

THE USEFULNESS OF THE BIOELECTRICAL IMPEDANCE VECTOR ANALYSIS

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ABSTRACT. Bioimpedance vector analysis (BIVA) is valid for body composition analysis both in healthy and pathological population. It is a useful method to evaluate tissue hydration. BIVA is particularly suited to follow hydration states in haemodialysis, to analyse emergency and ICU conditions, as well as optimize nutritional or physical activity programs.

Keywords: *bioelectrical impedance vector analysis, usefulness, body composition, hydration.*

REZUMAT. Utilizarea analizei vectoriale prin bioimpedanță. Analiza vectorială prin bioimpedanță (BIVA) este validă pentru analizarea compoziției corporale atât la populația sănătoasă și la cea bolnavă; este o metodă utilă în evaluarea hidratării tisulare. BIVA este deosebit de potrivit pentru a urmări stări de hidratare în hemodializă, pentru a analiza condiții de urgență și ATI, precum și optimizarea programelor de activități nutriționale sau fizice.

Cuvinte cheie: *analiza vectorială prin bioimpedanță, utilitatea, compoziția corporală, hidratare.*

Introduction

Bioimpedance vector analysis (BIVA) is a useful method to evaluate tissue hydration (Piccoli, 1994; Dumler, 2003; Savastano, 2010; Espinosa Cuevas, 2010; Erdogan, 2013).

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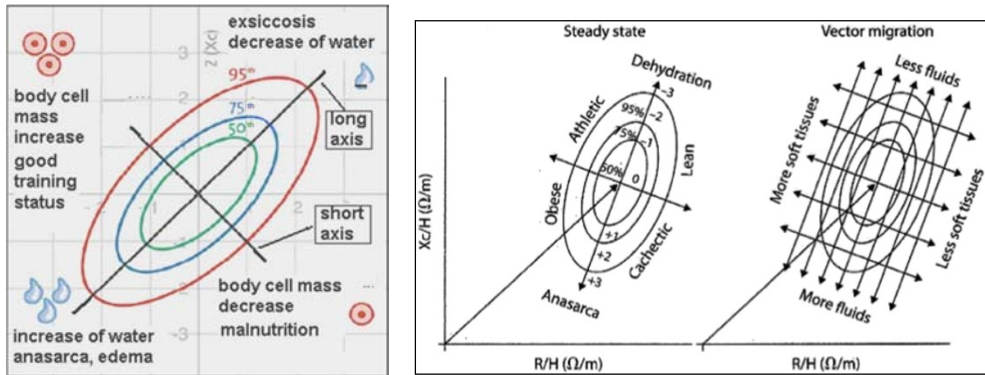
BIVA results are very easy to interpret. As previously discussed, fluids are good conductors, so the length of vector, which represents the body's impedance, is inversely related to fluid volume. Moreover, several studies have agreed to define the 75% tolerance ellipse as the boundary of normal volume status. Consequently, vectors outside the upper pole of the 75% tolerance ellipse indicate dehydration, whereas vectors outside the lower pole of the 75% tolerance ellipse represent over hydration or fluid overload. Thus, a short vector is associated with a fluid overload condition and oedema, while a longer one with a dehydration condition (Di Somma, 2014).

The RXc graph method was used to identify bivariate pattern distributions of mean vectors (95% confidence ellipses by sex, age, and body mass index), and individual impedance vectors (50%, 75%, and 95% tolerance ellipses) (Piccoli 2002; Norman, 2009).

Comprehensive Body Composition Analysis with Bodygram PRO: Resistance (Rz) in Ohms; Reactance (XC) in Ohms; Phase angle (PA) in degrees; Bio-active cell mass (BCM) in kilograms and percent; Total body water (TBW) in liters and percent; Extra cellular water (ECW) in liters and percent; Intra cellular water (ICW) in liters and percent; Fat free mass (FFM) in kilograms and percent; Fat mass (FM) in kilograms and percent; Muscle mass (MM) in kilograms and percent; Sodium/Potassium exchange and Basic Metabolic Rate (BMR) in kilocalories/kilojoules. An the graphical one-glance evaluation by: BiaVector® for the assessment of nutritional and hydration status and BiaGram enhancing the assessment of hydration state.

The test itself takes only a few seconds. Preparing the test and performing the evaluation with take a total of three to five minutes.

Impedance vector analysis enables classification (under-, normal and overhydration) and ranking of hydration (more or less than before intervention), as well as soft-tissue mass, for an individual by examining the position of the vector relative to a healthy reference population. Vector position on the RXc graph is interpreted relative to the two directions on the RXc plane. Vector displacements parallel to the major axis of tolerance ellipse indicate progressive changes in tissue hydration; dehydration is associated with long vectors outside of the upper region of 50% tolerance ellipse, and fluid overload with apparent oedema is characterised with short vectors out of the lower pole of the 50% ellipse. Peripheral vectors in the left side of the major axis, or in the right side of the major axis, of tolerance ellipse indicate more or less cell mass, respectively.



The length of the impedance vector is inversely related to TBW, and the combination of the vector length and its direction, defined as the phase angle, is an indicator of tissue hydration status (Stahn, 2012).

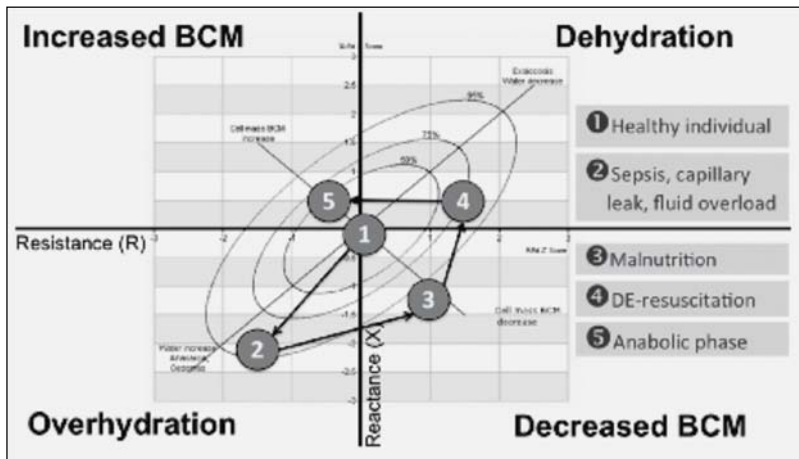


Fig. 3. BIVA-status (Malbrain, 2014)

The usefulness of the bioelectrical impedance vector analysis

The essential fundamentals of bioimpedance measurement in the human body and a variety of methods are used to interpret the obtained information. In addition there is a wide spectrum of utilization of bioimpedance in healthcare

facilities such as disease prognosis and monitoring of body vital status. Furthermore, there are comprehensive literatures, which analyse this topic. There are researches in cardiology (Di Somma, 2014), geriatrics (Buffa, 2014; Camina Martín, 2014), nephrology (Espinosa Cuevas, 2010; Teruel-Briones, 2012; Erdogan, 2013), pediatrics (Guida, 2008; Margutti, 2012), nutrition (Wright, 2008; Buffa, 2009; Marini, 2012).

However, several studies have suggested that the window of tolerance for hyper- or dehydration may vary in patients with different diseases (Di Somma, 2014). A positive fluid balance is a predictor of hospital mortality (Lansen, 2016).

Guida et al. in their observational study involving 464 healthy 8-year-old children draw the conclusion, that the BIVA may be useful for clinical purposes due to ability to detect changes in hydration or body composition in children (Guida, 2008).

Espinosa Cuevas M.A. et al. in their studies suggest that vector-BIA offers a comprehensive and reliable reproducible means of assessing both volume and masses at the bedside and can complement the traditional method (Espinosa Cuevas, 2010).

Norman et al. observed: BIVA has been shown to provide information about hydration and body cell mass and therefore allows assessment of patients in whom calculation of body composition fails due to altered hydration. BIVA is recommended for further nutritional assessment and monitoring, in particular when calculation of body composition is not feasible (Norman, 2012).

BIVA should be used with caution for evaluating body composition in the elderly. Specific bioelectrical values proved effective, showing promise as a methodological variant of BIVA, suitable for identifying age-related changes in body fatness (Marini, 2013).

The association between the impedance index and total body water was not modified by hydration status, which may support the utilization of leg-to-leg bioimpedance for the assessment of body composition in the very old (Siervo, 2015). Additionally, errors are minimized by using the BIVA as there is no need for the subject to be normally hydrated and it does not require the use of predictive models.

Saragat et al. obtain reference values for the healthy elderly Italian population, and they need to study age- and sex-related differences in body composition. Specific tolerance ellipses can be used for reference purposes for the Italian population when assessing body composition in gerontological practice and for epidemiological purposes (Saragat, 2014). Ibáñez et al. in their researches highly emphasize the need for new specific tolerance ellipses that can be used as references for assessing body composition in young adults from Western Mediterranean populations (Ibáñez, 2015).

In healthy elderly, impedance vectors clearly indicate the age associated reduction of soft tissue, particularly after the age of 80. X_c/H and phase angle decrease with age in both men and women. In patients with Alzheimer disease, mean vector position was significantly different in the patients with mild-moderate Alzheimer disease with respect to controls, indicating lower soft tissue. Women with severe Alzheimer disease also showed both reduced tissue mass and dehydration when compared with patients with mild-moderate disease severity (Norman, 2012).

BIVA detected muscle-mass variations in sarcopenic individuals, and specific BIVA was able to discriminate sarcopenic individuals from sarcopenic obese individuals. These procedures are promising tools for screening for presarcopenia, sarcopenia, and sarcopenic obesity in routine practice (Marini, 2012).

Piccoli et al. observed, that the agreement between BIVA and central venous pressure indications was good in the high central venous pressure group (93% short vectors), moderate in the medium central venous pressure group (35% normal vectors), and poor in low central venous pressure group (10% long vectors). The combined evaluation of intensive care unit patients by BIVA and central venous pressure may be useful in therapy planning, particularly in those with low central venous pressure in whom reduced, preserved, or increased tissue fluid content can be detected by BIVA (Piccoli, 2000).

In conclusion, the above mentioned studies emphasize the usefulness of the value of BIVA in physiological and clinical conditions. Over hydration was identified in late pregnancy and postpartum, as well as in weight-reduced obese adults with BIVA, and validated with isotope dilution methods. The use of BIVA improved the prescription of ultrafiltration in dialysis by monitoring the backward-forward displacement of vectors in relation to the wet-dry cycle of haemodialysis, and enhanced decision-making in dialysis by facilitating the interpretation of alterations in blood pressure relative to hydration status and thus adjusting ultrafiltration. Recent evidence supports the use of BIVA in the assessment of volume overload in patients with acute heart failure and discriminating pulmonary compared with cardiac dyspnoea, as well as its importance in guiding individualised volume reduction therapy because of its high sensitivity and specificity. Importantly, the combination of BIVA assessment of hydration status in conjunction with measurements of brain natriuretic peptide significantly decreased readmission rates of patients discharged with a diagnosis of heart failure (Lukaski, 2007). Further work is needed to determine how BIVA can be used to guide the management of fluid states in advanced cancer (Nwosu, 2014).

The RX_c graph method could be useful in the planning of the individual climber's appropriate dehydration and fluid intake at altitude since a feedback control of the hydration is allowed without any assumption of body composition (Piccoli et al, 1996).

According to Maughan and Shirreffs the dehydration, if sufficiently severe, impairs both physical and mental performance, and performance decrements are greater in hot environments and in long-lasting exercise. Athletes should begin exercise well hydrated and should drink during exercise to limit water and salt deficits. Many athletes are dehydrated to some degree when they begin exercise. During exercise, most drink less than their sweat losses, some drink too much and a few develop hyponatraemia. Athletes should learn to assess their hydration needs and develop a personalized hydration strategy that takes account of exercise, environment and individual needs. Pre-exercise hydration status can be assessed from urine frequency and volume, with additional information from urine colour, specific gravity or osmolality. Changes in hydration status during exercise can be estimated from the change in body mass: sweat rate can be estimated if fluid intake and urinary losses are also measured (Maughan, 2010).

Table.1. Measured parameters before and after the exercise dehydration plus cooling session (Gatterer, 2014)

	Pre	Post	p-value
body mass (kg)	72.29±6.34	70.78±6.18	<0.001
Posm (mOsm/kg)	295.5±4.4	301.6±3.0	<0.001
Hct (g/dl)	45.7±3.5	47.4±2.7	0.033
R/H (Ω /m)	284.1±23.0	298.0±26.0	<0.001
Xc/H (Ω /m)	37.5±3.3	39.8±3.2	<0.001
vector length	286.6±23.1	300.6±26.0	<0.001
skin temperature ($^{\circ}$ C)	29.3±1.1	28.8±1.3	0.105

* Plasma osmolarity (Posm), resistance divided by body height (R/H), reactance divided by body height (Xc/H).

Gatterer et al. in your study demonstrates that the BIVA graph reflects fluid loss after exercise within this specific setting. The lengthening of the vector along the major axis of the tolerance ellipse indicates fluid loss and is supported by the finding that the length of the vector is inversely related to TBW (Lukaski, 2012; Gatterer, 2014). Conversely also body mass measurements might have led to erroneous body fluid balance estimates. Even though body changes are usually considered to be useful in detecting short term body hydration changes, several exercise-related factors, such as sweat rate, respiratory water loss and oxidative water production may lead to substantial body mass loss without an effective net negative fluid balance. Beside body weight changes, plasma osmolarity (Posm) is proposed as an adequate dehydration marker, despite controversy regarding its specificity and sensitivity to detect dehydration.

In conclusion this study demonstrated that BIVA changes convincingly mirrors water loss within an exercise and heat induced fluid loss trial. Additionally $\Delta X_c/H$ values, reflecting changes in intracellular fluid content, might be useful to evaluate fluid shifts between compartments. However more studies are needed to establish if BIVA can be considered a reliable method for monitoring hydration status (Gatterer, 2014).

Mala et al. purposed to identify and compare the body composition (BC) variables in elite female athletes (age \pm years): volleyball (27.4 ± 4.1), softball (23.6 ± 4.9), basketball (25.9 ± 4.2), soccer (23.2 ± 4.2) and handball (24.0 ± 3.5) players. The results did not indicate any significant differences in percentage of fat mass (FMP) or α among the tested groups ($p > 0.05$). Significant changes in other BC variables were found in analyses when sport was used as an independent variable. Soccer players exhibited the most distinct BC, differing from players of other sports in 8 out of 10 variables. In contrast, the athletes with the most similar BC were volleyball and basketball players, who did not differ in any of the compared variables. Discriminant analysis revealed two significant functions ($p < 0.01$). The first discriminant function primarily represented differences based on the fat-free mass (FFM) proportion (volleyball, basketball vs. softball, soccer). The second discriminant function represented differences based on the extracellular water (ECW) proportion (softball vs. soccer) (Mala, 2015).

Contemporary applications of bioimpedance emphasise the value of bioimpedance variables per se in some novel biomedical applications with the objective of identifying opportunities for future outcome-based research (Lukaski, 2013).

Furthermore, another review is directed to define the efficacy of BIVA for assessing two-compartment body composition. A systematic literature review using MEDLINE database up to 12 February 2014 was performed. The list of papers citing the first description of BIVA, obtained from SCOPUS, and the reference lists of included studies were also searched. Specific BIVA is a promising alternative to classic BIVA for assessing two-compartment body composition, with potential application in nutritional, sport and geriatric medicine (Buffa, 2014).

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