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Clinical use of bioelectrical impedance analysis in patients affected by myotonic dystrophy type 1: A cross-sectional study

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ABSTRACT

Objectives: Myotonic dystrophy type 1 (DM1) is an inherited muscle disorder characterized by slowly progressive weakness due to muscle degeneration. The Muscular Impairment Rating Scale (MIRS) is validated to assess clinical muscle severity of patients with DM1, although the scale is not sensitive enough to assess disease progression in time intervals fit for clinical trials. The aim of this study was to analyze bioelectrical whole body and arm segmental parameters in patients with DM1 to explore a correlation between bioelectrical impedance analysis (BIA) parameters and disease stage.
Methods: Forty patients with DM1 were enrolled in a cross-sectional study. In all patients, MIRS, handgrip strength (HGS), and BIA were assessed. A Kruskal–Wallis test was used to assess the difference in continuous variables according to MIRS. Correlation between BIA values and HGS were made by Pearson's coefficient analysis. A linear regression analysis was performed.
Results: Eighteen of 40 patients were men (45%). The median age of the cohort was 42 y (30–58 y). Four patients (10%) were classified as MIRS 1; 20 (50%) MIRS 2; 11 (27.5%) MIRS 3; and 5 (12.5%) as MIRS 4. A correlation was observed between phase angle and MIRS ($P = 0.0001$). MIRS correlated with other BIA values such as resistance, impedance ratio, and capacitance ($P = 0.005$, $P = 0.0001$, $P = 0.0006$, respectively). At linear regression analysis, segmental resistance, phase angle, impedance ratio, and capacitance of both arms significantly correlated with HGS.
Conclusions: Results from the study support the use of BIA as a suitable procedure for staging DM1 muscle involvement and as a measure of muscle disease outcome, in clinical practice and in clinical trial design of therapeutic drugs.

Introduction

Myotonic dystrophy type 1 (DM1) or Steinert's disease is the most common form of adult-onset muscular dystrophy, with an estimated prevalence of about 1 in 8000 in Europe. It is an autosomal dominant inherited disease, caused by a pathologic expansion of a polymorphic CTG unstable repeat in the 3′UTR of the *DMPK* gene. From a clinical point of view, DM1 is a multisystem disease with a nonuniform clinical severity, including muscle symptoms such as myotonia, an impaired muscle relaxation after a voluntary contraction; and progressive muscle weakness typically affecting the cranial muscles, the distal limb muscle compartment, the axial, and the respiratory muscles. Other affected tissues include the heart, the central nervous system, the endocrine

Conflicts of interest: The authors declare that they have no conflicts of interest.

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system, the eyes, and the gastrointestinal tract [1]. Regarding muscle involvement, limitations in mobility or walking are common in patients with DM1, although the need for a wheelchair is not [2]. Genotype–phenotype studies documented a direct correlation between the number of the CTG in leukocytes and the severity of muscle impairment [3], which instead shows an inverse correlation with the age of symptom onset [4,5].

The Muscular Impairment Rating Scale (MIRS) was originally proposed by Mathieu et al. [3] as a disease-specific staging system, and it is currently and widely used in clinical practice to assess the severity of muscle impairment in patients with DM1. It is an ordinal 5-point rating scale, filled out by a trained observer (generally a neurologist) evaluating the clinically recognized distal-to-proximal progression of the muscular involvement, based on a manual muscle testing (MMT) assessed on 11 muscle groups [3].

On the other hand, as objective measures in the studies for diagnosis and staging of muscle impairment in patients with DM1, dual-energy x-ray absorptiometry (DXA) and handgrip strength test (HGS) have been employed to evaluate whole and regional body muscle composition and muscle function, respectively [6,7]. However, to our knowledge, none of these validated outcome measures of skeletal muscle involvement have been shown to be sensitive enough to detect any significant changes in patients with DM1 within a time span of 12 mo, and thus would not be fit as outcome measures for therapeutic trials [8].

Recently, the use of bioelectrical impedance analysis (BIA) has increased in clinical practice as a safe, reliable, and easy-to-perform tool for evaluating body composition changes in several clinical settings [9–11]. The BIA procedure is based on the principle that the passage of an alternate electric current in a body may find an impedance related to the patient's body composition [12]. The impedance (Z) to the passage of a current through the body consists of two components: resistance (R) and reactance (Xc), with R deriving from extracellular water (ECW) and intracellular water (ICW) content (water and electrolytes), and Xc arising from cell membranes and tissue interfaces. The relationship between R and Xc is expressed by a single parameter called phase angle (PhA), which has been largely accepted as a prognostic marker of body cell mass (BCM) and an indicator of cell membrane function [13,14]. PhA depends on R and Xc, according to the following formula:

$$\mathrm{PhA} = \arctan(\mathrm{Xc}/\mathrm{R}) \times (180/\pi).$$

The objectives of this cross-sectional study were as follow:

- Analyze the whole body and arm segmental bioelectrical parameters in patients affected by DM1 using a multifrequency (MF) BIA apparatus.
- Explore a possible correlation between whole body PhA and stage of disease as assessed by MIRS.
- Explore a possible correlation between segmental PhA, measured alternatively in both arms, and muscular function using HGS.

Material and methods

This was a cross-sectional, pilot clinical study conducted on a recruited cohort of 40 patients with DM1. Inclusion criteria were age ≥18 y, ascertained molecular diagnosis of DM1, and not carriers of implanted cardiac devices (pacemaker). Patients were progressively enrolled from May 2017 to September 2018, either at the ambulatory setting or during hospitalization at the Neurology Unit of Fondazione Policlinico "A. Gemelli" IRCCS (Rome, Italy).

The study protocol included the following:

- Clinical assessment of skeletal muscle disease severity, performed by the same physician by the MMT [15] and classified according to MIRS (3): MIRS 1 (no muscular impairment); MIRS 2 (minimal signs, such as myotonia, jaw and temporal wasting, facial weakness, neck flexor weakness, ptosis, nasal speech); MIRS 3 (distal weakness); MIRS 4 (mild to moderate proximal weakness); and MIRS 5 (severe proximal weakness).
- Nutritional assessment carried out by specialized dietitians: For each patient, demographic data, body weight, height and body mass index (BMI) were collected. Body weight was obtained using a professional balance beam scale with height rod (Seca 700 Physician's Balance, Seca, Germany) with patients not wearing shoes. BMI was calculated as weight divided by height squared (kg/m^2). The Nutritional Risk Screening (NRS) 2002, endorsed by European Society for Clinical Nutrition and Metabolism was performed to estimate nutritional risk and consisted of a two-phase test investigating nutritional status (1–3 points) and severity of disease (1–3 points). An additional point was added to the final score if the patient was >70 y of age. A numerical score of <3 stands for "no nutritional risk"; ≥3 identifies patients at nutritional risk, who are in need of a nutritional assessment and care plan [16].
- Assessment of HGS using a hand dynamometer (DynEx12-0455 Digital Hand Grip, Akern Srl, Florence, Italy) according to accepted standards [17]. Three measures were obtained from each patient, and the mean HGS was calculated.
- BIA measurement was carried out using the MF-BIA Bodystat Multiscan 5000 (Bodystat LTD, Isle of Man), a phase-sensitive bioimpedance device. The instrument directly measures Xc, R, and PhA through specifics in the electronic circuitry (direct measures; not calculated). The device also calculated the impedance ratio (IR), which is the ratio between the impedance Z measured at 200 and 5 kHz [18], according to the formula:

  $$\mathrm{IR} = (\mathrm{Z\ at\ 200\ kHz})/(\mathrm{Z\ at\ 5\ kHz})$$

  and cell membrane capacitance (C), which corresponds to the ratio of charge collected on the conductor to the potential of the conductor [19]. C is linked to R according to the formula:

  $$\mathrm{R} = 1/2 \times \pi \times \mathrm{frequency} \times \mathrm{C}.$$

  Whole body and segmental measures of each arm alternatively were obtained with patients lying supine on the bed, with arms not touching the torso (trunk) and legs not touching at the thigh [20]. We used low inherent impedance electrodes, as recommended by Lukasky et al. [12], specifically made for Bodystat (electrode conformity agreement is available, on request from the manufacturer).

This research was carried out according to the Declaration of Helsinki. The protocol was approved by the local Ethical Committee. As requested, an informed consent was provided to patients. The study was written according to the STROBE Statement for cross-sectional studies [21].

Statistical analysis

Data were collected and shared in an Excel spreadsheet. Statistical analysis was performed using STATA Version 14 (Stata Corporation; College Station, TX, USA). A Kolmogorov–Smirnov test was used to assess whether continuous variables had a normal distribution. Given the small population of the study, nonparametric analyses were performed. Continuous variables are reported as median (interquartile range); discrete variables as number (percentage). A Kruskal–Wallis test was used to assess the difference in continuous variables according to MIRS. Correlation between BIA values and HGS were made with Pearson's coefficient analysis. A linear regression analysis was performed to create a model between the same variables. Type I (α) error was set at 0.05. Statistical significance was defined when $P < 0.05$ (two-tailed).

Results

From May 2017 to September 2018, forty patients were considered eligible and enrolled. Of these, 18 (45%) were men. Median age was 42 y (30–58). According to NRS-2002, only five patients (12.5%) were at risk for malnutrition (NRS-2002 = 3). Median BMI was 25.5 kg/m^2 (21.6–27.1). At neurologic visit, four patients (10%) were classified as MIRS 1; 20 (50%) as MIRS 2; 11 (27.5%) as MIRS 3; 5 (12.5%) as MIRS 4; and none were classified as MIRS 5. Median HGS values were 10.5 (4.7–16.9) and 9.6 kg (4.7–17.2), respectively in right and left arm (Table 1). Whole body BIA revealed PhA, IR, and C respectively of 4.1° (2.6–4.9), 0.848 (0.831–0.899) and 1389.3 pF (769.7–1877.3). Both whole body and segmental measures are reported in Table 2. We found a significant association between all whole body BIA-derived values and MIRS classes: At

Table 1
Patient characteristics

Patients enrolled (N = 40)		
	n (%)	Median (IQR)
Male	18 (45)	
Age, y		42 (30–58)
NRS-2002		
0	8 (20)	
1	7 (17.5)	
2	20 (50)	
3	5 (12.5)	
Height, m		1.64 (1.58–1.74)
Weight, kg		66.8 (58–74)
BMI, kg/m^2		25.5 (21.6–27.1)
MIRS		
1	4 (10)	
2	20 (50)	
3	11 (27.5)	
4	5 (12.5)	
5	0 (0)	
Right HGS, kg		10.5 (4.7–16.9)
Left HGS, kg		9.6 (4.7–17.2)

BMI, body mass index; HGS, handgrip strength; MIRS, Muscular Impairment Rating Scale; NRS, Nutritional Risk Screening

Table 2
Whole body and arm segmental BIA values

	Median (IQR)
Whole body	
R, Ω	628.3 (558–719.8)
Xc, Ω	42.1 (35.3–50.1)
PhA °	4.1 (2.6–4.9)
IR	0.848 (0.831–0.899)
C, pF	1389.3 (769.7–1877.3)
Right arm	
R, Ω	314.3 (254.7–371.5)
Xc, Ω	20.5 (18.3–25.7)
PhA °	4.2 (3.2–4.9)
IR	0.861 (0.831–0.888)
C, pF	2570.3 (1322.6–4270)
Left arm	
R, Ω	332.4 (262.8–372.9)
Xc, Ω	20.3 (16.7–23.6)
PhA °	3.8 (2.8–4.2)
IR	0.865 (0.839–0.887)
C, pF	2053.7 (1595.4–2592.9)

BIA, bioelectrical impedance analysis; C, capacitance; IR, impedance ratio; PhA, phase angle; R, resistance; Xc, reactance

MIRS 1, PhA median value was 5.9° (5.1–6.1), at MIRS 2, median PhA is 4.6° (4.1–5), at MIRS 3, 3° (2.5–4), at MIRS = 4, 2° (1.8–2.1; $P = 0.0001$). Additionally, a strong statistical correlation with MIRS was found with other BIA values such as R, IR, and C ($P = 0.005$, $P = 0.0001$, and $P = 0.0006$, respectively; Table 3). At linear regression, segmental R, PhA, IR, and C of right and left arms significantly correlated with HGS (Table 4).

Discussion

One of the unmet needs regarding the clinical research about DM1 is the individuation, in relation to slow disease progression occurring in such a disorder, of a fit and sensitive tool able to measure small changes in a relatively short time span, as is usually needed in therapeutic trials. The quantified muscular testing (QMT) and the MMT are included among the outcome measures of muscle impairment, widely applied by neurologists in clinical practice and research. QMT measures the level of maximum voluntary isometric force of a muscle group in a given position using a dynamometer. MMT does not require any technical equipment as it is manual according to the Medical Research Council (MRC) scale [15]. The results of both tests rely on patient cooperation, and in the case of MMT on the strength opposed by the examiner, which might influence the score assignment, particularly for MRC scores >3.

In DM1, the MIRS scale. which relies on MMT, was validated as a measure of global muscle severity outcome, useful for the clinical practice at baseline and in the long-term follow-up; indeed, MIRS has been used for most clinical studies in patients with DM1, especially for those studies concerning genotype–phenotype correlations.

As mentioned previously, the main issue is that in patients with DM1, the decline in skeletal muscle strength is very slow, so that MTT, HGS, or other functional disability methods are not sensitive enough to measure significant changes over a 12-mo period [2]. MIRS would allow the detection of changes occurring over a 3- to 4-y period; therefore, it cannot be used to assess the efficacy of therapies in trials lasting up to 24 to 36 mo [7,8].

Moreover, the individual variability of the natural history of DM1, related to the underlying genetic defect associated with this disorder, represents the other issue limiting the use of outcome measures for muscle impairment successfully applied in other neuromuscular disorders. Finally, other disease manifestations (i.e., the presence of muscle myotonia together with cognitive and behavioral problems) might affect patient compliance, thus influencing the reliability of measures using objective tools such as the handheld dynamometer.

Therefore, we decided to assess BIA in a cohort of patients with DM1 in parallel with other outcome measures (MIRS, HGS), to verify its potential role as a quick and reliable objective measure of muscle involvement.

BIA is a non-invasive, inexpensive, and easy-to-perform method for measuring electrical characteristics of cell membranes. BIA methods are single frequency (SF) and MF. The most used in clinical practice is SF. A low-level alternate current generated by a phase-sensitive impedance instrument passes throughout the whole body within a tetrapolar surface electrode system (two electrodes on the hand and two electrodes on the foot, on the same side). Current finds an impedance (Z) penetrating cell membrane and tissue interfaces, expressed as phase shift or PhA, mostly measured at the frequency of 50 kHz (SF-BIA). It depends on R, relying on resistive components (water and electrolytes; at SF mainly ECW) and on Xc, which reflects the capacitative properties of tissues (cells and tissue interfaces); PhA has been considered an index of cell membrane (structural and/or functional) integrity and vitality [12]. PhA positively correlates with lean body mass (LBM) and BCM and is inversely related to the ratio of ECW to ICW in healthy adults, which is higher in critical conditions such as disease-related malnutrition or fluid overload [22]. A low PhA is a negative prognostic factor in several clinical settings, ranging from chronic diseases to acute illness, and has been demonstrated to negatively affect morbidity and mortality [23–25].

In MF-BIA, current passes at several frequencies (5, 50, 100, 200–500 kHz), depending on the device: At frequencies <50 kHz, R depends on the ECW, whereas at higher frequencies, it also evaluates ICW, given the capacity of current to pass through cell membranes. Thus, MF-BIA devices are able to measure the ratio between high (200 kHz) and low (5 kHz) frequency Z (Z at 200 kHz)/(Z at 5 kHz), also called IR. A high IR has been associated with low lumbar muscle mass and greater risk for malnutrition [12,18,26].

The application of the BIA method goes beyond the clinical settings. Many reports in sport science have investigated the relationship between BIA parameters and muscle hypertrophy among

Table 3
Whole body BIA parameters and correlation with MIRS

	MIRS 1	MIRS 2	MIRS 3	MIRS 4	*P*-value
R	484 (424–603)	588 (543–639)	712 (628–794)	868 (693–1033)	0.005
Xc	50 (38–64)	46 (41–55)	37 (34–43)	28 (24–31)	0.001
PhA	5.9 (5.1–6.1)	4.6 (4.1–5.0)	3.0 (2.5–4.0)	2.0 (1.8–2.1)	0.0001
IR	0.788 (0.777–0.814)	0.838 (0.820–0.847)	0.884 (0.857–0.899)	0.919 (0.915–0.925)	0.0001
C	2748 (2731–3025)	1703 (1352–2007)	948 (736–1367)	296 (167–499)	0.0006

BIA, bioelectrical impedance analysis; C, capacitance; IR, impedance ratio; MIRS, Muscular Impairment Rating Scale; PhA, phase angle; R, resistance; Xc, reactance

healthy individuals and in particular among athletes. BIA values, and in particular higher PhA values, have been correlated to BCM, muscle mass, and higher performance and are significantly different among normal individuals and amateur and professional athletes [27,28]. Given the reliability of this technique in investigating BCM in several contexts, we are confident that this method can be shifted to the monitoring of DM1.

The present study showed a strong correlation between whole body BIA values and clinical stage, according to MIRS. Moreover, at linear regression analysis, the segmental BIA values of the right and left arms showed a significant association with functional muscle capacity, measured with HGS. To our knowledge, this was the first report, to demonstrate that BIA-derived parameters correlate with the clinical staging of Steinert's disease.

In the present cohort, only a few patients (12.5%) were at risk for malnutrition. Also, mean BMI was normal. BMI in the normal range could be explained by the progressive increase of fat mass (FM) with a concomitant decrease in fat-free mass (FFM) both in the trunk and the arms, as observed in studies analyzing body composition through DXA [6,7]. In patients with DM1, muscle tissue is progressively replaced by fibrosis and fat. A relationship between metabolic disturbances and fat accumulation in DM1 has been suggested [6]. Insulin resistance is a hallmark in this disease and is probably linked to a skeletal muscle reduction of insulin receptor RNA and protein expression, due to an altered splicing of the insulin receptor premRNA [29]. This, in turn, increases the expression of 11 β-hydroxysteroid dehydrogenase type 1 (cortisone reductase) in adipose tissue, whose activity in myotonic dystrophy has been positively associated with obesity [30]. On the other hand, a probable mechanism of muscle wasting in DM1 could be explained through an abnormal postabsorptive and insulin-stimulated regulation of protein breakdown due to low plasma insulin-like growth factor 1 concentration and higher tumor necrosis factor α receptor 2 [4].

Table 4
Correlation between segmental BIA values in right and left arms values and HGS

	Pearson's coefficient		Model		
	Coefficient	*P*-value	Coefficient (95% CI)	*P*-value	R^2
Right arm					
R	−0.589	0.004	−0.067 (−0.11 to −0.02)	0.004	0.347
Xc	0.111	0.622	0.168 (−0.53 to 0.87)	0.62	0.012
PhA	0.574	0.05	4.03 (1.35 to 6.72)	0.005	0.329
IR	−0.655	0.0009	−0.002 (−0.004 to −0.001)	0.001	0.429
C	0.716	0.0006	0.003 (0.002 to 0.005)	0.001	0.513
Left arm					
R	−0.698	0.0003	−0.081 (−0.12 to −0.04)	<0.0001	0.487
Xc	0.298	0.178	0.59 (−0.29 to 1.49)	0.178	0.089
PhA	0.829	<0.0001	6.78 (4.65 to 8.91)	<0.0001	0.689
IR	−0.788	<0.0001	−0.003 (−0.004 to −0.002)	<0.0001	0.621
C	0.791	<0.0001	0.004 (0.002 to 0.005)	<0.0001	0.626

BIA, bioelectrical impedance analysis; C, capacitance; HGS, handgrip strength; IR, impedance ratio; PhA, phase angle; R, resistance; Xc, reactance

The patients in the present study affected by DM1 also had mean HGS values below the normative population values [31]. This evidence is in agreement with Bouchard et al., who reported mean values of 9.1 ± 6 kg (range 0–26) and 15.5 ± 14 kg (range 0–66), respectively, fo women and men affected by DM1 [2]. The reduction in HGS values is directly correlated with the reduction of FFM and the increase of FM [7].

We hypothesized that PhA could be a reliable tool for the evaluation of LBM and BCM in Steinert's disease. Indeed, it has a close correlation with disease stage according to MIRS. To date, the gold standard techniques used to investigate body composition are the DXA and a computed tomography (CT) scan at the third lumbar vertebral level [32,33]. However, these tools are not frequently used in clinical practice given the employment of x-rays. Moreover, DXA-assessed lean tissue mass does not discriminate between muscle mass (metabolically active) and fibrosis, which is still represented as lean tissue [6]. BIA data, on the contrary, are based on the electrical potential of healthy cell membranes. We thus argue that BIA-derived PhA could be a safe, reliable, and quick tool to investigate LBM (metabolically active) in DM1. At the same time, IR revealed a significant correlation with MIRS. This could be useful when using MF devices [21]. Moreover, we found a significant correlation between C and clinical staging. As previously mentioned, C is the ratio of charge collected on the conductor over the potential of the conductor. Recently, C was proposed as a prognostic indicator of survival in patients with head and neck cancer. [19]. We suggest reckoning C as a potential prognostic factor if further studies will continue to indicate healthy cell membranes as efficient electrical capacitors.

Several studies showed a significant correlation between BIA and DXA-derived data in terms of body composition [34,35]. In a recent work, Yang et al., reported a high correlation between the two methods in healthy Korean adults [36]. However, wide limits of agreement between DXA and BIA have been detected when applied to patients affected by heart failure and the issue is still under debate [37].

We are not able to speculate about the histologic or physical changes of muscle mass based only on the BIA method. In our opinion, other techniques such as CT scan or magnetic resonance imaging or DXA could be more reliable for this purpose. However, on the basis of our observations, we can argue a progressive and detectable reduction of BCM and a worsening of membrane electrical properties across incremental stages of MIRS in DM1. In our opinion, this could be useful to justify the clinical use of BIA in patients with DM1, also for the lack of subjective interpretation biases of this method.

Further studies are warranted, due to the small sample size of the present study population, and also to estimate prospective changes of these aforementioned bioelectrical variables according to disease progression. However, the present study may be considered as a pilot experience that could begin a debate on the use of BIA as a reliable instrumental procedure for investigating bioelectrical parameters in similar and possibly larger patients groups for

evaluating disease stage. This kind of information could be translated also in the setting of clinical trials.

Conclusions

The present study demonstrated, in a cohort of 40 patients affected by DM1, a significant correlation between BIA values and disease staging according to MIRS and HGS. Given the spread and feasibility of BIA in the clinical settings, such evidence could open several perspectives such as the monitoring of diseases at the bedside and the implementation of prognostic score in clinical trial design of therapeutic drugs.

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References

[1] Harper PS. Myotonic dystrophy. London, UK: WB Saunders Co; 2001.
[2] Bouchard JP, Cossette L, Bassez G, Puymirat J. Natural history of skeletal muscle involvement in myotonic dystrophy type 1: a retrospective study in 204 cases. J Neurol 2015;262:285–93.
[3] Turner C, Hilton-Jones D. The myotonic dystrophies: diagnosis and management. J Neurol Neurosurg Psychiatry 2010;81:358–67.
[4] Perseghin G, Comola M, Scifo P, Benedini S, De Cobelli F, Lanzi R, et al. Postabsorptive and insulin-stimulated energy and protein metabolism in patients with myotonic dystrophy type 1. Am J Clin Nutr 2004;80:357–64.
[5] Mathieu J, Boivin H, Meunier D, Gaudreault M, Bégin P. Assessment of a disease-specific muscular impairment rating scale in myotonic dystrophy. Neurology 2001;56:336–40.
[6] Pruna L, Chatelin J, Pascal-Vigneron V, Kaminsky P. Regional body composition and functional impairment in patients with myotonic dystrophy. Muscle Nerve 2011;44:503–8.
[7] Sedehizadeh S, Brook JD, Maddison P. Body composition and clinical outcome measures in patients with myotonic dystrophy type 1. Neuromuscul Disord 2017;27:286–9.
[8] Petitclerc É, Hébert LJ, Mathieu J, Desrosiers J, Gagnon C. Lower limb muscle strength impairment in late-onset and adult myotonic dystrophy type 1 phenotypes. Muscle Nerve 2017;56:57–63.
[9] Rinninella E, Cintoni M, De Lorenzo A, Anselmi G, Gagliardi L, Addolorato G, et al. May nutritional status worsen during hospital stay? A sub-group analysis from a cross-sectional study. Intern Emerg Med 2019;14:51–7.
[10] Uccella S, Mele MC, Quagliozzi L, Rinninella E, Nero C, Cappuccio S, et al. Assessment of preoperative nutritional status using BIA-derived phase angle (PhA) in patients with advanced ovarian cancer: correlation with the extent of cytoreduction and complications. Gynecol Oncol 2018;149:263–9.
[11] Pineda-Juárez JA, Lozada-Mellado M, Ogata-Medel M, Hinojosa-Azaola A, Santillán-Díaz C, Llorente L, et al. Body composition evaluated by body mass index and bioelectrical impedance vector analysis in women with rheumatoid arthritis. Nutrition 2018;53:49–53.
[12] Lukaski HC, Kyle UG, Kondrup J. Assessment of adult malnutrition and prognosis with bioelectrical impedance analysis: phase angle and impedance ratio. Curr Opin Clin Nutr Metab Care 2017;20:330–9.
[13] Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, et al. Composition of the ESPEN Working Group. Bioelectrical impedance analysis—part I: review of principles and methods. Clin Nutr 2004;23:1226–43.
[14] Rinninella E, Ruggiero A, Maurizi P, Triarico S, Cintoni M, Mele MC. Clinical tools to assess nutritional risk and malnutrition in hospitalized children and adolescents. Eur Rev Med Pharmacol Sci 2017;2:2690–701.
[15] Daniels L, Worthingham C. Muscle testing: technique of manual examination. Philadelphia PA: WB Saunders Co; 1986.
[16] Kondrup J, Allison SP, Elia M, Vellas B, Plauth M. Educational and Clinical Practice Committee, European Society of Parenteral and Enteral Nutrition (ESPEN). ESPEN guidelines for nutrition screening 2002. Clin Nutr 2003;22:415–21.
[17] Flood A, Chung A, Parker H, Kearns V, O'Sullivan TA. The use of hand grip strength as a predictor of nutrition status in hospital patients. Clin Nutr 2014;33:106–14.
[18] Rinninella E, Cintoni M, Addolorato G, Triarico S, Ruggiero A, Perna A, et al. Phase angle and impedance ratio: two specular ways to analyze body composition. Ann Clin Nutr 2018;1:1003.
[19] Małecka-Massalska T, Mlak R, Smoleń A, Brzozowska A, Surtel W, Morshed K. Capacitance of membrane as a prognostic indicator of survival in head and neck cancer. PLoS One 2016;11:E0165809.
[20] Ling CH, de Craen AJ, Slagboom PE, Gunn DA, Stokkel MP, Westendorp RG, et al. Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in middle-aged adult population. Clin Nutr 2011;30:610–5.
[21] STROBE statement. Available at: https://www.strobe-statement.org/index.php?id=strobe-home. [Accessed 16 July 2019].
[22] Gonzalez MC, Barbosa-Silva TG, Bielemann RM, Gallagher D, Heymsfield SB. Phase angle and its determinants in healthy subjects: Influence of body composition. Am J Clin Nutr 2016;103:712–6.
[23] da Silva TK, Berbigier MC, Rubin Bde A, Moraes RB, Corrêa Souza G, Schweigert Perry ID. Phase angle as a prognostic marker in patients with critical illness. Nutr Clin Pract 2015;30:261–5.
[24] Belarmino G, Gonzalez MC, Torrinhas RS, Sala P, Andraus W, D'Albuquerque LA, et al. Phase angle obtained by bioelectrical impedance analysis independently predicts mortality in patients with cirrhosis. World J Hepatol 2017;9:401–8.
[25] Axelsson L, Silander E, Bosaeus I, Hammerlid E. Bioelectrical phase angle at diagnosis as a prognostic factor for survival in advanced head and neck cancer. Eur Arch Otorhinolaryngol 2018;275:2379–86.
[26] Kuchnia A, Earthman C, Teigen L, Cole A, Mourtzakis M, Paris M, et al. Evaluation of bioelectrical impedance analysis in critically ill patients: results of a multicenter prospective study. JPEN J Parenter Enteral Nutr 2017;41:1131–8.
[27] Micheli ML, Pagani L, Marella M, Gulisano M, Piccoli A, Angelini F, et al. Bioimpedance and impedance vector patterns as predictors of league level in male soccer players. Int J Sports Physiol Perform 2014;9:532–9.
[28] Giorgi A, Vicini M, Pollastri L, Lombardi E, Magni E, Andreazzoli A, et al. Bioimpedance patterns and bioelectrical impedance vector analysis (BIVA) of road cyclists. J Sports Sci 2018;36:2608–13.
[29] Savkur RS, Philips AV, Cooper TA. Aberrant regulation of insulin receptor alternative splicing is associated with insulin resistance in myotonic dystrophy. Nat Genet 2001;29:40–7.
[30] Johansson A, Andrew R, Forsberg H, Cederquist K, Walker BR, Olsson TJ. Glucocorticoid metabolism and adrenocortical reactivity to ACTH in myotonic dystrophy. Clin Endocrinol Metab 2001;86:4276–83.
[31] Werle S, Goldhahn J, Drerup S, Simmen BR, Sprott H, Herren DB. Age- and gender-specific normative data of grip and pinch strength in a healthy adult Swiss population. J Hand Surg 2009;1:76–84.
[32] Day K, Kwok A, Evans A, Mata F, Verdejo-Garcia A, Hart K, et al. Comparison of a bioelectrical impedance device against the reference method dual energy x-ray absorptiometry and anthropometry for the evaluation of body composition in adults. Nutrients 2018;10. pii: E1469.
[33] Rollins KE, Javanmard-Emamghissi H, Awwad A, Macdonald IA, Fearon KCH, Lobo DN. Body composition measurement using computed tomography: Does the phase of the scan matter? Nutrition 2017;41:37–44.
[34] Fakhrawi DH, Beeson L, Libanati C, Feleke D, Kim H, Quansah A, et al. Comparison of body composition by bioelectrical impedance and dual-energy x-ray absorptiometry in overweight/obese postmenopausal women. J Clin Densitom 2009;12:238–44.
[35] Gupta N, Balasekaran G, Victor Govindaswamy V, Hwa CY, Shun LM. Comparison of body composition with bioelectric impedance (BIA) and dual energy x-ray absorptiometry (DEXA) among Singapore Chinese. J Sci Med Sport 2011;14:33–5.
[36] Yang SW, Kim TH, Choi HM. The reproducibility and validity verification for body composition measuring devices using bioelectrical impedance analysis in Korean adults. J Exerc Rehabil 2018;14:621–7.
[37] Alves FD, Souza GC, Biolo A, Clausell N. Comparison of two bioelectrical impedance devices and dual-energy x-ray absorptiometry to evaluate body composition in heart failure. J Hum Nutr Diet 2014;27:632–8.