TECHNOLOGY REVIEW (MINI-HTA)

BIO-ELECTRICAL IMPEDANCE ANALYSIS FOR THE ASSESSMENT OF SARCOPENIA IN ELDERLY

Malaysian Health Technology Assessment Section (MaHTAS)
Medical Development Division
Ministry of Health Malaysia
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EXECUTIVE SUMMARY

Introduction

Body composition assessment is the practise of dissecting the human body into its constituent parts, which include body fat mass, muscle mass, bone, tissue and water, and determines the contribution of its composition. The higher the body fat percentage, particularly visceral fat that lines the organs in the abdomen, the greater the chance of acquiring nutrition-related chronic diseases such as metabolic syndrome, heart disease, obesity and diabetes. Accurate body composition measurement is a valuable diagnostic aid in elderly patients with or without sarcopenia. Sarcopenia defined as the gradual loss of muscle mass accompanied by decreased strength or performance. Sarcopenia has been associated with increased morbidity and mortality in elderly population. Malnutrition, immobility, chronic inflammation and hormonal changes associated with ageing all contribute to its development. Sarcopenia prevalence rises with age and is higher among institutionalised older adults. Prevention of sarcopenia is the most effective measure. Early detection and treatment will reduce morbidity and mortality, and improve quality of life.

This technology review was requested by the Geriatric Unit, Hospital Kuala Lumpur, to evaluate the effectiveness, safety, cost-effectiveness and organisational issues related to the bio-electrical impedance analysis for the assessment of sarcopenia in elderly.

Objective/aim

To evaluate the effectiveness, safety, cost-effectiveness and organisational issues related to the bio-electrical impedance analysis for the assessment of sarcopenia in elderly.

Results and conclusions

A total of 21,721 titles were retrieved. After removing duplicates, applying inclusion and exclusion criteria, there were 11 studies reported on bio-electrical impedance analysis for the assessment of sarcopenia in elderly included in this review; one systematic review of cross sectional studies, three cohort studies and seven cross sectional studies. The studies were conducted in Poland, Italy, Sweden, Turkey, Netherlands, German, Brazil, Switzerland, Taiwan and China.

Based on the review, there was sufficient evidence retrieved on the diagnostic accuracy of the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. The evidence showed bio-electrical impedance analysis correlated well with dual-energy X-ray absorptiometry and magnetic resonance imaging-measured in measuring muscle mass, appendicular skeletal muscle mass and appendicular skeletal muscle mass index. However, evidence also showed that bio-electrical impedance analysis may over and underestimate the measurement of fat mass, fat-free mass, lean soft tissue and appendicular skeletal muscle mass especially in obesity, very old patients and patients with prosthesis.

As per safety, there was no study retrieved on the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. However, there were studies reported no adverse events, rhythm disturbances and implantable electronic devices malfunctions. Despite an increased arrhythmic potential on inotropic support or the presence of implanted electronic devices, a bio-electrical impedance analysis was reported as safe.

There was no study retrieved on cost-effectiveness of the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. The estimated cost per test was reported between $15 (RM 66.92) and $150 (RM 669.23). The cost was determined by the location and the level of professional consultation.

Methods

Electronic databases were searched through the Ovid interface; Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) 1946 to 11 January 2023, Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily 1946 to January 11, 2023, Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations 1946 to January 11, 2023, Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily 2017 to January 11, 2023, Ovid MEDLINE(R) 1946 to January Week 1 2023, Ovid MEDLINE(R) 1996 to January Week 1 2023, Ovid MEDLINE(R) Epub Ahead of Print January 11, 2023, Ovid MEDLINE(R) Daily Update January 11, 2023 and Ovid MEDLINE(R) 2017 to January Week 1 2023. Searches were also run in PubMed, INAHTA, Cochrane Library and US Food and Drug Administration. Google was used to search for additional web-based materials and information. Additional articles were identified from reviewing the references of retrieved articles. Last search was conducted on 12 January 2023.

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ABBREVIATIONS

ASM	Appendicular skeletal muscle
ASMI	Appendicular skeletal muscle index
ASMM	Appendicular skeletal muscle mass
AUC	Area under curve
AWGS	Asian Working Group for Sarcopenia
BMI	Body mass index
CASP	Critical Appraisal Skills Programme
cf-VAD	Continuous flow ventricular assist device
CI	Confidence interval
CIED	Cardiac implantable electronic device
CRT	Cardiac resynchronisation therapy
CRT-D	Cardiac resynchronisation therapy defibrillator
DXA	Dual-energy X-ray absorptiometry
EMI	Electromagnetic interference
EWGSOP	European Working Group on Sarcopenia in Older People
FFM	Fat-free mass
FFMI	Fat-free mass index
HTA	Health technology assessment
ICD	Implantable cardioverter defibrillator
JBI	Joanna Briggs Institute
LST	Lean soft tissue
MRI	Magnetic resonance imaging
OR	Odd ratio
PRESS	Prediction of the Sum of Squares
r	Correlation coefficient
r^2	Coefficient of determination
RCT	Randomised control trial
ROC	Receiver operating characteristic
SD	Standard deviation
SEE	Standard error of the estimate
SR	Systematic review

1.0 BACKGROUND

Body composition assessment is the practise of dissecting the human body into its constituent parts, which include body fat mass, muscle mass, bone, tissue and water, and determines the contribution of its composition. The higher the body fat percentage, particularly visceral fat that lines the organs in the abdomen, the greater the chance of acquiring nutrition-related chronic diseases such as metabolic syndrome, heart disease, obesity and diabetes. Accurate body composition measurement is a valuable diagnostic aid in elderly patients with or without sarcopenia. Sarcopenia defined as the gradual loss of muscle mass accompanied by decreased strength or performance. Sarcopenia has been associated with increased morbidity and mortality in elderly population. Malnutrition, immobility, chronic inflammation and hormonal changes associated with ageing all contribute to its development. Sarcopenia prevalence rises with age and is higher among institutionalised older adults.[1] Prevention of sarcopenia is the most effective measure. Early detection and treatment will reduce morbidity and mortality, and improve quality of life.[2]

The estimated prevalences of sarcopenia were 10.0% (95% CI: 8, 12) in men and 10.0% (95% CI: 8, 13) in women, respectively. The prevalence was higher among non-Asian than Asian individuals in both genders especially, when the bio-electrical impedance analysis was used to measure muscle mass (19.0% vs. 10.0% in men; 20.0% vs. 11.0% in women).[3] Meanwhile in Malaysia, the prevalence of sarcopenia among community dwelling older adults in Klang Valley was 33.6%, and women (35.9%) were more affected compared to men (30.1%).[4] Another study stated that pre-sarcopenia/ sarcopenia was detected in 103 (51.0%) among independently mobile, institutionalised older people in the Klang Valley.[5]

The key component in detecting sarcopenia is muscle mass assessment. High resolution imaging methods, such as magnetic resonance imaging (MRI) and computed tomography are expensive and the latter requires radiation exposure, making both methods impractical in the clinical setting. Although dual-energy X-ray absorptiometry (DXA) is the gold standard for measuring muscle mass and can be found in a variety of clinical settings, it is not portable or practical for use in large epidemiological studies.[6] As a result, an increasing number of studies are employing bio-electrical impedance analysis to detect low muscle mass in the context of sarcopenia.[3,7,8]

According to the Sarcopenia and Cachexia Consensus, bio-electrical impedance analysis is an acceptable method for identifying sarcopenia.[9] The device's benefits are well-known; it is a portable, low-cost and well-tolerated tool that can be used for epidemiological, clinical and follow-up studies.[8] However, the main issue with this device is that bio-electrical impedance analysis does not measure any body compartment and is considered a doubly indirect method. The device's assessments all rely on the measurement of tissue conductivity when an electric current is applied.[10]

Figure 1: The condition primarily affects the elderly and is thought to be caused by ageing.[11]

This technology review was requested by the Geriatric Unit, Hospital Kuala Lumpur, to evaluate the effectiveness, safety, cost-effectiveness and organisational issues related to the bio-electrical impedance analysis for the assessment of sarcopenia in elderly.

2.0 OBJECTIVE/ AIM

To evaluate the effectiveness, safety, cost-effectiveness and organisational issues related to the bio-electrical impedance analysis for the assessment of sarcopenia in elderly.

3.0 TECHNICAL FEATURES

Bio-electrical impedance analysis is a low-cost, portable body composition testing device. Body composition is determined using bio-electrical impedance analysis, which involves passing small electrical currents through the body. Because the electrical conductivity of various bodily tissues (e.g., muscle, fat, bone, etc.) varies due to differences in water content, the small electrical current passes through the tissues at different speeds **(see Figure 2)**. The device then calculates the impedance (i.e. the resistance of the electrical current) of the current and then estimate body composition.[12]

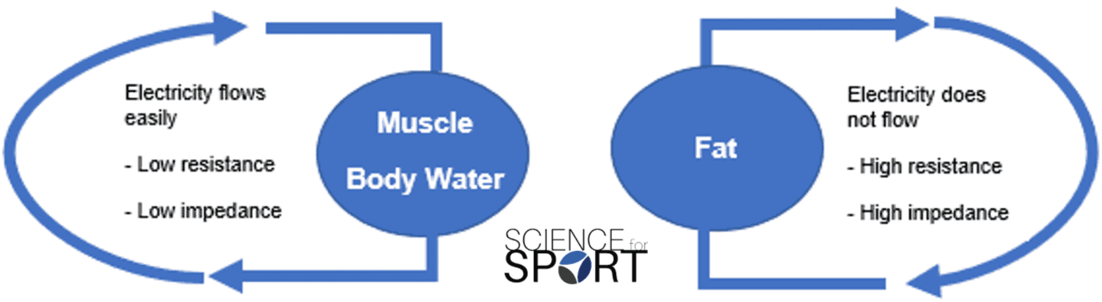

Figure 2: The difference in bio-electrical conductivity between muscle and fat.[12]

The basic idea behind bio-electrical impedance analysis is that different tissues in the body act as conductors, semi-conductors or dielectrics (insulators). Because they contain a lot of water, lean tissues are highly conductive. Bone and adipose tissue, on the other hand, are dielectric and poor conductors. Bio-electrical impedance analysis assumes that the human body is made up of a series of cylinders that are uniform in shape, length, cross-sectional area and conductivity.[12]

The total body water is estimated and used to calculate fat-free mass. This is based on the assumption that 73.0% of the body's fat-free mass is water, and the percentage remains constant over time and across individuals. The difference between fat-free mass and body mass is then used to calculate fat mass.[12]

There are two types of frequency that have been used:[13]

1. Dual-frequency: By using different frequencies, even higher accuracy of measurements can be achieved.
2. Multi-frequency: Able to measure impedance at three, five or six different frequencies. The additional frequencies provide an exceptional level of accuracy compared to single-frequency monitors and also makes it possible to estimate extracellular water, intracellular water and total body water. This information is essential for providing a detailed insight into a personal health status and for indicating health risks such as severe dehydration or oedema (water retention).

Bio-electrical impedance analysis device can be classified into three categories **(see Figure 3):**[12]

1. **Hand-held** bio-electrical impedance analysis device measures the conductance of a small alternating current through the upper body and use built-in software to calculate body composition after calibration with weight, height, age and gender. Due of its convenience, this method may be useful in a field setting.

2. A **leg-to-leg** device, similar to hand-held methods, involves an individual standing on scales with four electrodes located at each footplate with a low-level current passed through the lower-body. The path of the electrical current may differ between this method and the hand-held method, which may affect body composition results.

3. **Hand-to-foot** device measures the entire body using electrodes in a mounted footplate as well as electrodes in hand grips. Because hand-held and leg-to-leg methods may not account for lower- or upper-body resistance, it is reasonable to believe that hand-to-foot measurements may better reflect whole body composition than the alternatives.

Figure 3: Category of bio-electrical impedance analysis devices.[14]

4.0 METHODS

4.1 Searching

Electronic databases were searched through the Ovid interface:

- Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) 1946 to 11 January 2023
- Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily 1946 to January 11, 2023
- Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations 1946 to January 11, 2023
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Searches were also run in PubMed, INAHTA, Cochrane Library and US Food and Drug Administration. Google was used to search for additional web-based materials and information. Additional articles were identified from reviewing the references of retrieved articles. Last search was conducted on 12 January 2023. Appendix 1 shows the detailed search strategies.

4.2 Selection

A reviewer screened the titles and abstracts against the inclusion and exclusion criteria and then evaluated the selected full text articles for final article selection. The inclusion and exclusion criteria were:

Inclusion criteria

Population	Elderly with or without sarcopenia
Interventions	Bio-electrical impedance analysis
Comparators	Dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI), computed tomography
Outcomes	**Effectiveness:** Measurement on appendicular skeletal muscle mass (ASMM), appendicular skeletal muscle index (ASMI), fat mass, fat-free mass (FFM), fat-free mass index (FFMI), fat mass (FM), lean soft tissue (LST) **Safety:** Adverse events, electrical interference on cardiac implantable electronic devices **Cost:** Price and fee of bio-electrical impedance analysis
Study design	Health Technology Assessment (HTA) reports, Systematic Review (SR) and Meta-Analysis, Randomised Control Trial (RCT), Non-randomised Control Trial (RCT), cohort studies, cross-sectional studies, case studies
Type of publication	English, full text articles

Exclusion criteria

Study design	Studies conducted in animals, narrative reviews
Type of publication	Non-English full text articles

Relevant articles were critically appraised using ROBIS checklist for systematic review of cross sectional studies, Critical Appraisal Skills Programme (CASP) checklist for cohort studies and Joanna Briggs Institute (JBI) Critical Appraisal checklist for cross sectional studies. The evidence graded according to the US/Canadian Preventive Services Task Force **(see Appendix 2)**. Data were extracted from included studies using a pre-designed data extraction form (evidence table as shown in **Appendix 3**) and presented in tabulated format with narrative summaries. No meta-analysis was conducted for this review.

5.0 RESULTS

5.1 Selection of the included studies

A total of 21,721 titles were retrieved. After removing duplicates, applying inclusion and exclusion criteria, there were 11 studies reported on bio-electrical impedance analysis for the assessment of sarcopenia in elderly included in this review; one systematic review of cross sectional studies, three cohort studies and seven cross sectional studies as shown in **Figure 4**. The studies were conducted in Poland, Italy, Sweden, Turkey, Netherlands, German, Brazil, Switzerland, Taiwan and China.

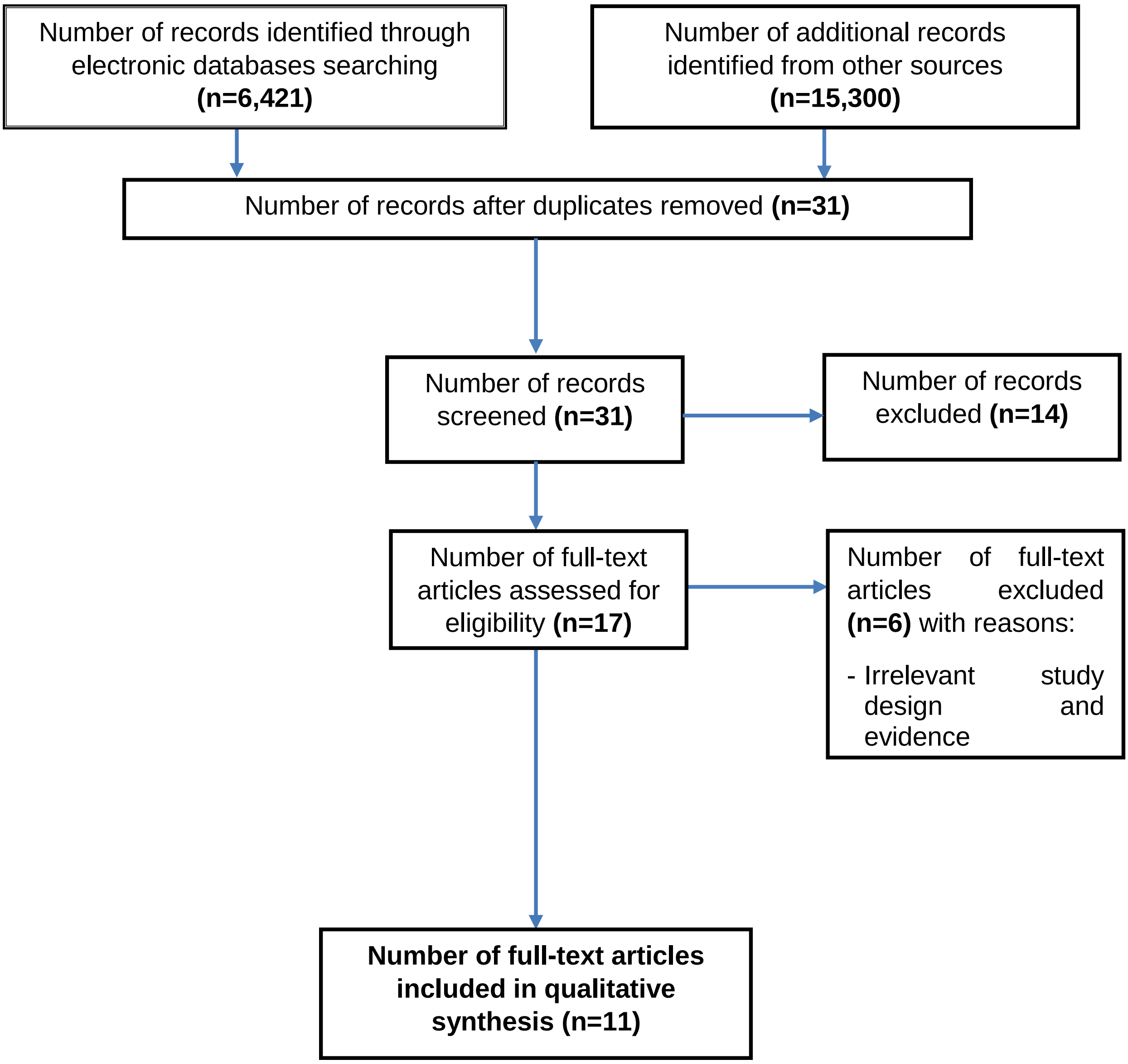

Figure 4: Flow chart of study selection

5.2 Critical appraisal of the included studies

The systematic review of cross sectional studies was appraised using the ROBIS checklist, meanwhile the cohort studies were appraised using the CASP checklist. For the systematic review of cross sectional studies, the concerns regarding methods used to collect data and appraise studies and the synthesis and findings were high, this was due to insufficient information presented in the study **(see Table 1)**. As for the cohort studies in **Figure 5**, all three studies reported no information on the follow-up of the subjects (CASPA6[a] and CASPA6[b]). The appraisal of the literature indicated that the literature in this review was of acceptable relevance, even though there were six out of nine domains were appraised as yellow judgement reported in Meyer P et al. (2016).

Sbrignadello S et al. (2022)

Table 1: Assessment of risk of bias of systematic review of cross sectional studies.

Domain 1: Concerns regarding specification of study eligibility criteria	Unclear
Domain 2: Concerns regarding methods used to identify and/or select studies	Unclear
Domain 3: Concerns regarding methods used to collect data and appraise studies	High
Domain 4: Concerns regarding the synthesis and findings	High

	CASPA1	CASPA2	CASPA3	CASPA4	CASPA5(a)	CASPA5(b)	CASPA6(a)	CASPA6(b)	CASPB7	CASPC8	CASPC9
Meyer P et al. (2016)	+	+	?	?	?	?	?	?	+	+	+
Garlini LM et al. (2020)	+	+	+	+	?	?	?	?	+	+	+
Roehrich L et al. (2020)	+	+	+	+	?	?	?	?	+	+	+

CASPA1	**Did the study address a clearly focused issue?**
CASPA2	**Was the cohort recruited in an acceptable way?**
CASPA3	**Were the exposure accurately measured to minimise bias?**
CASPA4	**Was the outcome accurately measured to minimise bias?**
CASPA5 (a)	**Have the authors identified all important confounding factors?**
CASPA5(b)	**Have they taken account of the confounding factors in the design and/or analysis?**
CASPA6(a)	**Was the follow up of subjects complete enough?**
CASPA6(b)	**Was the follow up of subjects long enough?**
CASPB7	**Do you believe the results?**
CASPC8	**Were all clinically important outcomes considered?**
CASPC9	**Do the results of this study fit with other available evidence?**

Judgement	
+	Yes
?	Can't tell
-	No

Figure 5: Assessment of risk of bias of cohort studies

Meanwhile for the cross sectional studies, the results of the appraisal were outlined in **Figure 6**. From the JIB appraisal, four literature reviews shared the same judgement on the two domains; the confounding factors were not identified (CAJIB5) and there were no strategies stated on how to deal with confounding factors (CAJIB6). Other three literature reviews had no information whether the outcomes were measured in a valid and reliable way (CAJBI7).

	CAJBI1	CAJBI2	CAJBI3	CAJBI4	CAJBI5	CAJBI6	CAJBI7	CAJBI8
Chien MY et al. (2008)	+	-	+	?	+	+	+	+
Baar HV et al. (2015)	+	+	+	+	+	+	+	+
Tognon G et al. (2015)	-	?	+	?	-	-	+	+
Wang H et al. (2016)	+	+	+	+	-	-	+	+
Kilic MS et al. (2016)	-	+	?	+	-	-	?	+
Perna S et al. (2020)	+	?	+	+	-	-	?	+
Tsutsumimoto K et al. (2020)	+	+	+	+	+	+	?	+
Kolodziej M et al. (2022)	+	+	-	+	+	+	+	+

CAJBI1	**Were the criteria for inclusion in the sample clearly defined?**
CAJBI2	**Were the study subjects and the setting described in detail?**
CAJBI3	**Was the exposure measured in a valid and reliable way?**
CAJBI4	**Were objective, standard criteria used for measurement of the condition?**
CAJBI5	**Were confounding factors identified?**
CAJBI6	**Were strategies to deal with confounding factors stated?**
CAJBI7	**Were the outcomes measured in a valid and reliable way?**
CAJBI8	**Was appropriate statistical analysis used?**

Judgement	
+	Yes
-	No
?	Unclear
x	Not applicable

Figure 6: Assessment of risk of bias of cross sectional studies

5.3 Effectiveness

A review by MaHTAS in 2007 showed that bio-electrical impedance analysis method tended to underestimate the percentage of body fat especially in overweight and obese individuals. Hence, the validity of this method was at stake. Most of the studies used classical (whole body) bio-electrical impedance analysis method or tetra-polar devices which measured impedance from foot to hand and only a few of the studies used hand-held method. The studies reported that the whole body bio-electrical impedance analysis method was more accurate in estimating percentage of body fat compared to hand-held bio-electrical impedance analysis. It was also reported that the measurement of body fat by handheld bio-electrical impedance analysis was affected by the change in the posture of the subject, during the measurement process.[15]

For this review, the electronic databases were searched from 2008 onwards. There were seven cross sectional studies on the effectiveness of bio-electrical impedance analysis for the assessment of sarcopenia in elderly.

5.3.1 Outcome: Muscle mass, appendicular skeletal muscle mass (ASMM), appendicular skeletal muscle index (ASMI)

A **cross sectional study was conducted by Baar HV et al. (2015)** to develop an age specific bio-impedance prediction equation for the assessment of ASMM in (pre-) frail elderly people aged 65 and older. The community-dwelling elderly participants were recruited between December 2009 and September 2010. Potentially eligible subjects were screened for pre-frailty and frailty using the Fried criteria; unintentional weight loss, weakness or poor handgrip strength, self-reported exhaustion, slow walking speed and low physical activity. The Blande-Altman plot showed that, on average $ASMM_{BIS}$ tended to underestimate ASMM slightly (0.56kg) **(see Figure 7A to 7C).** The difference between $ASMM_{DXA}$ and both $ASMM_{50kHz}$ and $ASMM_{Fc}$ was close to zero (0.03 and -0.02kg respectively).[16]

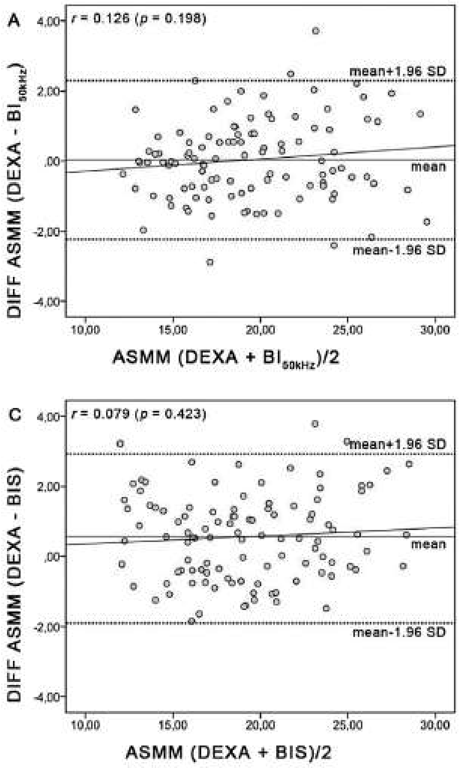

Figure 7: Systemic difference between ASMM measured by DXA and calculated with ASMM prediction equations. For evaluating the agreement, the difference in ASMM (between bio-electrical impedance analysis and DXA) was plotted against the mean of the two methods ([DXA + bio-electrical impedance analysis] / 2). The diagonal line was the regression line, the middle horizontal line was the mean difference (kg) and the outer lines were the 95% limits of agreement (±1.96 x standard deviation [SD]).[17]

Wang H et al. (2016) in another cross sectional study validated the usefulness of the new octapolar multi-frequency bio-electrical impedance analysis for assessment of ASMM by comparing it with DXA and, investigated the prevalence of sarcopenia in Chinese community-dwelling elderly according to Asian Working Group for Sarcopenia (AWGS) definition. The 944 subjects (462 men, 482 women) aged 60 to 90 year voluntarily participated in the study through leaflets and posters provided by the Center of Gerontology and Geriatrics, West China Hospital, Sichuan University between March 2014 and October 2014. The study showed that, the correlation between ASM obtained by using bio-electrical impedance analysis and DXA was high in both the men and women. The Pearson correlation coefficient and standard error of the estimate (SEE) of the regression equation were 0.94 and 1.05kg in the men, and 0.90 and 0.93kg in the women, respectively (both p>0.05). The agreement of these two methods in the Bland-Altman analysis showed only two points were outside the limit of agreement in the men; and three points, in the women. The ASMM showed significant declines with age in both sexes (p<0.005).[18]

Another **cross sectional study** investigated the role of bio-electrical impedance analysis-derived phase angle as a determinant of sarcopenia **(Kilic MK et al., 2016)**. The study was conducted in two tertiary care centers with geriatric out-patient clinics and wards. A total of 263 community-dwelling and hospitalised geriatric (more than 65 years old) patients were enrolled. The univariate analysis revealed that the low ASMI (median: 8.2 versus 9.4kg/m^2, p<0.001) was associated with lower phase angle (the phase angle evaluates cellular health by examining the integrity of the cell and the amount of water it contains. This can be used to estimate a cell's health and nutrition level. In general, the greater the phase angle, the healthier a person is).[2]

Chien MY et al. (2008) conducted a cross sectional study to compare a bio-electrical impedance analysis prediction equation for estimating ASMM with magnetic resonance imaging (MRI)-measured ASMM and to investigate the prevalence of sarcopenia in community-dwelling elderly people in Taiwan. Three hundred two individuals (157 men, 145 women) aged 65 and older volunteered for this study. Each patient was interviewed using a structured questionnaire to obtain basic demographic on medical conditions necessitating long-term treatment. The study reported that the correlation between ASMM obtained using a bio-electrical impedance analysis prediction equation and ASMM measured using MRI was high **(see Figure 8A)**. However, the average difference between MRI-measured and bio-electrical impedance analysis-predicted ASMM was not significant (-0.44 ± 1.55kg, p=0.08). Furthermore, the systematic differences between bio-electrical impedance analysis-predicted and MRI-measured ASMM were determined using a Bland-Altman plot **(see Figure 8B).** The positive slope of the regression of the differences in the means suggested a slight tendency to underestimate ASMM in individuals with high ASMM and to overestimate ASMM in those with low ASMM.[19]

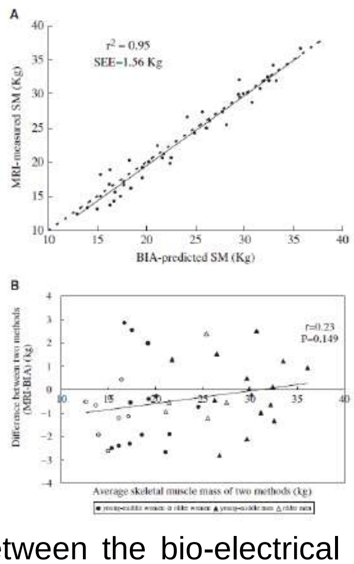

Figure 8: (A) Regression between the bio-electrical impedance analysis-predicted and MRI-measured ASMM. Solid line, regression line; dotted line, line of identity. (B) Bland-Altman plot for difference between MRI-measured and bio-electrical impedance analysis-predicted ASMM and the average skeletal muscle mass of the two methods. *r^2 = coefficient of determination; SEE = standard error of the estimate; r = correlation coefficient.*[19]

The next **cross sectional study was conducted by Kolodziej M et al. (2022)** to evaluate the association between the bio-electrical impedance phase angle and the occurrence of pre-sarcopenia in people aged 50 and above. The study included 1,567 patients (406 men and 1,161 women) aged 50 to 87 who in 2010 to 2015 volunteered for free tests advertised in local media, health centers and associations of elderly people in south-west Poland. The ASMM was estimated in accordance with the recent European Working Group on Sarcopenia in Older People (EWGSOP2) recommendations. The study reported that, the prevalence of pre-sarcopenia in women was almost twice as high as in men (χ^2=19.3, p<0.001). In the multivariate modeling of the probability of pre-sarcopenia, the variables for which significance were confirmed in univariate analyses were taken into account. In the input model, sex (OR: 1.34, p=0.18) and hand grip strength/ ASMM (OR: 0.82, p=0.33) turned out to be insignificant factors in explaining the probability of pre-sarcopenia, and therefore were omitted in the subsequent stages of the analysis. Finally, the age, body mass index (BMI) and phase angle turned out to be the significant predictors. The analysis of the receiver operating characteristic (ROC) curve showed a high classification performance of phase angle (area under curve [AUC] = 0.821, p<0.001 in men and [AUC] = 0.836, p<0.001 in women) and the cut-off points for pre-sarcopenia phase angle was 5.42 in men and 4.76 in women **(see Figure 9)**.[20]

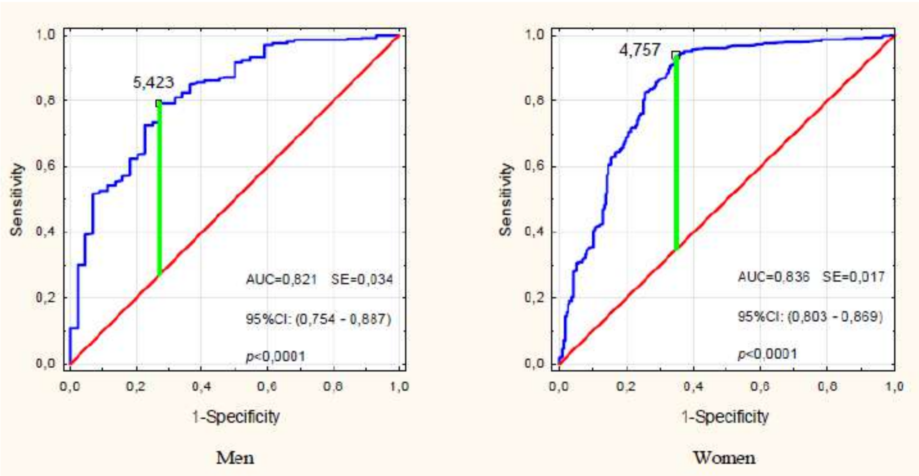

Figure 9: The ROC curve for impedance phase angle in identifying pre-sarcopenia in males and females over the age of 50. The marked point was the cut-off points for the pre-sarcopenia state.
ROC = receiver operating characteristic; AUC = area under the ROC curve; SE = standard error; 95% CI = confidence interval.[20]

5.3.2 Outcome: Fat mass, fat-free mass (FFM), fat-free mass index (FFMI), lean soft tissue (LST)

Tognon G et al. (2015) in a diagnostic cross sectional study assessed whether a segmental multi-frequency bio-electrical impedance analysis scale can be an accurate and reliable tool for the monitoring of body composition in the elderly and whether the presence of metallic prostheses can influence the agreement between the two techniques. The study included 92 healthy patients (39 men, 53 women) aged 80 to 81 years who participated in a follow-up examination of the Gerontological and Geriatric Population Studies in Gothenburg in 2010. The study revealed that, the multi-frequency bio-electrical impedance analysis underestimated fat mass by 7.6kg and overestimated LST by 7.2kg in the male sample, indicating poor absolute agreement between DXA and multi-frequency bio-electrical impedance analysis in men. On average, fat mass in women was underestimated by -12.0% with limits of agreement ranging from -31.0% to +7.0% while appendicular LST was overestimated by about +11.0% with limits of agreement given by -9.0% and +31.0%. Despite the low agreement with respect to fat mass and LST, the overestimation of ASMM was below 2kg in both sexes. Sensitivity analyses excluding subjects with metal prostheses did not change the conclusions. Prosthesis status was associated with a larger difference between DXA- and multi-frequency bio-electrical impedance analysis-derived values but did not significantly influence the agreement between both methods for all variables.[21]

The next **cross sectional study was conducted by Perna S et al. (2019)** to compare bio-electrical impedance analysis with DXA as a measure for the assessment of FFM, fat mass and body fat percentage in a large sample of very old (including oldest old) Italian hospitalised subjects. The study was performed in the city of Pavia in northern Italy. Eligible patients were elderly men and women aged 65 years and older and patients were limited to only those patients who were able to be tested by DXA. The study stated that:[22]

- There was an underestimation of FFM in both women (-0.97kg; p<0,01) and men (-1.99kg; p<0.01).
- In both genders there was an overestimation in fat mass (women: +1.11kg; p<0.01; men: +1.67kg; p<0.01) and percentage of body fat (women: 2.1%; p<0.01; men: 2.8%; p<0.01).
- When both methods were compared in different age categories, in both women and men there was an underestimation of FFM (–0.85kg; p<0.01 and –2.27kg; p<0.01, respectively) but there was also an overestimation of fat mass and percentage of body fat (+0.99kg; p<0.01 and +1.7%; p<0.01 in women and +1.73kg; p<0.01 and +2.8%; p<0.01 in men).
- For patients over 85 years old, significant differences in all considered variables were only observed in women, but not in men with FFM being underestimated (–1.10kg; p<0.01), while fat mass and percentage of body fat being overestimated (+1.40kg; p<0.01 and +2.8%; p<0.01).

5.4 Safety

There was no retrievable study on the safety of bio-electrical impedance analysis for the assessment of sarcopenia in elderly. However, three studies reported on the safety of the device on patients with cardiac implantable electronic devices.

Garlini LM et al. (2020) conducted a cohort study to analyse the dual interference between cardiac implantable electronic devices (CIEDs) and bio-electrical impedance analysis. The study included adult patients (age ≥ 18 years old) from the Brazilian Public Health System referred for CIEDs (pacemaker, implantable cardioverter defibrillator [ICD] and cardiac resynchronisation therapy defibrillator [CRT-D]) implantation from June 2015 to November 2016. The sample consisted of 43 individuals, most were male and Caucasian, mean age was 66 ± 10 years, and 39.0% of them presented heart failure. Regarding variations in anthropometric and bio-electrical impedance analysis measurements, weight, BMI, phase angle, body cell mass and intracellular showed no difference between the first assessment, without the implanted device, and the second, with the implanted device. However, there were significant reductions (before and after CIEDs implantations) in direct bio-electrical impedance analysis measurements, reflecting an increase (+1kg) in results of total body water and extracellular water and, consequently, increased in FFM and extracellular mass. Because of changes in the hydration status and FFM values, without changes in weight, fat mass was significantly lower.[23]

The impact of bio-electrical impedance analysis assessment on CIEDs showed no electrical interference on intracardiac electrogram of any lead (atrial, right ventricular, left ventricular), in any patient. There was no inappropriate sensing or tachycardia detection in any device. Full interrogation of CIEDs after bio-electrical impedance analysis showed no significant differences in lead parameters or device function. No patient presented symptoms during the procedure.[23]

Another **cohort study conducted by Roehrich L et al. (2020)** evaluated the safety of bio-electrical impedance analysis in advanced heart failure patients on pro-arrhythmogenic therapy with an implanted CIED and/or with a continuous flow ventricular assist device (cf-VAD). The study was performed between April 2018 and October 2019, and included a total of 217 bio-electrical impedance analysis measurements in 143 advanced heart failure patients at risk of severe arrhythmias due to inotropic support/ a history of ventricular arrhythmias and/ or treated with CIED, including 104 patients with an ICD, cardiac resynchronisation therapy (CRT) or pacemaker and 95 patients with a cf-VAD.[24]

The study showed:[24]

- **Bio-electrical impedance analysis measurement and arrhythmic events**
  No supraventricular or ventricular rhythm disturbances occurred during and within 30 minutes after the bio-electrical impedance analysis measurement. Within 30 minutes to 24 hours, six arrhythmic events were observed: onset of atrial fibrillation was seen in one patient with a history of paroxysmal atrial fibrillation 30 minutes after bio-electrical impedance analysis. In five patients, ventricular tachycardia was documented; the onset was at least one hour after the measurement. All patients had a recent history of documented recurrent ventricular tachycardias: two patients were on cf-VAD support and listed for high-urgency heart transplantation due to severe refractory arrhythmias. Three ventricular tachycardias remained subclinical, and two were terminated by an appropriate ICD shock. Fifty-nine percent of patients were on inotropic support, 20% with at least two inotropic agents. No increased rate of arrhythmias during/ after bio-electrical impedance analysis was seen in patients with inotropic therapy; however, all three patients with arrhythmias under inotropic therapy received dobutamine. Seventy-six percent of patients were on antiarrhythmic medication mainly with beta-blockers and amiodarone. Compared to patients without antiarrhythmic therapy, no change in rhythm disturbances was observed.

- **Interference of bio-electrical impedance analysis and CIED**
  In 104 patients with a CIED (103 ICD/CRT, one pacemaker), no inappropriate shocks or CRT/ pacemaker malfunctions were recorded during or after the

measurement, regardless of the location (left or right) measured. Furthermore, no difference was observed with regard to the device manufacturer. Three patients were supported by external devices had no rhythm disturbances occurred. No over-sensing or under-sensing was recorded in the telemetric surveillance.

- **Interference of bio-electrical impedance analysis and VAD**
  No technical problems occurred during the bio-electrical impedance analysis measurement in 95 cf-VAD patients, regardless of whether the left or the right side of the body was measured. No irregularities in cf-VAD flow or technical alarms were recorded, regardless of the manufacturer.

Meyer P et al. (2016) in a cohort study tested the occurrence of electromagnetic interferences (EMI) in a setting where this risk was experimentally maximised. During three months, consecutive outpatients scheduled for routine ICD controls at the device clinic of the Geneva University Hospitals were included in the study. Patients who were pacemaker-dependent or aged less than 18 years were excluded from the study.[25]

Sixty-three patients (54 men; nine women) were included with a mean age of 64.8 ± 14.6 years, mean left ventricular ejection fraction of 32.1 ± 16.5% and mean BMI of 27.9 ± 4.8kg/m^2. Primary prevention was the main ICD indication (62.0%), a CRT being implanted in more than half of the patients. The study reported no EMI were detected by the ICDs during bio-electrical impedance analysis measurements assessed at three current frequencies in the 63 participants. Further, no artefacts were visualised during the intra-cardiac electro-gram recordings in any of the ICDs.[25]

According to the Medical Device Authority Malaysia, there were five bio-electrical impedance analysis registered.[26] Various brands of bio-electrical impedance analysis had been approved by United States of Food and Drug Administration.[27]

5.5 Cost-analysis/ Cost-effectiveness

There was no study retrieved on cost-effectiveness of bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly. The average amount charged for a bio-electrical impedance analysis test was between $15 (RM 66.92) and $150 (RM 669.23). The price depended on the location and the degree of professional consultation.[28]

5.6 Organisational Issue

There was one study reported on the organisational issue of bio-electrical impedance analysis for the assessment of body composition including sarcopenia. **Sbrignadello S et al. (2022) conducted a systematic review of cross sectional studies** to analyse the studies using bio-electrical impedance analysis for body composition analysis in T2DM patients with sarcopenia or at risk of catching it. The search of scientific literature was performed in PubMed. The indicated search strategy yielded 103 articles and ended with a set of 40 articles after analysing them. The relevant methodological aspects related to bio-electrical impedance analysis examination was summarised in **Figure 10**.[29, level I]

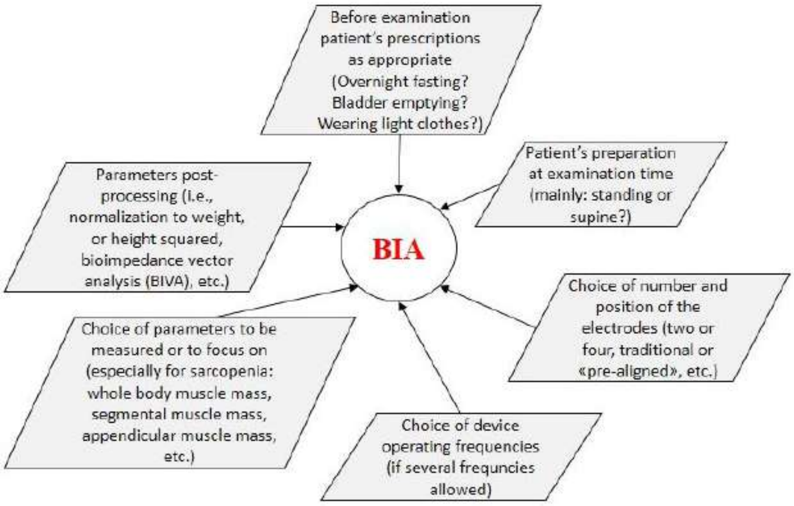

Figure 10: Methodological aspects related to bio-electrical impedance analysis examination.[29, level I]

5.7 Limitations

This technology review has a limitation. Although there was no restriction in language during the search but only English full text articles were included in this review. Most of the evidence included were observational studies, lack of comparison of long term outcome.

6.0 CONCLUSION

Based on the review, there was sufficient evidence retrieved on the diagnostic accuracy of the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. The evidence showed bio-electrical impedance analysis correlated well with DXA and MRI-measured in measuring muscle mass, ASMM and ASMMI. However, evidence also showed that bio-electrical impedance analysis may over and underestimate the measurement of fat mass, FFM, LST and ASMM especially in obesity, very old patients and patients with prosthesis.

As per safety, there was no study retrieved on the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. However, there were studies reported no adverse events, rhythm disturbances and implantable electronic devices malfunctions. Despite an increased arrhythmic potential on inotropic support or the presence of implanted electronic devices, a bio-electrical impedance analysis was reported as safe.

There was no study retrieved on cost-effectiveness of the bio-electrical impedance analysis for the assessment of sarcopenia in elderly. The estimated cost per test was reported between $15 (RM 66.92) and $150 (RM 669.23). The cost was determined by the location and the level of professional consultation.

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8.0 APPENDICES

8.1 Appendix 1: Search strategy

Ovid MEDLINE® In-Process & Other Non-Indexed Citations and Ovid MEDLINE® 1946 to 11 January 2023

1	SARCOPENIA/	8957
2	sarcopenia*.tw.	13345
3	BODY COMPOSITION/	48085
4	body composition*.tw.	44386
5	AGED/	3395118
6	Aged.tw.	709013
7	Elderly.tw.	283501
8	GERIATRICS/	31310
9	Geriatrics.tw.	8004
10	Gerontology.tw.	4168
11	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10	4018061
12	ELECTRIC IMPEDANCE/	19973
13	bioelectric* impedance.tw.	7631
14	electric* impedance.tw.	5559
15	electric* resistance.tw.	8065
16	12 or 13 or 14 or 15	33221
17	11 and 16	9430
18	limit 17 to (english language and yr="2008 -Current")	6350

OTHER DATABASES	
Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily 1946 to January 11, 2023	Same MeSH, keywords, limits used as per MEDLINE search
Ovid MEDLINE(R) and In-Process, In-Data-Review & Other Non-Indexed Citations 1946 to January 11, 2023	
Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations and Daily 2017 to January 11, 2023	
Ovid MEDLINE(R) 1946 to January Week 1 2023	
Ovid MEDLINE(R) 1996 to January Week 1 2023	
Ovid MEDLINE(R) Epub Ahead of Print January 11, 2023	
Ovid MEDLINE(R) Daily Update January 11, 2023	
Ovid MEDLINE(R) 2017 to January Week 1 2023	
Cochrane Library	

PubMeD

((((((Sarcopenia[MeSH Terms]) OR (Sarcopenia[Text Word])) OR (Elderly[MeSH Terms])) OR (Elderly[Text Word])) OR (Geriatric[MeSH Terms])) OR (Geriatric[Text Word])) AND ((((Bio-electrical impedance analysis[MeSH Terms]) OR (Bio-electrical impedance analysis[Text Word])) OR (Bio-impedance analysis[MeSH Terms])) OR (Bio-impedance analysis[Text Word]))

8.2 Appendix 2: Hierarchy of evidence for effectiveness/ diagnostic

I Evidence obtained from at least one properly designed randomised controlled trial.

II-I Evidence obtained from well-designed controlled trials without randomization.

II-2 Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one centre or research group.

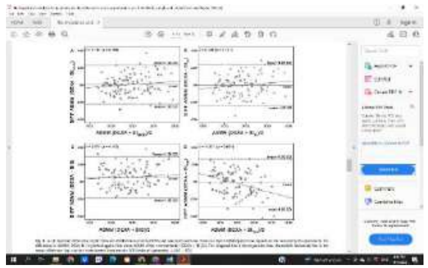
II-3 Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence.

III Opinions or respected authorities, based on clinical experience; descriptive studies and case reports; or reports of expert committees.

SOURCE: US/CANADIAN PREVENTIVE SERVICES TASK FORCE (Harris 2001)

8.3 Appendix 3: Evidence tables

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
1. Baar HV, Hulshof PJM, Tieland M et al. Bio-impedance Analysis for Appendicular Skeletal Muscle Mass Assessment in (Pre-) Frail Elderly People. Clinical Nutrition ESPEN. 2015; 10: 147-153 NETHERLANDS	**Cross Sectional Studies** **Objective:** To develop an age specific bio-impedance prediction equation for the assessment of appendicular skeletal muscle mass (ASMM) in (pre-) frail elderly people aged 65 and older. **Method:** Community-dwelling elderly participants, ≥65 years, were recruited between December 2009 and September 2010 for participation. Potentially eligible subjects were screened for pre-frailty and frailty using the Fried criteria. These criteria were: 1) unintentional weight loss of more than 4.5 kg in the preceding year by self-report, 2) measured handgrip strength below 20th percentile by gender and body mass index, 3) self-reported exhaustion		Total = 106 Female (n=61) Male (n=65)	Bio-electrical impedance analysis	Dual-energy X-ray absorptiometry (DEXA)		PRESS statistics showed that $ASMM_{50kHz}$ was the best fitting model. The PRESS value for $ASMM_{50kHz}$ was 163.4, $ASMM_{Fc}$ had a PRESS value of 175.9 and for ASMMBIS it was 177.1. The Blande-Altman plot showed that on average $ASMM_{BIS}$ tended to underestimate ASMM slightly (0.56 kg). The difference between $ASMM_{DEXA}$ and both $ASMM_{50kHz}$ and $ASMM_{Fc}$ was close to zero (0.03 and -0.02 kg respectively). The Blande-Altman plot revealed that $ASMM_{Kyle}$ tended to overestimate ASMM with 0.17 kg on average. The 95% limits of agreement were -2.93-2.56 kg. The confidence interval for the lower limit was -3.05 to -2.82, and for the upper limit 2.49 to 2.71. Furthermore, a significant negative correlation was found between the differences in ASMM ($ASMM_{DEXA}$-$ASMM_{Kyle}$) and the mean ASMM of the two methods (r = -0.337, p < 0.001), suggesting that $ASMM_{Kyle}$ underestimates ASMM in people with a lower amount of ASMM and overestimates ASMM in people with a higher amount of ASMM. 	

Evidence Table : **Efficacy**
Question : **What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?**

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
	based on two questions in the CES-D depression scale, 4) 15 feet distance walking speed below 20th percentile by gender and height, 5) weekly physical activity measured with the Minnesota Leisure Time Activity questionnaire < 383 kcal (men) or <270 kcal (women). Furthermore, subjects who were diagnosed with any form of cancer, chronic obstructive pulmonary disease (COPD), diabetes type 1 and 2 (≥7 mmol/L), or renal insufficiency (eGFR <60 mL/min/1.73 m2) were excluded.							

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
2. Wang H, Hai S, Cao L et al. Estimation of Prevalence of Sarcopenia by Using a New Bioelectrical Impedance Analysis in Chinese Community-Dwelling Elderly People. BMC Geriatrics. 2016; 16(216). CHINA	**Cross Sectional Studies** **Objective:** To validate the usefulness of the new octapolar multi-frequency bio-electrical impedance analysis for assessment of appendicular skeletal muscle mass by comparing it with that of dual-energy X-ray absorptiometry (DXA) and, To investigate the prevalence of sarcopenia in Chinese community-dwelling elderly according to Asian Working Group for Sarcopenia (AWGS) definition. **Method:** We recruited 944 subjects (462 men and 482 women) aged 60 to 92 years who voluntarily participated in the study, through leaflets and posters provided by the Center of Gerontology and Geriatrics, West China Hospital, Sichuan		Total = 944 Female (n=482) Male (n=462)	Bio-electrical impedance analysis	Dual-energy X-ray absorptiometry (DEXA)		**Correlation between BIA- and DXA-measured ASM** The correlation between ASM obtained by using BIA and DXA was high in both the men and women. The Pearson correlation coefficient and standard error of the estimate (SEE) of the regression equation were 0.94 and 1.05 kg in the men, and 0.90 and 0.93 kg in the women, respectively (both $p > 0.05$). No significant method-related biases were found. The agreement of these two methods in the Bland-Altman analysis is presented. Only 2 points were outside the limit of agreement in the men; and 3 points, in the women. **Differences in body composition according to age and sex** The differences in body composition according to age and sex are shown in the table. ASM and ASMI showed significant declines with age in both sexes ($p < 0.005$).	

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
	University, between March 2014 and October 2014. Volunteers were excluded if they had any diseases such as hyperthyroidism or hypothyroidism, or chronic heart and renal failure, or been receiving prescribed medications such as long-term steroid treatment, which is known to affect body composition. Individuals who could not communicate with the interviewers owing to severe cognitive impairment, mental disorders, and severe hearing and eye problems were also excluded from the study. All the participants were ambulatory without physical disability or amputation.							

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
3. Kilic MK, Kizilarslanoglu MC, Arik G et el. Association of Bioelectrical Impedance Analysis-derived Phase Angle and Sarcopenia in Older Adults. Nutrition in Clinical Practice. 2016; DOI: 10.1177/0884533616664503 TURKEY	**Cross Sectional Studies** **Objective:** To investigate the role of bio-electrical impedance analysis–derived phase angle as a determinant of sarcopenia. **Method:** This study was conducted in 2 tertiary care centers with geriatric outpatient clinics and wards. A total of 263 community-dwelling and hospitalized geriatric (>65 years old) patients were enrolled in the study. Bio-electrical assessment of sarcopenia was performed with 2 analyzers at 2 centers. Quadscan and InBody bioimpedance analyzers measured skeletal muscle mass (SMM) and SMI, which is calculated as SMM divided by height in meters squared. Measurements were done after at least 8 hours of fasting and micturition.		Total = 263 Inpatients (n=75) Outpatient (n=188)	Bio-electrical impedance analysis			Univariate analysis revealed that the low SMI (median: 8.2 vs 9.4 kg/m^2, $p < .001$), was associated with lower phase angle.	

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
	To the best of our knowledge, SMI cut-off values to define sarcopenia were not determined in our population. Hence, we assessed a group of our patients (32 men, 29 women) aged 18–40 years old who were enrolled to a recent study, and <–2 SD from the mean SMI was used. Accordingly, low SMI values for women and men were considered as <7.34 and <8.72 kg/m2, respectively. Phase angle was directly measured and recorded by the devices.							

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
4. Chien MY, Huang TY, Wu YT. Prevalence of Sarcopenia Estimated Using a Bioelectrical Impedance Analysis Prediction Equation in Community-dwelling Elderly People in Taiwan. The American Gerietrics Society. 2008; 56: 1710-1715. TAIWAN	**Cross Sectional Studies** **Objective:** To compare a bioelectrical impedance analysis (BIA) prediction equation for estimating skeletal muscle mass (SM) with magnetic resonance imaging (MRI)-measured SM and to investigate the prevalence of sarcopenia in community-dwelling elderly people in Taiwan. **Method:** Three hundred two individuals (157 men and 145 women) aged 65 and older volunteered for this investigation. Each subject was interviewed using a structured questionnaire to obtain basic demographic data and information on medical conditions necessitating long-term treatment. Information on physical activity habits was obtained from one simple question. If the subject participated in regular physical activity		Total = 302 Female (n=145) Male (n=157)	Bio-electrical impedance analysis	Magnetic resonance imaging (MRI)		The 41 volunteers invited for equation validation varied in age (22–90) and BMI (17.6–34.6 kg/m^2). The correlation between SM obtained using a BIA prediction equation and SM measured using MRI was high. The average difference between MRI-measured and BIA-predicted SM was not significant (-0.44 ± 1.55 kg, p = 0.08). Systematic differences between BIA-predicted and MRI-measured SM were determined using a Bland-Altman plot. The average difference between BIA-predicted and MRI-measured SM and the mean SM of MRI-measured and BIA-predicted SM showed a small but non-significant positive correlation (r = 0.23, p = 0.15). The positive slope of the regression of the differences in the means suggests a slight tendency to underestimate SM in individuals with high SM and to overestimate SM in those with low SM. The characteristics of the elderly subjects showed that the men were taller and had greater FFM and less fat mass than the women, although the SMI was significantly greater for men than for women (9.80 ± 1.14 kg/m^2 vs 7.25 ± 0.95 kg/m^2, p < 0.001). Sarcopenia defined using SM/SMI would result in a higher prevalence than FFM/ FFMI. When SMI was used to define sarcopenia, the prevalence of sarcopenia was 18.6% in women and 23.6% in men.	

Evidence Table : Efficacy
Question : What is the effectiveness of Bio-electrical impedance analysis for the assessment of body composition including sarcopenia in elderly?

Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
	or exercise for more than 30 minutes a day, more than 3 days a week, that individual was considered to be a regular exerciser. Volunteers were excluded if any disease or prescribed medication being taken was known to affect whole-body composition, as previously mentioned.							

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5. Tognon G, Malmros V, Freyer E. Are Segmental MF-BIA Scales Able to Reliably Assess Fat Mass and Lean Soft Tissue in an Elderly Swedish Population? Exp Gerontol. 2015; 72: 239-243. SWEDEN	**Cross Sectional Studies** **Objective:** To assess whether a segmental MF-BIA scale can be an accurate and reliable tool for the monitoring of body composition in the elderly and whether the presence of metallic prostheses can influence the agreement between the two techniques. **Method:** This study included 92 healthy subjects (39 men and 53 women) aged 80-81 years who participated in a follow-up examination of the Gerontological and Geriatric Population Studies in Gothenburg (H70) in 2010. The analysis of body composition by DXA was performed. The device was equipped with a software which calculated Bone Mineral Content (BMC), LST and FM, both total and segmental. The number and location of metal prostheses was		Total = 92 Female (n=53) Male (n=39)	Bio-electrical impedance analysis	Dual X-ray absorptiometry (DXA)		• Spearman correlation coefficients vary between 0.55 and 0.95 indicating that subjects are ranked similarly by both techniques. However, MF-BIA underestimated FM by 7.6 kg and overestimated LST by 7.2 kg in the male sample, indicating poor absolute agreement between DXA and MF-BIA in men. • No dependence on the mean value was found for the ratio of DXA over MF-BIA-derived values as shown in the right column of the figure. On average, FM in women was underestimated by -12% with limits of agreement ranging from -31% to +7% while ALST was overestimated by about +11%with limits of agreement given by -9% and +31%. • Despite the low agreement with respect to FM and LST the overestimation of skeletal muscle mass is below 2 kg in both sexes. Sensitivity analyses excluding subjects with metal prostheses did not change the conclusions. Prosthesis status was associated with a larger difference between DXA- and MFBIA-derived values but did not significantly influence the agreement between both methods for all variables.	

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	determined from the DXA scan. On the same day as DXA, bio-electrical impedance analysis was performed with subjects standing upright and barefoot on a segmental MF-BIA scale.							

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6. Perna S, Alalwan TA, Spadaccini D et al. Comparison Between Bioimpedance Analysis and Dual-energy X-ray Absroptiometry in Assessment of Body Composition in a Cohort of Elderly Patients Aged 65-90 Years. Adv. Geront. 2019; 32(6): 1023-1033. ITALY	**Cross Sectional Studies** **Objective:** To compare BIA with DXA as a measure for the assessment of FFM, FM and body fat percentage in a large sample of very old (including oldest old) Italian hospitalized subjects. **Method:** The study was performed in the city of Pavia in northern Italy. Eligible patients were elderly men and women, aged 65 years and older. We have limited the sample to only those patients who were able to be tested by DXA (excluding bedridden patients or subjects with diminished independent living skills). Furthermore, patients with bedsores or wearing compression stockings were excluded because they were not able to be assessed by BIA. Hydration assessment by bioelectrical impedance		Total = 110 Female (n=68) Male (n=42)	Bio-electrical impedance analysis	Dual-energy X-ray absorptiometry (DXA)		**Participants' characteristics and general comparison between DXA and BIA** As shown in the table, there was an underestimation of FFM in both women (–0.97 kg; p<0,01) and men (–1.99 kg; p<0.01). In both genders there was an overestimation in FM (women: 1.11 kg; p<0.01; men: 1.67 kg; p<0.01) and percentage of body fat (women: 2.07 %; p<0.01; men: 2.82 %; p<0.01). **Comparison between methods in different age categories** • In both women and men there was an underestimation of FFM (–0.85 kg; p<0.01 and –2.27 kg; p<0.01, respectively) but there was also an overestimation of FM and percentage of body fat (+0.99; p<0.01 kg and +1.70 %; p<0.01 in women and +1.73 kg; p<0.01 and +2.84 %; p<0.01 in men). • For patients over 85 years old, significant differences in all considered variables were only observed in women, but not in men with FFM being underestimated (–1.10 kg; p<0.01), while FM and percentage of body fat being overestimated (+1.40 %; p<0.01 and +2.78 %; p<0.01). **Comparison between methods in different hydration status** • For patients with an ICW percentage lower than 55%, there were significant differences in all considered settings. FFM was underestimated (–1.00 kg; p<0.01 in women and –2.02 kg; p<0.01 in men), while FM and percentage of body fat were overestimated (+1.14 kg; p<0.01 and +2.11 %;	

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	was performed on the elderly patients because changes in fluid status affect the soft tissue composition estimated by DXA.						p<0.01 in women and +1.51 kg; p<0.01 and +2.63 %; p<0.01 in men). • Similarly, for patients with an ECW percentage higher than 45%, there were significant differences in all considered settings. FFM was underestimated (–0.98 kg; p<0.01 in women and –1.92 kg; p<0.01 in men), while FM and percentage of body fat were overestimated (+1.14 kg; p<0.01 kg and +2.12 %; p<0.01 in women and +1.54 kg; p<0.01 and +2.55 %; p<0.01 in men). **Comparison between methods for BMI categories** • For normal weight patients, there were significant differences in all considered settings. FFM was underestimated (–1.45 kg; p<0.01 in women and –3.07 kg; p<0.01 in men), while FM and percentage of body fat were overestimated (+1.75 kg; p<0.01 kg and +2.82 %; p<0.01 in women and +2.68 kg; p<0.01 and +4.41 %; p<0.01 in men). • No significant differences were found in the overweight • group with the exception of FFM in men where it was underestimated (–1.46 kg; p<0.05). For obese patients, no significant differences were found in all evaluated settings in both genders. **Comparison between methods for sarcopenia stages** • The sample was divided into non-sarcopenic subjects (SMI>5.45 kg/m^2 in women and SMI>7.26 kg/m^2 in men) and sarcopenic subjects (SMI<5.45 kg/m^2 in women and SMI<7.26 kg/m^2 in men). • For non-sarcopenic patients, there were significant differences in all considered settings.	

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							FFM was underestimated (–1.01 kg; p<0.01 in women and –2.40 kg; p<0.01 in men), while FM and percentage of body fat were overestimated (+1.22 kg; p<0.01 and +2.18 %; p<0.01 in women and +2.20 kg; p<0.01 and +3.52 %; p<0.01 in men).	

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7. Kolodziej M, Koziel S, Ignasiak Z. The Use of the Bioelectrical Impedance Phase Angle to Assess the Risk of Sarcopenia in People Aged 50 and Above in Poland. Int. J. Environ. Res. Public Health. 2022; 19: 4687. POLAND	**Cross sectional study** **Objective:** To evaluate the association between the bioelectrical impedance phase angle and the occurrence of pre-sarcopenia in people aged 50 and above. **Method:** The study included 1567 people (406 men and 1161 women) aged 50 to 87, who in 2010–2015 volunteered for free tests advertised in local media, health centers and associations of elderly people in south-west Poland. The inclusion criteria were aged 50 or more, as well as independence and autonomy in everyday life. Participants were evaluated to be subjectively healthy based on declarations of good health, no difficulty in walking, and no limitations in daily activities.		Total = 1567 Female (n=1161) Male (n=406)	Bio-electrical impedance analysis			• The prevalence of pre-sarcopenia in women was almost twice as high as in men ($\chi^2 = 19.3$, $p < 0.001$). In addition to the expected differences in age, weight, BMI and parameters that constituted the criteria for sarcopenia (i.e., muscle strength, mass and walking speed), it was observed that those identified as pre-sarcopenia compared to no sarcopenia had significantly lower phase angle values. The relative percentage differences in PhA between the sarcopenic status groups were significantly higher (13% in men and 12% in women) than the differences in ASMM-adjusted strength (9% in men and 5% in women). • The associations of selected variables (without their mutual interaction) with the probability of pre-sarcopenia state were initially checked using the method of univariate logistic regression. The variables that were the criteria for sarcopenia in this study were not taken into account. Age was a positive predictor of pre-sarcopenia, while sex, BMI, PhA, HGS/ASMM were negative predictors (Table 2). The phase angle most strongly determined the probability of sarcopenia risk. Increasing the PhA value by one unit reduces the chances of developing a pre-sarcopenia state by almost 17 times. For men, the chance of developing pre-sarcopenia was two times lower than the chance of developing it in women. Slightly lower reductions in odds were seen for a unit increase in BMI. Annual changes in age were the weakest determinant of the increase in the probability of pre-sarcopenia, but the logit results indicate that people 10 years older will be twice as likely to develop pre-sarcopenia than people younger than that (OR: $1.08^{10} = 2.15$).	

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							• In the multivariate modeling of the probability of pre-sarcopenia, the variables for which significance were confirmed in univariate analyzes were taken into account. In the input model, sex (OR: 1.34, $p = 0.18$) and HGS/ASMM (OR: 0.82, $p = 0.33$) turned out to be insignificant factors in explaining the probability of pre-sarcopenia, and therefore were omitted in the subsequent stages of the analysis. Finally, age, BMI and PhA turned out to be the significant predictors. • The analysis of the ROC curve showed a high classification performance of PhA (AUC = 0.821, $p < 0.001$ in men and AUC = 0.836, $p < 0.001$ in women) and the cut-off points for pre-sarcopenia PhA = 5.42 in men and PhA = 4.76 in women.	

Evidence Table : Safety
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Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
1. Garlini LM, Alves FD, Kochi A et al. Safety and Results of Bioelectrical Impedance Analysis in Patients with Cardiac Implantable Electronic Devices. Braz J Cardiovasc Surg. 2020; 35(2): 169-174. BRAZIL	**Prospective Cohort Study** **Objective:** To analyze the dual interference between cardiac implantable electronic devices (CIEDs) and bioelectrical impedance analysis (BIA). **Method:** Forty-three individuals admitted for CIEDs implantation were submitted to a tetrapolar BIA with an alternating current at 800 microA and 50 kHz frequency before and after the devices' implantation. During BIA assessment, continuous telemetry was maintained between the device programmer and the CIEDs in order to look for evidence of possible electric interference in the intracavitary signal of the device.		43 patients with CIED	Bio-electrical impedance analysis			The sample consisted of 43 individuals, most were male and Caucasian, mean age was 66 ± 10 years, and 39% of them presented HF (see the table). Twenty-two patients had PM implanted, 15 had an ICD, and six had CRT-D. Implanted CIEDs were manufactured by Medtronic (n=27) and Biotronik (n=16) (Table 2). Regarding variations in anthropometric and BIA measurements, weight, BMI, PA, BCM, and ICW showed no difference between the first assessment, without the implanted device, and the second, with the implanted device. However, there were significant reductions (before and after CIEDs implantations) in direct BIA measurements (R, R/H, Xc, Xc/H), reflecting an increase (+ 1 kg) in results of TBW (L) and ECW (L) and, consequently, increases in FFM (kg) and ECM (kg). Because of changes in the hydration status and FFM values, without changes in weight, FM was significantly lower (see the table). All of these variants were approximately 1.36% of the patients' weight, being within the possible margin of error, referring to the protocol to make the examination, especially if they were changes in hydration status. The impact of BIA assessment on CIEDs showed no electrical interference on intracardiac electrogram of any lead (atrial, right ventricular, left ventricular), in any patient. There was no inappropriate sensing or tachycardia detection in any device. Full interrogation of CIEDs after BIA showed no significant differences in lead parameters or device function (see the table). No patient presented symptoms during BIA.	

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2. Roehrich L, Suendermann S, Just IA et al. Safety of bioelectrical impedance analysis in advanced heart failure patients. Pacing Clin Electrophysiol. 2020; 1–8. GERMAN	**Prospective Cohort Study** **Objective:** To evaluate the safety of BIA in AHF patients on pro-arrhythmogenic therapy with an implanted CIED and/or with a cf-VAD. **Method:** Between April 2018 and October 2019, the prospective study was performed, and included a total of 217 BIA measurements in 143 AHF patients at risk of severe arrhythmias due to inotropic support/a history of ventricular arrhythmias and/or treated with CIED, including 104 patients with an ICD, CRT or pacemaker and 95 patients with a cf-VAD. All patients were under continuous Electrocardiogram (ECG) monitoring and clinical surveillance for 24 hours.		143 AHF patients	Bio-electrical impedance analysis			No patient achieved the primary endpoint, while six patients achieved the secondary endpoint. **BIA measurement and arrhythmic events** No supraventricular or ventricular rhythm disturbances occurred during and within 30 minutes after the BIA measurement. Within 30 minutes to 24 hours, six arrhythmic events were observed: onset of atrial fibrillation was seen in one patient with a history of paroxysmal atrial fibrillation 30 minutes after BIA. In five patients, ventricular tachycardia (VT) was documented; the onset was at least 1 hour after the measurement. All patients had a recent history of documented recurrent VTs: two patients were on cf-VAD support and listed for high-urgency heart transplantation due to severe refractory arrhythmias. Three VTs remained subclinical, and two were terminated by an appropriate ICD shock. Fifty-nine percent of patients were on inotropic support, 20% with at least two inotropic agents. No increased rate of arrhythmias during/after BIA was seen in patients with inotropic therapy (3 vs 3); however, all three patients with arrhythmias under inotropic therapy received dobutamine. Seventy-six percent of patients were on antiarrhythmic medication mainly with beta-blockers and amiodarone. Compared to patients without antiarrhythmic therapy, no change in rhythm disturbances was observed. **Interference of BIA and CIED** In 104 patients with a CIED (103 ICD/CRT, one pacemaker), no inappropriate shocks or CRT/pacemaker malfunctions were recorded during or	

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	The primary endpoint was defined as any kind of change in heart rhythm that was either clinically apparent or noted during the surveillance, appropriate or inappropriate CIED actions and/or alarms, disturbances in flow or performance of the cf-VAD during the BIA measurement or within 30 minutes thereafter. Arrhythmias during the first 24 hours after the measurement were defined as a secondary endpoint.						after the measurement, regardless of the location (left or right) measured. Furthermore, no difference was observed with regard to the device manufacturer: 37 (35.7%)Medtronic, 28 (26.9%) Biotronik, 17 (16.4%) Boston Scientific and 12 (11.5%) St. Jude Medical/Abbott. Three patients were supported by external devices (LifeVest, Zoll); here, too, no rhythm disturbances occurred. No oversensing or undersensing was recorded in the telemetric surveillance. **Interference of BIA and VAD** No technical problems occurred during the BIA measurement in 95 cf- VAD patients, regardless of whether the left or the right side of the body was measured. No irregularities in cf-VAD flow or technical alarms were recorded, regardless of the manufacturer.	

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3. Meyer P, Makhlouf AM, Engkolo LPM et al. Safety of Bioelectrical Impedance Analysis in Patients Equipped With Implantable Cardioverter Debrillators. Journal of Parenteral and Enteral Nutrition, SAGE Publications (UK and US). 2016. In press. <10.1177/0148607116633823>. <hal-01282334> SWITZERLAND	**Prospective Cohort Study** **Objective:** To test the occurrence of EMI in a setting where this risk was experimentally maximized. **Method:** This was a single-center prospective study examining potential EMI between BIA and ICDs. During 3 months, consecutive outpatients scheduled for routine ICD controls at the device clinic of the Geneva University Hospitals were included in the study. Patients who were pacemaker-dependent or aged < 18 years were excluded from the study. As there were no previous reports of EMI between ICDs and BIA in the literature we could not calculate a sample size for our study. We tested the hypothesis that there would be no EMI detected between BIA and ICD in a larger population		63 patients (54 men, 9 women)	Bio-electrical impedance analysis			63 patients (54 men) were included with a mean age of 64.8 ± 14.6 years, mean LVEF of 32.1 ± 16.5% and mean BMI of 27.9 ± 4.8 kg/m2. Primary prevention was the main ICD indication (62%), a CRT being implanted in more than half of the patients. Other patients' characteristics are detailed in the table. The different ICD manufacturers and models are listed in the table. Five major companies were represented: Medtronic (n=20), Boston scientific (n=15), St-Jude (n=13), Biotronik (n=11), Sorin Group (n=4). Table 3 details the maximum programmable sensitivity for right atrial, right ventricular and left ventricular electrodes according to each manufacturer. No EMI were detected by the ICDs during BIA measurements assessed at three current frequencies in the 63 participants. Further, no artefacts were visualized during the EGM recordings in any of the ICDs.	

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	equipped with a wider range of different ICD manufacturers and models compared to previous studies. During ICD interrogation by a cardiologist (LPM) all patients underwent body composition measurements using BIA by a specifically trained Ph.D. student (AMM). This protocol was approved and accepted as part of a quality control study by the Geneva University Hospitals Ethics Committee. All subjects volunteered for the study.							

Evidence Table : Organisational issue
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Bibliographic citation	Study Type / Methodology	LE	Number of patients and patient characteristics	Intervention	Comparison	Length of follow up (if applicable)	Outcome measures/ Effect size	General comments
1. Sbrignadello S, Gobl C, Tura A. Bioelectrical Impedance Analysis for the Assessment of Body Composition in Sarcopenia and Type 2 Diabetes. Nutrients. 2022; 14 (1864). SWITZERLAND	**Systematic review of cross sectional studies** **Objective:** To analyse the studies using BIA for body composition analysis in T2DM patients with sarcopenia or at risk of catching it. **Method:** The search of scientific literature was performed in PubMed. The indicated search strategy yielded 103 articles and ended with a set of 40 articles after analysing them.	I	40 articles	Bio-electrical impedance analysis			The relevant methodological aspects related to bio-electrical impedance analysis examination was summarised in the figure.	