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ORIGINAL ARTICLE

Feasibility of bioelectrical impedance analysis in routine clinical care to assess body composition in geriatric rehabilitation inpatients: RESORT

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Abstract

Background Sarcopenia is prevalent in 20–50% of geriatric rehabilitation inpatients, but it is often undiagnosed.

Aims The aim of the study is to evaluate the feasibility of bioelectric impedance analysis (BIA) to measure muscle mass in routine clinical care in a cohort of geriatric rehabilitation inpatients.

Methods REStORing Health of acutely unwell adulTs (RESORT) is an observational, longitudinal inception cohort of geriatric rehabilitation inpatients. BIA was implemented at admission and discharge as routine care performed by nursing staff. BIA feasibility was defined as completion rate (low ≤ 25%, moderate > 25–≤ 50%, good > 50–≤ 75%, excellent > 75%), reasons for non-completion and need for remeasurement. Clinical characteristics associated with BIA completion and remeasurements were assessed.

Results Patients ($n = 1890$, 56% females) had a median age of 83.4 years (interquartile range: [77.6–88.4]). Of the total cohort, 5.7% had a contraindication (pacemaker/other electronic medical device) for BIA at admission and 4.5% at discharge. BIA was completed in 77.1% of patients eligible for BIA at admission and 63.2% at discharge indicating good feasibility; remeasurement was required in 7.4 and 6.9%, respectively; 5.9% had a medical reason preventing BIA completion at admission and 3.7% at discharge. Refusal and technical issues occurred in 1.6 and 0.7% at admission and 2.1 and 1.8% at discharge. Reason for non-completion was unknown/missing in 14.7% at admission and 28.6% at discharge. Worse functional and physical performance was associated with BIA non-completion and remeasurement.

Conclusions BIA in routine clinical care in geriatric rehabilitation inpatients is feasible; completion rates may be enhanced further by reviewing barriers and enablers.

Keywords Sarcopenia · Body composition · Impedance · Feasibility · Aged

Introduction

Sarcopenia, the age-related low muscle strength and mass [1], is associated with a twofold higher mortality risk in geriatric rehabilitation inpatients [2], but remains largely undiagnosed in routine clinical care [3] despite a prevalence of 20–50% [4]. This is partly due to a lack of knowledge and equipment availability to assess muscle strength and mass [3], and evidence of efficacy of interventions in this population [5]. Bioelectrical impedance analysis (BIA) is

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a portable, affordable and easy to use device to measure body composition [6]. There are different types of BIA including single-frequency, multi-frequency, segmental, and vector BIA, each requiring validation against the gold standard [6]. Direct segmental multi-frequency (DSM)-BIA has been validated for assessing body composition against dual-energy X-ray absorptiometry (DXA) in middle-aged and older adults [7, 8] and is recommended by the European Working Group on Sarcopenia in Older People (EWGSOP) to estimate muscle mass in research and clinical practice [1].

To facilitate sarcopenia diagnosis in routine clinical care, feasibility of body composition assessment needs to be ensured. While BIA is commonly used in the research setting, with varying BIA completion rates between 40 and 85% in cohorts of hospitalized older patients [9–12], evidence on feasibility as part of routine clinical care is scarce. One feasibility study concluded BIA measurement to be challenging in the hospital setting because of patients' refusal, technical difficulties with the BIA machine and contraindications [10], while another study in geriatric psychiatry inpatients concluded that BIA measurement was well accepted by all patients [13]. Also, no studies have previously assessed clinical characteristics associated with completion of BIA in inpatients. Better insight into the reasons for BIA non-completion is important to comprehensively assess BIA feasibility in a population with a high prevalence of multimorbidity, cognitive impairment and low physical function [14]. Moreover, the need for BIA remeasurement due to inaccurate results needs further investigation as it may affect feasibility in clinical care.

This study aimed to investigate: the feasibility of BIA in routine clinical care at admission and discharge from geriatric rehabilitation in terms of completion rate, reasons for non-completion and need for remeasurement; and the clinical characteristics associated with BIA completion and remeasurement.

Methods

Study design and population

REStoRing Health of Acutely Unwell AdulTs (RESORT) is an observational, longitudinal inception cohort of geriatric rehabilitation inpatients admitted to the geriatric rehabilitation wards at the Royal Melbourne hospital (Melbourne, Victoria, Australia). Patients were excluded if they were receiving palliative care at admission or if they were unable to provide informed consent and had no nominated proxy to consent on their behalf. BIA was not performed when contraindicated in patients with an electronic medical device (EMD) or implant, such as a pacemaker and in patients with medical reasons preventing measurement: 1) cast/dressing/bandage that interfered with the placement of the electrodes; 2) amputation; 3) contact isolation; and 4) other reasons such as delirium and other conditions causing agitation, fracture limiting good positioning, etc. Patients admitted from 16 October 2017 and discharged by 18 March 2020 were included. All included patients were assessed using a Comprehensive Geriatric Assessment (CGA) [15] at admission and discharge from geriatric rehabilitation wards by physicians, nurses, physiotherapists, occupational therapists, and dietitians. The study was approved by the Melbourne Health Research Ethics Committee (HERC/17/MH/103) and was conducted in accordance with the Declaration of Helsinki [16]. Written informed consent was provided by either the patient or a nominated proxy.

Patient characteristics

Age, sex, length of stay in geriatric rehabilitation, primary reason for acute admission and number of medications were obtained from medical records. Burden of disease was reported by physicians using the 37-point Charlson Comorbidity Index (CCI) [17] and 56-point Cumulative Illness Rating Scale (CIRS) [18]. Cognitive impairment was defined as a dementia diagnosis reported in medical records, CCI or CIRS or by a cognitive score below cutoff values for one of the following tests: standardized Mini-Mental State Examination (sMMSE) < 24 points [19], Montreal Cognitive Assessment (MoCA) < 6 points [20] or Rowland Universal Dementia Assessment Scale (RUDAS) < 23 points [21]. Delirium was defined as either a clinical diagnosis or indicated by the Short Confusion Assessment Method (short CAM) [22]. The Hospital Anxiety and Depression Scale (HADS) [23] was used to assess symptoms of anxiety and depression, with scores ranging from 0 to 21 points.

Standing height was measured without footwear; if a patient was not able to stand, knee height measured with a sliding caliper was used to calculate an approximate standing height using the Chumlea equation [24]. Weight, up to the closest 0.1 kg, was measured by nurses with a calibrated weighing scale, weighing chair or hoist without shoes or bulky clothing. Body mass index (BMI) was calculated by dividing weight by height squared (kg/m^2). Malnutrition risk was assessed by nurses with the Malnutrition Screening Tool (MST) on a scale from 0 to 5 [25].

Occupational therapists assessed functional independence using the Katz index for activities of daily living (ADL) [26] and the Lawton and Brody scale for instrumental activities of daily living (IADL) [27]. ADL and IADL scores range between 0–6 and 0–8, respectively. Frailty status was assessed by physicians with the Clinical Frailty Scale (CFS) on a scale from 1 (very fit) to 9 (terminally ill) [28].

Physical function and muscle strength were assessed by physiotherapists. Functional Ambulation Classification

(FAC) was used to assess ambulation status with a score ranging from 0 (bed-bound) to 5 (full independence) [29]. The Short Physical Performance Battery (SPPB) included the standing balance test, the timed chair stand test and the timed 4-meter walk test to measure gait speed. Score ranges were from 0 to 12 points [30]. Handgrip strength was assessed three times on both hands, alternating between right and left, instructing patients to squeeze with maximum effort with a handheld dynamometer (JAMAR, Sammons Preston, Inc. Boling-Brook, IL, USA) [31]. The maximum score in kilograms was used.

Body composition measurement

DSM-BIA (InBody S10, Biospace Co., Ltd, Seoul, South Korea) was performed in the morning, in a supine position for at least 10–15 min, with arms not touching the trunk and legs apart. Patients were asked to remain still during the measurement. Nursing staff were trained to use the DSM-BIA device during educational group sessions before implementation. Nurse 'champions' who were the contact persons for DMS-BIA-related questions did regular audits to ensure that protocols were followed. Nurses, allied health staff and physicians were trained to interpret the output of the DSM-BIA and to diagnose sarcopenia. When recommended by the device (an automated message on the result sheet), remeasurement(s) were conducted. This may be caused by movement during the measurement, inaccurate posture or suboptimal conductivity due to dry skin or body lotion use, as indicated by the manufacturer. Muscle mass was expressed as skeletal muscle mass (SMM, kg), appendicular lean mass (ALM, kg), skeletal muscle mass index (SMI) (SMM/height2 in kg/m^2), and ALM index (ALMI) (ALM/height2 in kg/m^2) [7]. DSM-BIA also provided body water analysis including intracellular body water (ICW), extracellular body water (ECW), total body water (TBW) and ECW/TBW ratio.

BIA feasibility

Feasibility of a measurement in clinical practice depends on several factors including time, complexity of the measurement and patient willingness; therewith completion rate can be used as a proxy of feasibility [10, 13]. BIA feasibility was defined based on the following factors: 1) BIA completion rate in patients without a contraindication categorized as: low (≤25%), moderate (>25 and ≤50%), good (>50% and ≤75%), and excellent (>75%) [32]; 2) reasons for non-completion classified into medical reason, refusal, technical issue/invalid data or other reason and 3) need for remeasurement.

Statistical analysis

Patient characteristics were reported with descriptive statistics. Continuous variables were reported as mean with standard deviation (SD) when normally distributed or else as median with interquartile range [IQR], and categorical variables as frequency (n) with percentages (%).Clinical characteristics associated with BIA completion and remeasurement were assessed with the Mann–Whitney *U* test (not normally distributed continuous variables), independent *t* test (normally distributed continuous variables) or Chi-square test of homogeneity (categorical variables). Patients deceased during hospitalization were excluded from discharge analysis. *P* values < 0.05 were considered statistically significant. All statistical analyses were performed using the Statistical Package for Social Sciences (IBM SPSS Advanced Statistics 27.0, Armonk, NY: IBM Corp.).

Results

Of the 2692 patients admitted to geriatric rehabilitation, 446 patients were excluded and 356 refused to consent; a total of 1890 patients were included in the RESORT cohort (Fig. 1). Table 1 shows the patient characteristics at admission. The median age was 83.4 years [IQR: 77.6–88.4], 56.3% were females and median length of stay was 20 days [IQR: 13–31]. Median CIRS score was 12 [IQR: 9–16] and 65.1% of inpatients had cognitive impairment. Median SPPB score was 1 [IQR:0–4] and median ADL score was 2 [IQR:1–2].

BIA feasibility

Contraindication (pacemaker/other EMD) for BIA completion was present in 5.7% ($n = 109$) of the total cohort at admission and 4.5% ($n = 83$) at discharge. BIA was completed in 77.1% ($n = 1373$) of the patients eligible for BIA measurement at admission and in 63.2% ($n = 1096$) at discharge (Fig. 1). Out of the 1466 patients with a completed BIA at either admission or discharge, 68.4% ($n = 1003$) had completed BIA at both admission and discharge (Fig. 2b). At admission, the reasons for non-completion were medical in 5.9% ($n = 105$) (cast/dressing/bandage: 1.5% ($n = 26$); amputation: 0.6% ($n = 11$); contact isolation: 1.7% (n = 30); other: 2.1% ($n = 38$)), refusal in 1.6% ($n = 29$), technical issues in 0.7% ($n = 13$), and unknown/missing reasons in 14.7% ($n = 261$). At discharge, 3.7% ($n = 65$) of the total cohort had medical reasons, 2.1% ($n = 36$) refused, 1.8% ($n = 31$) technical issues, 0.6% ($n = 10$) other reasons and 28.6% ($n = 496$) unknown/ missing reasons (Fig. 1). Remeasurement was required in 7.4% ($n = 101$) of the patients

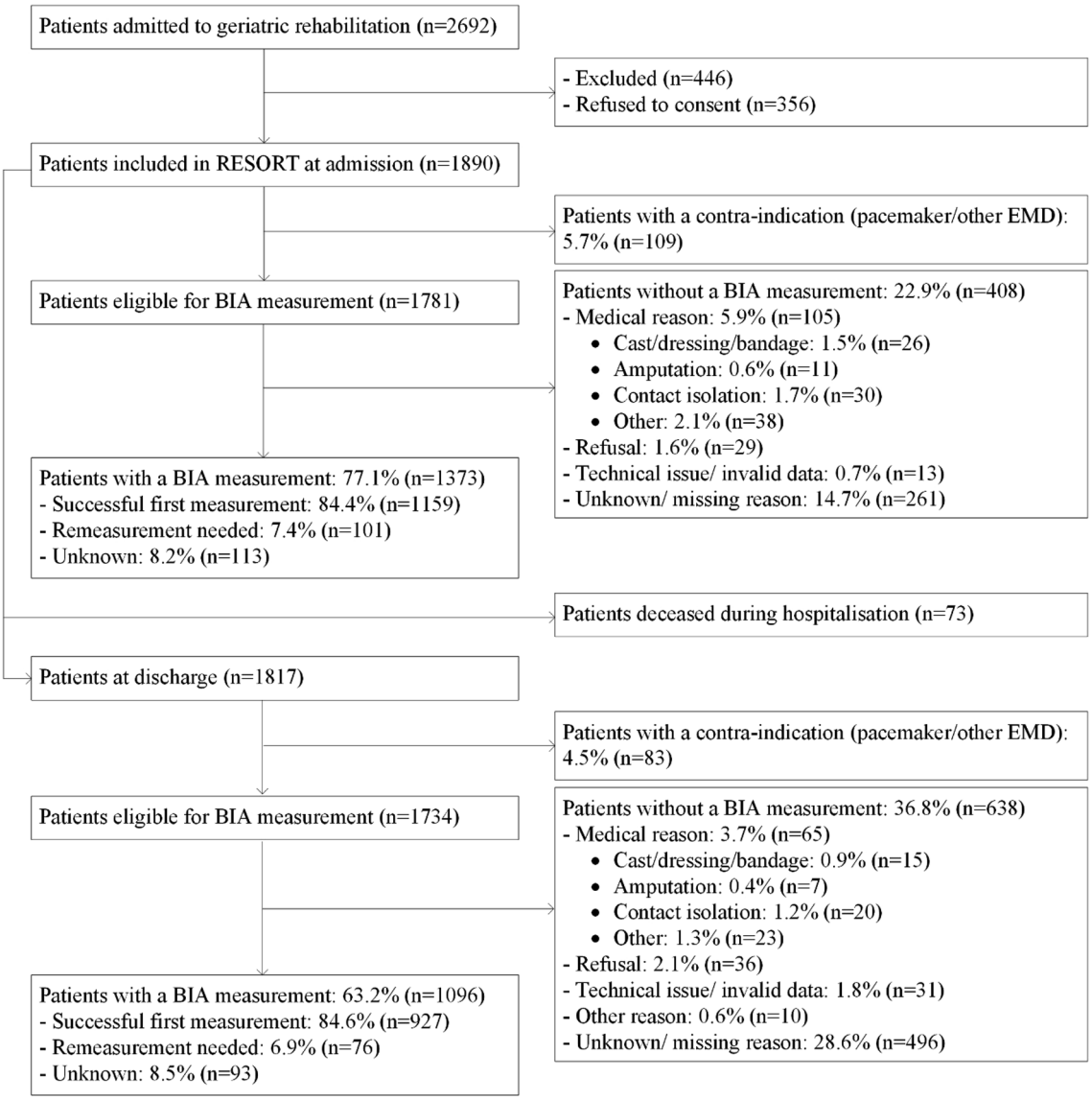

Fig. 1 BIA completion at admission and at discharge and reasons for non-completion. MD electronic medical device, BIA bioelectrical impedance analysis

with a completed BIA at admission and in 6.9% ($n=76$) at discharge. In patients that had a completed BIA at both admission and discharge and in whom a remeasurement was required ($n=127$), 4.7% ($n=6$) required a remeasurement at both admission and discharge (Fig. 2b).

Clinical characteristics associated with BIA completion

Patients with no completed BIA had a greater number of medications, worse ADL and IADL function, higher CFS score and lower FAC and SPPB scores compared to patients with a completed BIA (Table 2). At admission, patients with no completed BIA had a significantly longer length of stay, higher CCI and CIRS scores and higher percentage of delirium compared to patients with a completed BIA. At discharge, there was a lower percentage of females among patients without a completed BIA. Distribution graphs are given in Online Resource 1. There was no difference in age, admission reason, cognitive impairment, HADS score, MST and handgrip strength.

Clinical characteristics associated with BIA remeasurement

Patients in whom a BIA remeasurement was required had a higher percentage of females, worse IADL function and lower SPPB score (Table 3). At admission, patients in whom

Table 1 Patient characteristics at admission to geriatric rehabilitation

	n	Total
Age (years)	1890	83.4 [77.6–88.4]
Female, *n* (%)	1890	1065 (56.3)
Length of stay at geriatric rehabilitation (days)	1890	20 [13–31]
Morbidity		
Primary reason for acute admission, *n* (%)	1890	
Musculoskeletal		893 (47.2)
Neurological		285 (15.1)
Cardiac		142 (7.51)
Respiratory		129 (6.83)
Infection		118 (6.24)
Gastrointestinal		104 (5.50)
Other		219 (11.6)
Medication (number)	1890	9 [7–12]
CCI score [0–37] (points)	1890	2 [1–4]
CIRS score [0–56] (points)	1890	12 [9–16]
Cognition and psychology		
Cognitive impairment, *n* (%)	1890	1231 (65.1)
Delirium, *n* (%)	1890	451 (23.9)
HADS score [0–21] (points)		
Anxiety	1246	7 [3–10]
Depression	1268	7 [3–11]
Anthropometry and nutrition		
Height (cm), mean ± SD	1844	161.6 ± 10.7
Weight (kg)	1880	68.2 [57.8–79.1]
Body mass index (kg/m^2)	1838	25.9 [22.5–30.2]
Malnutrition Screening Tool [0–5] (points)	1863	1 [0–2]
Functional performance		
Katz-ADL score [0–6] (points)	1869	2 [1, 2]
Lawton-IADL score [0–8] (points)	1870	1 [0–2]
Clinical Frailty Scale [0–9] (points)	1716	6 [5–7]
Physical performance		
FAC score [0–5] (points)	713	2 [0–3]
SPPB score [0–12] (points)	1789	1 [0–4]
Handgrip strength (kg)	1722	16.0 [10.0–20.0]
Body composition		
SMI (kg/m^2), mean ± SD	1366	8.92 ± 1.47
ALMI (kg/m^2), mean ± SD	1356	7.23 ± 1.56
ECW/TBW ratio, mean ± SD	1356	0.40 ± 0.02

All data presented as median [IQR] unless otherwise indicated. *IQ R* interquartile range, *CCI* Charlson Comorbidity Index, *CIRS* Cumulative Illness Rating Scale, *HADS* Hospital Anxiety and Depression Scale, *SD* standard deviation, *ADL* Activities of Daily Living, *IADL* Instrumental Activities of Daily Living, *FAC* Functional Ambulation Categories, *SPPB* Short Physical Performance Battery, *SMI* skeletal muscle mass index, *ALMI* appendicular lean mass index, *ECW* extracellular body water, *TBW* total body water

a BIA remeasurement was required were older and had a higher percentage of cardiac conditions compared to patients in whom it was not. At discharge, patients in whom a BIA remeasurement was required had higher percentage of musculoskeletal conditions, lower percentage of neurological conditions, worse ADL function, higher CFS and lower FAC scores and lower handgrip strength. Distribution graphs are given in Online Resource 1. There was no difference in the number of medications, CCI and CIRS scores, cognitive impairment, delirium, HADS score, BMI, MST score, muscle mass and body water.

Discussion

In a cohort of geriatric rehabilitation inpatients, less than one-tenth had a contraindication for BIA measurement. BIA was completed in more than three-quarters of eligible inpatients at admission and almost two-thirds at discharge. Worse functional and physical performances were associated with BIA non-completion and remeasurement. Remeasurement was required in less than one-tenth of the patients.

BIA feasibility

BIA completion rate in the present cohort pointed at a good feasibility [32], although there was a lack of agreement on cutoffs to assess feasibility of measurement instruments in clinical care. One cohort of hospitalized older patients ($n = 378$) had a higher BIA completion rate (85%) at admission, but comparable to our cohort at discharge [61%] [33]. In another cohort of hospitalized older patients ($n = 233$), BIA completion rate was 49% with a higher proportion of refusal (11%) and technical issues (9%), but similar percentage of contraindications/medical reasons (7%) [10]. BIA completion rate was higher in hospitalized adult patients (≥ 18 years old) [34] and children [35, 36], which may be explained by different patient characteristics including fewer comorbidities and better functional and physical performance. In the present cohort, BIA was implemented as routine care, performed by the nursing staff, which differs from studies where BIA was performed by research staff [12, 33] with a higher interest in high completion rate. This explains the lower completion rate in the present cohort and a lower percentage of refusal as patients accept care provided by the nursing staff.

The high proportion of unknown/ missing reason for BIA non-completion compared to contraindication and medical reason may suggest that lack of time, other priorities or the nursing staff forgetting to perform the BIA played an important role [37]. Moreover, although training was provided to the nursing staff to interpret BIA results as part of the RESORT study, sarcopenia diagnosis was rarely applied in clinical practice. Lack of knowledge and focus on the use of BIA outcome among healthcare professionals [3], which are known barriers to the implementation

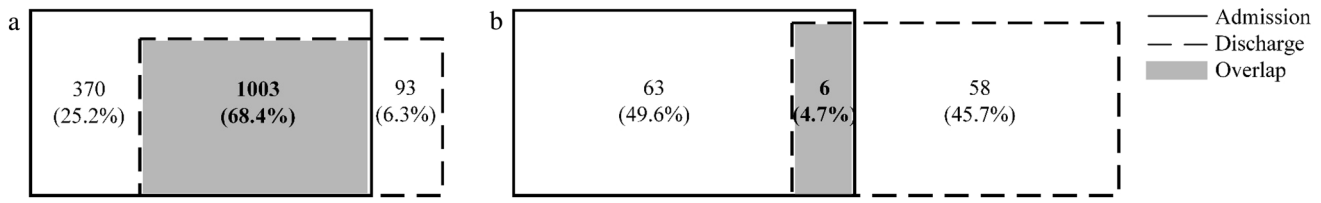

Fig. 2 **a** Overlap of patients with a completed BIA at both admission and discharge ($n=1466$). **b** Overlap of patients with a BIA remeasurement at both admission and discharge ($n=127$). Patients with missing remeasurement data at admission or discharge were excluded

Table 2 Clinical characteristics associated with BIA completion at admission and discharge from geriatric rehabilitation

	Admission			Discharge		
	BIA	No BIA	*p*	BIA	No BIA	*p*
	($n=1373$)	($n=517$)		($n=1096$)	($n=721$)	
Age (years)	83.2 [77.5–88.3]	83.8 [78.4–88.8]	0.110	83.1 [77.6–88.4]	83.6 [77.4–88.3]	0.899
Female, *n* (%)	784 (57.1)	281 (54.4)	0.283	641 (58.5)	386 (53.5)	**0.037**
Length of stay at geriatric rehabilitation (days)	20 [13–30]	21 [14–34]	**0.024**	20 [13–31]	20 [13–31]	0.902
Morbidity						
Primary reason for acute admission, *n* (%)						
Musculoskeletal	650 (47.3)	243 (47.0)	0.895	525 (47.9)	341 (47.3)	0.800
Neurological	219 (16.0)	66 (12.8)	0.085	164 (15.0)	113 (15.7)	0.681
Cardiac	101 (7.4)	41 (7.9)	0.673	92 (8.4)	44 (6.1)	0.069
Respiratory	91 (6.6)	38 (7.4)	0.579	76 (6.9)	49 (6.8)	0.909
Infection	80 (5.8)	38 (7.4)	0.222	56 (5.1)	54 (7.5)	**0.037**
Gastrointestinal	74 (5.4)	30 (5.8)	0.726	60 (5.5)	39 (5.4)	0.952
Other	158 (11.5)	61 (11.8)	0.86	123 (11.2)	81 (11.2)	0.994
Medication (number)	9 [6–12]	10 [7–13]	**< 0.001**	9 [7–12][a]	10 [7–13]	**0.018**
CCI score [0–37] (points)	2 [1–4]	2 [1–4]	**0.013**	2 [1–4]	2 [1–4]	0.403
CIRS score [0–56] (points)	12 [8–16]	13 [9–17]	**0.004**	12 [8–16]	12 [9–16]	0.129
Cognition and psychology						
Cognitive impairment, *n* (%)	887 (64.6)	334 (66.5)	0.431	707 (64.5)	475 (65.9)	0.548
Delirium, *n* (%)	311 (22.7)	140 (27.1)	**0.044**	244 (22.3)	180 (25.0)	0.183
HADS score [0–21] (points)						
Anxiety	6 [3–10]	7 [3–11]	0.065	5 [1–8][a]	4 [1–8][a]	0.256
Depression	7 [3–11]	7 [4–12]	0.123	5 [2–9][a]	5 [2–9][a]	0.910
Anthropometry and nutrition						
Body mass index (kg/m^2)	26.1 [22.6–30.3]	25.5 [22.2–29.6]	0.086	26.1 [22.6–30.1][a]	25.6 [22.1–29.4]	**0.047**
Malnutrition Screening Tool [0–5] (points)	1 [0–2]	1 [0–2]	0.063	0 [0–1][a]	0 [0–1]	0.060
Functional performance						
Katz-ADL score [0–6] (points)	2 [1–3]	1 [1, 2]	**< 0.001**	4 [2–6][a]	4 [1–5]	**< 0.001**
Lawton-IADL score [0–8] (points)	1 [0–2]	1 [0–2]	**< 0.001**	3 [1–5][a]	2 [1–4]	**< 0.001**
Clinical Frailty Scale [0–9] (points)	6 [5–7]	6 [5–7]	**0.020**	6 [5, 6][a]	6 [5–7]	**< 0.001**
Physical performance						
FAC score [0–5] (points)	3 [0–3]	2 [0–3]	**0.007**	4 [3, 4][a]	3 [2–4]	**0.001**
SPPB score [0–12] (points)	1 [0–4]	0 [0–3]	**< 0.001**	4 [2–6][a]	4 [1–6]	**0.004**
Handgrip strength (kg)	16.0 [10.0–20.0]	15.0 [8.0–20.0]	0.078	16.0 [11.0–22.0][a]	16.0 [10.0–22.0]	0.610

$p < 0.05$ (in bold)

All data presented as median [IQR] unless otherwise indicated. *IQR* interquartile range, *BIA* bioelectrical impedance analysis, *CCI* Charlson Comorbidity Index, *CIRS* Cumulative Illness Rating Scale, *HADS* Hospital Anxiety and Depression Scale, *ADL* Activities of Daily Living, *IADL* Instrumental Activities of Daily Living, *FAC* Functional Ambulation Categories, *SPPB* Short Physical Performance Battery

[a] Discharge data used

Table 3 Clinical characteristics associated with BIA remeasurement at admission and discharge from geriatric rehabilitation

	Admission			Discharge		
	No remeasurement	Remeasurement	*p*	No remeasurement	Remeasurement	*p*
	(n = 1159)	(n = 101)		(n = 927)	(n = 76)	
Age (years)	83.0 [77.1–88.1]	86.0 [80.0–89.6]	**0.001**	83.1 [77.6–88.4]	85.6 [79.2–90.0]	0.062
Female, *n* (%)	652 (56.3)	74 (73.3)	**< 0.001**	527 (56.9)	54 (71.1)	**0.016**
Morbidity						
Primary reason acute admission, *n* (%)						
Musculoskeletal	550 (47.5)	53 (52.5)	0.333	435 (46.9)	47 (61.8)	**0.012**
Neurological	186 (16.0)	15 (14.9)	0.753	144 (15.5)	5 (6.6)	**0.035**
Cardiac	80 (6.9)	14 (13.9)	**0.011**	75 (8.1)	8 (10.5)	0.459
Respiratory	81 (7.0)	4 (4.0)	0.245	67 (7.2)	3 (3.9)	0.281
Infection	68 (5.9)	4 (4.0)	0.428	51 (5.5)	1 (1.3)	0.114
Gastrointestinal	64 (5.5)	2 (2.0)	0.125	50 (5.4)	4 (5.3)	0.961
Other	130 (11.2)	9 (8.9)	0.478	105 (11.3)	8 (10.5)	0.832
Medication (number)	9 [6–12]	9 [7–12]	0.912	9 [7–12][a]	10 [8–13]	0.096
CCI score [0–37] (points)	2 [1–4]	2 [1–4]	0.865	2 [1–4]	2 [1–3]	0.186
CIRS score [0–56] (points)	12 [8–15]	13 [9–17]	0.143	12 [8–15]	12 [9–16]	0.101
Cognition and psychology						
Cognitive impairment, *n* (%)	739 (63.8)	71 (70.3)	0.189	587 (63.3)	52 (68.4)	0.374
Delirium, *n* (%)	257 (22.2)	27 (26.7)	0.293	206 (22.2)	17 (22.4)	0.976
HADS score [0–21] (points)						
Anxiety	6 [3–10]	8 [3–10]	0.271	5 [1–8][a]	7 [1–10][a]	0.272
Depression	7 [3–11]	8 [3–11]	0.749	5 [2–9][a]	6 [2–10][a]	0.194
Anthropometry and nutrition						
Body mass index (kg/m^2)	26.1 [22.7–30.5]	25.4 [21.8–29.8]	0.113	25.9 [22.5–29.9][a]	26.5 [22.8–30.5]	0.529
Malnutrition Screening Tool [0–5] (points)	1 [0–2]	1 [0–2]	0.574	0 [0–1][a]	0 [0–1]	0.129
Functional performance						
Katz-ADL score [0–6] (points)	2 [1–3]	1 [1, 2]	0.259	4 [2–6][a]	4 [1–5]	**0.030**
Lawton-IADL score [0–8] (points)	1 [0–2]	1 [0–1]	**0.003**	3 [1–5][a]	2 [1–4]	**0.047**
Clinical Frailty Scale [0–9] (points)	6 [5–7]	6 [5–7]	0.718	6 [5, 6][a]	6 [5–7]	**0.010**
Physical performance						
FAC score [0–5] (points)	3 [0–3]	2 [0–3]	0.219	4 [3, 4][a]	4 [2–4]	**0.052**
SPPB score [0–12] (points)	1 [0–4]	1 [0–3]	**0.035**	4 [2–7][a]	3 [1–6]	**0.013**
Handgrip strength (kg)	16.0 [10.0–21.0]	13.0 [10.0–20.0]	0.099	17.0 [12.0–22.0][a]	12.0 [10.0–18.0]	**< 0.001**
SMI (kg/m^2), mean ± SD	8.94 ± 1.45	8.76 ± 1.56	0.239	8.94 ± 1.44[a]	8.78 ± 1.40	0.369
ALMI (kg/m^2), mean ± SD	7.23 ± 1.53	7.24 ± 1.78	0.951	7.29 ± 1.54[a]	7.22 ± 1.62	0.678
ECW/TBW ratio, mean ± SD	0.41 ± 0.02	0.40 ± 0.03	0.125	0.41 ± 0.02[a]	0.41 ± 0.02	0.884

$p < 0.05$ (in bold)

All data presented as median [IQR] unless otherwise indicated. *IQR* interquartile range, *BIA* bioelectrical impedance analysis, *CCI* Charlson Comorbidity Index, *CIRS* Cumulative Illness Rating Scale, *HADS* Hospital Anxiety and Depression Scale, *ADL* Activities of Daily Living, *IADL* Instrumental Activities of Daily Living, *FAC* Functional Ambulation Categories, *SPPB* Short Physical Performance Battery, *SD* standard deviation, *SMI* skeletal muscle mass index, *ALMI* appendicular lean mass index, *ECW* extracellular body water, *TBW* total body water. Remeasurement data were missing in 1373 patients at admission and 93 patients at discharge because of missing BIA printouts

[a] Discharge data used

of measurement instruments in clinical practice [38], may thus also have affected BIA completion. Lastly, the completion rate was higher at admission than discharge, suggesting BIA measurement is less easy to plan at discharge for the nursing staff, possibly due to unexpected or changing discharge date, lack of communication and other priorities [39].

Clinical characteristics associated with BIA completion

Lower functional and physical performance interfered with BIA completion, possibly due to difficult and time-consuming bed transfers [40]. Also, more medications, higher disease burden and delirium impeded BIA completion at admission. These patients may have had more contraindication/ medical reasons preventing BIA completion and required more nursing care, leaving less time for BIA completion. As sarcopenia prevalence is high in these patients, barriers and enablers of BIA measurement should be further assessed among clinicians with semi-structured interviews and focus groups to enhance completion rate and prevent underdiagnosis of sarcopenia.

Clinical characteristics associated with BIA remeasurement

No studies have previously assessed BIA remeasurement rate. Findings from this cohort suggest that remeasurement, which was required in less than 10% of the patients, does not affect feasibility in clinical care, as it takes 2 min and electrodes can stay in place. However, remeasurement may have affected nursing staff readiness to complete the BIA. It remains unexplained why more females than males required a remeasurement. Lower functional and physical performance also interfered with remeasurement, likely due to unrest and difficulty to keep the supine position for 10–15 min. However, while BIA completion at admission was associated with completion at discharge, this was not the case for remeasurement. This may suggest that BIA remeasurement is less related to intrinsic patient characteristics than the completion of the measurement.

Strengths and limitations

To the best of our knowledge, this is the first study investigating the feasibility of BIA in a large cohort of geriatric rehabilitation inpatients reflecting routine clinical care. Moreover, all measurements were conducted by a multidisciplinary team as part of a CGA with validated and standardized assessments appropriate to older patients. A limitation of this study is the high percentage of unknown/ missing reason for BIA non-completion and the lack of insights from the nursing staff on time constraint, difficulty to plan and other possible barriers. Furthermore, this was a single-site study, which could limit generalizability to other hospitals.

Conclusion

BIA feasibility is good in routine clinical care of geriatric rehabilitation inpatients. Worse functional and physical performance were associated with non-completion and remeasurement, which may hamper sarcopenia diagnosis. The relatively low percentage of contraindications, medical reasons, refusal and technical issues indicates that completion rates may be enhanced further by reviewing barriers and enablers such as time constraint, lack of knowledge, access to protocols and better planning.

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Data availability statement The data is available from the corresponding author on reasonable request, within the existing privacy legislations.

Declarations

Conflict of interest A.B. Maier reports grants from Danone Nutricia Research, outside the submitted work; J.P. van Wijngaarden reports that she is an employee of Danone Nutricia Research. The other authors declare that they have no conflicts of interest.

Statement of human and animal rights The study was approved by the Melbourne Health Research Ethics Committee (HERC/17/MH/103) and was conducted in accordance with the Declaration of Helsinki.

Informed consent Written informed consent was provided by either the patient or a nominated proxy.

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