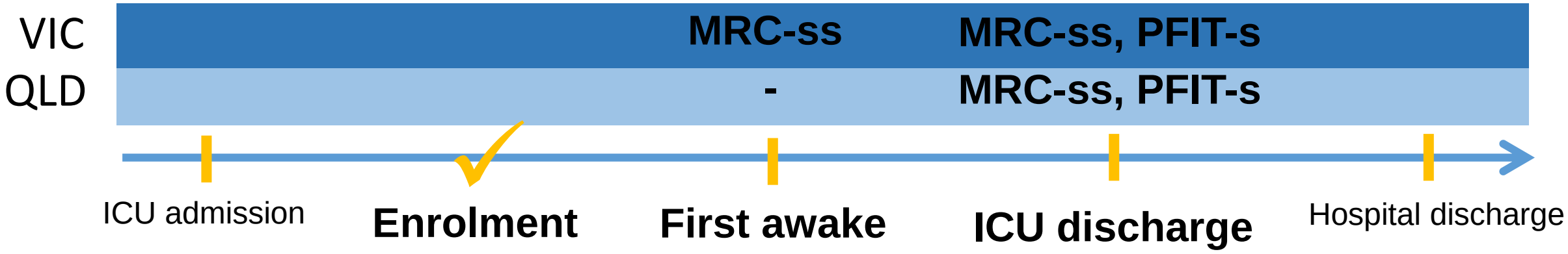
Orange shading represents significant difference between sites, Mann-Whitney test

[a] in healthy subjects ECF:ICF approximates 0.70, ↑ECF:ECF → ↓outcome

Body composition @ enrolment

≤ 48 hours of ICU admission, VIC and QLD

Aim 2: associations



No associations

Muscle strength (MRC-ss) at awakening (VIC)

Muscle strength (MRC-ss) or physical function (PFIT-s) at ICU D/C (pooled)

Weak association (QLD site only)

FFM (kg) and physical function (PFIT-s) at ICU D/C rho = 0.333, p=0.047

Body composition @ awakening

VIC and SA

Aim 1: comparison between sites

	ICU day Median [IQR]			
		ICU day 5 [5-12]	**ICU day 15 [9-18]**	p value
	All available n=77	VIC (RMH) n=45	SA (FMC) n=32	
FM (% of body weight)	31.8 [22.0-38.9]	25.0 [11.7-31.8]	39.4 [33.0-46.8]	≤0.001
FFM (% of body weight)	68.2 [61.2-78.1]	75.0 [68.2-88.3]	60.6 [53.2-67.7]	≤0.001
TBW (% of body weight)	50.0 [44.8-57.1]	54.9 [50.0-64.6]	44.4 [39.0-49.0]	≤0.001
ICF (% of TBW)	48.3 [45.6-51.4]	47.2 [44.6-49.1]	51.4 [48.5-54.0]	≤0.001
ECF (% of TBW)	51.1 [48.6-54.4]	52.4 [50.9-55.0]	48.6 [46.0-51.5]	≤0.001
ECF:ICF[a]	1.05 [0.93-1.19]	1.09 [1.01-1.21]	0.95 [0.85-1.06]	≤0.001

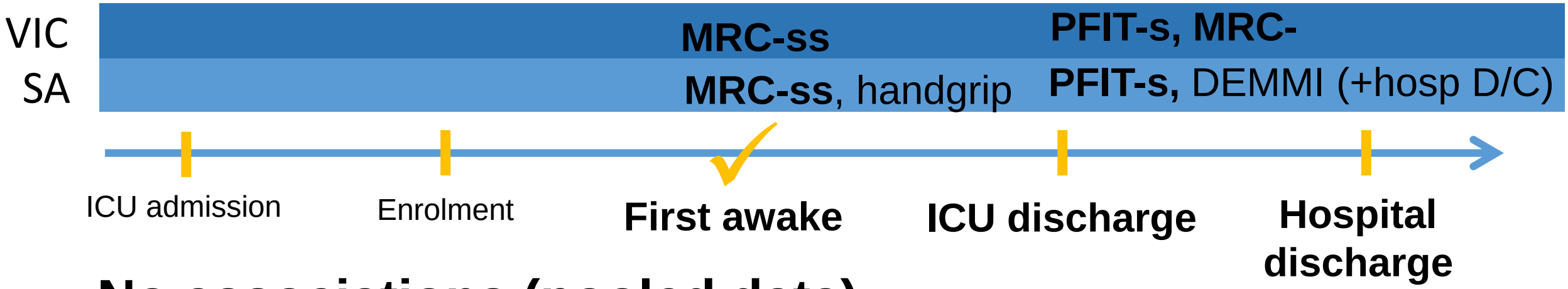
Orange shading represents significant difference between sites, Mann-Whitney test

[a] in healthy subjects ECF:ICF approximates 0.70, ↑ECF:ECF → ↓outcome

Body composition @ awakening

VIC and SA

Aim 2: associations



No associations (pooled data)

MRC-ss at awakening (or ICU D/C, VIC), PFIT-s at ICU discharge

↑ TBW(%), ↑ FFM(kg), ↓FM(kg) (SA site only)

~ ↑ **muscle strength** (MRC-ss and handgrip) at awakening rho ≥0.457, p≤0.049

~ ↑ **physical function** (PFIT-s and DEMMI) at hospital D/C rho ≥0.733, p≤0.003

Comparison of BIS procedure between sites

	VIC (RMH)	SA (FMC)	QLD (RBH)
Body weight	Actual to nearest 0.1kg Bed scales	Actual to nearest 0.1kg Lifter/chair scale	Actual to nearest 0.1kg Lifter/chair scale
Height	Estimated from ulnar length	Actual supine body length	Actual supine body length
Body position for testing	Supine Pillow under head Bed elevation ≤30° Limbs abducted	Supine Pillow under head Bed elevation ≤20° Limbs abducted	Supine Pillow under head Bed elevation ≤20° Limbs abducted
Number of device operators	Single operator	Single operator	Single operator
Electrode type	Dual tab	Single tab (consistent spacing to dual tab)	Single tab (consistent spacing to dual tab)
Electrode placement	Unilateral dorsum of hand and foot on right	Unilateral dorsum of hand and foot on right, skin preparation	Unilateral dorsum of hand and foot on right, skin preparation
Data processing	Bioimp Software on device only, default device constants	Bioimp Software with post-processing (automatic point rejection, frequency limits), default device constants	Bioimp Software on device only, default device constants

Discussion

Methodological variations

- Cohort differences
- Site-to-site BIS procedural differences
- Inconsistent descriptions of standard nutrition and physiotherapy care across sites

Fluid management (Bihari et al *Crit Care Resusc* 2016;18:89–94)

- Fat free mass may reflect other aspects of fluid and tissue health

Design limitations

- Retrospective
- Associations only (no causation)
- Cross-sectional

Conclusions

Main finding: some strong associations at the SA (FMC) site in particular

- Next steps: explanatory analysis of raw impedance variables
- phase angle, impedance ratio (200kHz:5kHz), Rinf:Ro, characteristic frequency

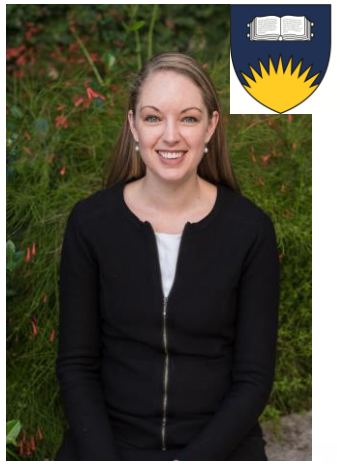
Future clinical implications

- Identify impedance variables that are indicative of functional outcomes

New knowledge

- We added to and confirmed findings from other research studies
- We outlined variability in patients' body (and fluid) composition profiles between cohorts/sites
- **We are the first to report associations between bioimpedance data and strength/function in critically ill patients**

Thank you and acknowledgements



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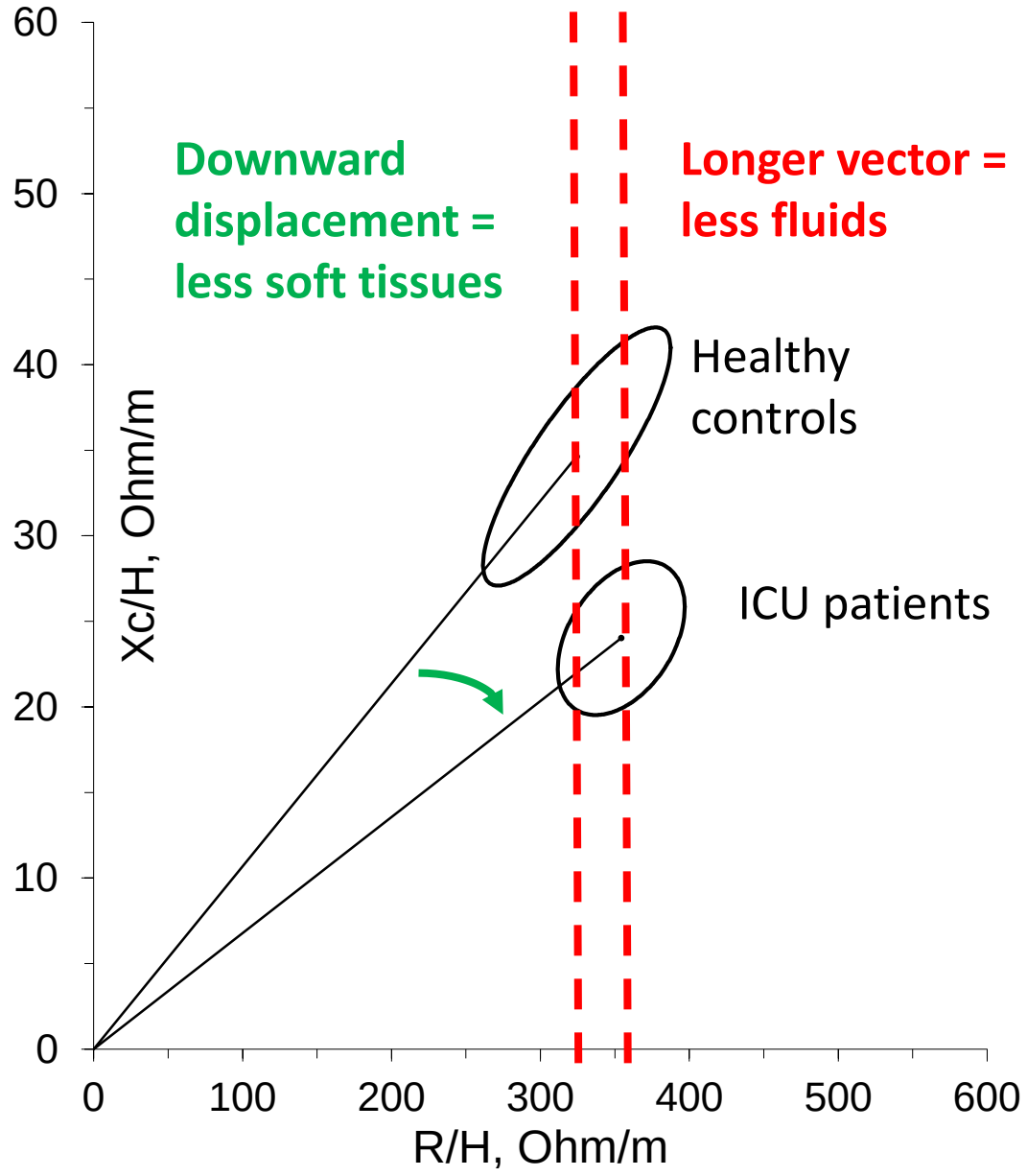
Downward displacement = less soft tissues
Longer vector = less fluids
Healthy controls
ICU patients
Xc/H, Ohm/m
R/H, Ohm/m
0
10
20
30
40
50
60
0
100
200
300
400
500
600

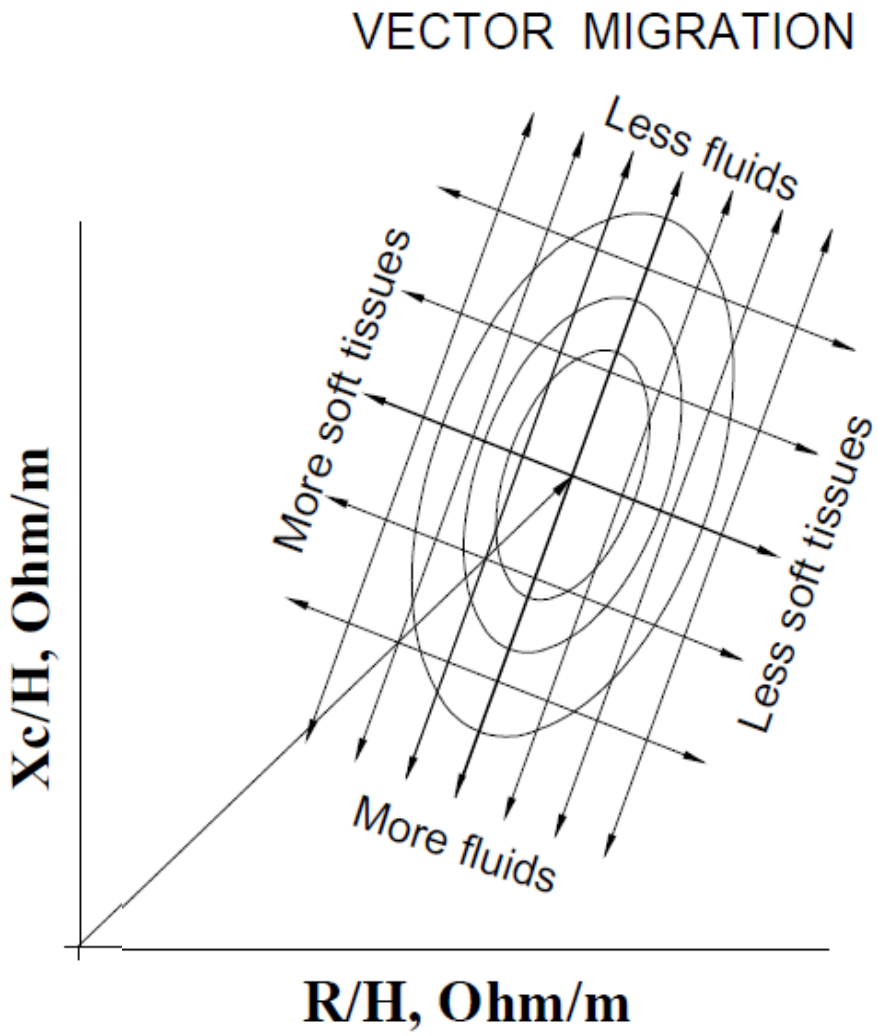
VECTOR MIGRATION
Less fluids
More soft tissues
Less soft tissues
More fluids
Xc/H, Ohm/m
R/H, Ohm/m

TABLE: Associations between raw impedance variables from Site 2 (FMC) at awakening with functional and other outcomes

Eta^2 effect size interpretation, 0.020 = small (S), 0.130 = medium (M), 0.260 = large

BIS variable	MRC-ss awake	Grip awake	PFIT-s ICU D/C	DEMMI ICU D/C	PFIT-s hosp D/C	DEMMI hosp D/C	ICU LOS	Hosp LOS	CCI	NUTRIC	Hosp mortality Eta^2
	N=19	N=32	N=15	N=15	N=14	N=17	N=32	N=32	N=32	N=31	N=32
Phase angle	0.702 P=0.001	0.642 P=0.000	0.438 P=0.103	0.635 P=0.011	0.437 P=0.118	0.596 P=0.012	-0.692 p≤0.001	-0.801 p≤0.001	-0.419 P=0.017	-0.577 p≤0.001	0.109 (S)
ECF:ICF	-0.260 P=0.282	-0.285 P=0.114	-0.263 P=0.343	-0.254 P=0.360	0.100 P=0.735	-0.070 P=0.788	0.548 P=0.001	0.691 p≤0.001	0.522 P=0.002	0.700 p≤0.001	0.118 (S)
	N=16	N=29	N=12	N=12	N=11	N=15	N=29	N=29	N=29	N=28	N=29
Rinf:Ro	-0.797 p≤0.001	-0.636 p≤0.001	-0.390 P=0.210	-0.481 P=0.113	-0.424 P=0.194	-0.558 P=0.031	0.698 p≤0.001	0.866 p≤0.001	0.418 P=0.024	0.546 P=0.003	0.107 (S)
IR 200kHz:5kHz	-0.785 p≤0.001	-0.664 p≤0.001	-0.404 P=0.192	-0.571 P=0.052	-0.513 P=0.106	-0.610 P=0.016	0.721 p≤0.001	0.855 p≤0.001	0.427 P=0.021	0.591 P=0.001	0.116 (S)
Characteristic frequency	-0.901 p≤0.001	-0.606 p≤0.001	-0.561 P=0.058	-0.621 P=0.031	-0.463 P=0.151	-0.482 P=0.069	0.566 p≤0.001	0.699 p≤0.001	0.406 P=0.029	0.557 P=0.002	0.166 (M)
Membrane capacitance	0.797 p≤0.001	0.681 p≤0.001	0.227 P=0.478	0.198 P=0.538	0.528 P=0.095	0.626 P=0.012	-0.660 p≤0.001	-0.800 p≤0.001	-0.377 P=0.044	-0.392 P=0.039	0.085 (S)