

Bioimpedance: PHASE ANGLE

NUTRITIONAL STATUS PROGNOSTIC INDICATOR

www.bodystat.com



BIOELECTRICAL IMPEDANCE ANALYSIS (BIA)

Introduction

Bioelectrical Impedance Analysis (BIA) measures body composition by running a series of alternating electrical currents (AC Circuit) ranging from 5 kHz to 1 mHz, through the body.

These signals then interact differently with body cells and fluids, transmitting the potential difference (voltage) back to the BIA device. The resulting data is given as impedance (Ohms) which is a combination of resistance and capacitance data. Data obtained can be used either in its raw form or via a series of body composition regression equations. The raw data may be used in a number of ways, by studying capacitance, monitoring the impedance ratio (or Prediction Marker) or utilising Phase Angle. This brochure examines Phase Angle, how it is derived and the medical applications.

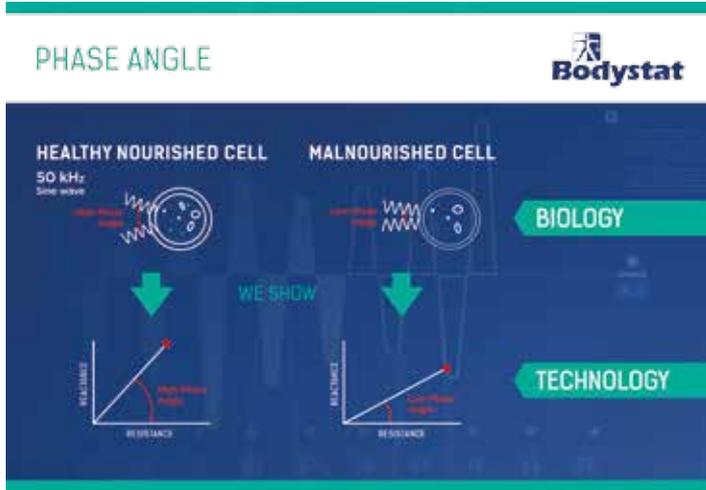
Phase Angle in brief:

Impedance is a ratio of the magnitude of potential difference to the magnitude of current. The phase shift is given by the time difference between voltage and current signal waves. From this we obtain the phase angle. phase angle is the time relationship between the electrical current passing through the body and the potential difference invoked by this current across body tissue.

Bodystat is unique in that it MEASURES phase shift (as opposed to calculating), which is important in clinical practice.

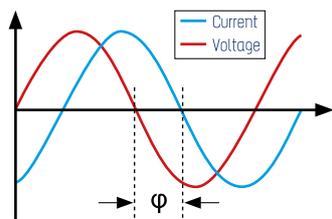
How does this apply in clinical practice?

The phase angle reflects the relative contribution of body fluid (resistance) and cellular membrane integrity (capacitance). Malnutrition reduces cellular membrane mass and integrity and promotes shifts in fluid balance. As a consequence of these changes the phase angle decreases. Conversely, a higher phase angle implies larger body cell mass and preserved membrane integrity.



WHAT IS PHASE ANGLE?

Laws of physics dictate the calculation of phase angle. In a capacitor AC (impedance) circuit, reactance of the current through cells causes the current to lag behind the voltage; consequently, current (blue) and voltage (red) do not meet at the same time. The time difference in the period between this voltage peak and current peak is called the phase shift.

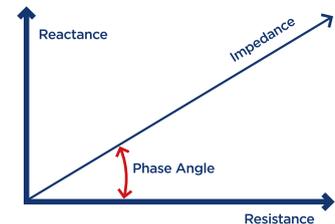


Current flows by the movement of ions; movement impeded by the viscosity of the medium is known as resistance and measured in Ohms. It should be noted that the human body does not adhere to Ohm's Law (Current = Voltage / Resistance) due to the presence of dielectrics (or insulators) in the body. Groups of cells perform specialised functions and form part of a complex communicative network, sending signals throughout the body via an ion concentration or gradient. These electromagnetic gradients or dielectrics absorb some of the current causing the cells to become electronically charged, an essential function for cellular survival. It is these cells that store electricity that act as capacitors (measured in Farad F).

The impedance obtained by the BIA device is a combination of capacitive and resistive type elements, the calculation of which is shown opposite. Consequently, BIA measures resistance (R) and capacitance in combination. Reactance (Xc) is subsequently calculated from capacitance and representative of the opposition to the electrical current or voltage. Furthermore, the phase shift is always relative

to the resistance line as the resistance line is always in phase with the voltage. When the device receives this signal it is 'decoded' using a series of electronics called synchronous demodulators. This is why the quality of the electronics within the device is fundamental in obtaining accurate and consistent measurements.

Once the phase shift data is received, a series of complex number equations are then applied to derive the resistance and the reactance and thus the Impedance measurements (refer to figure). From this the phase angle (ϕ) is calculated.



$$\phi = \text{Arctangent} \times \left(\frac{\text{Reactance}}{\text{Resistance}} \right)$$

Bioelectrical Impedance Analysis calculates body composition by measuring resistance (R) and reactance (Xc) (through capacitance). By recording the voltage drop between the applied current and the two output sites, the phase shift is measured and the phase angle calculated.

SO HOW DOES PHASE ANGLE RELATE TO CELLULAR HEALTH

AND HOW DOES THIS HELP THE MEDICAL PROFESSION?

Consider the diagram.

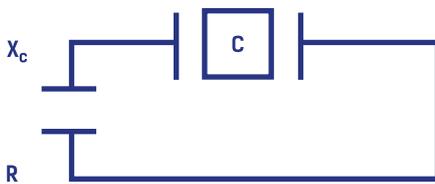


Illustration of current pathways

The current enters the 'circuit' (in this case the body), and faces a number of different obstacles called capacitors (C) (in this example body cells). This either will allow the current to pass through (R) or will impede the flow of the current (X_c).

In a healthy cell, as the cellular gradient improves, more nutrients and salts enter the cell therefore intracellular fluid, increases and cells become healthier. The healthier the cell the stronger the cellular membrane (i.e. cellular insulation), with an improved ability to retain fluids, nutrition and communication properties. Healthy cell membranes are poor conductors but good capacitors (Remember: ability to retain current) at the frequency range used by bioelectrical impedance analysis.

KEY POINT

The greater the cell's capacitance, the greater the difference in phase shift between voltage and the current. Consequently the higher the phase angle.

KEY POINT

A low phase angle is indicative of diminished cellular integrity and thus a reduced survival time. Equally, a higher phase angle suggests larger quantities of intact cell membranes and thriving health.

In electromagnetic terms, the current at 5 kHz has not been strong enough to penetrate the cellular membrane. This resistance is associated with a measure of extracellular water. When the current enters the cell at a high frequency, the reactance (Remember: reactance calculated from capacitance) to the current is associated with a measure of intracellular water.

The greater the cell's capacitance, the greater the difference in phase shift between voltage and current. Consequently, the higher the phase angle. Equally, when the cell has less ability to store electrical current, the capacitance of the cell membrane is lower and the phase shift lower. The degradation of the cellular membrane is due to shifts in the gradient, that is, cellular losses of essential nutrients. This protein leakage is commonly associated with illness and muscle wasting. Conversely, the integrity of the cell membrane can be greatly improved with nutritional intervention and resistance-type training programmes.

TO SUMMARISE: Phase angle is positively associated with capacitance and negatively associated with resistance. That is, phase angle reflects the relative contribution of fluid (resistance) and cellular membranes (capacitance) of the human body.



POINTS TO CONSIDER

- + Phase Angle provides information regarding an individual's cellular health. The greater the data points collected, the better informed the physician in their clinical decisions
- + Phase Angle is independent of age, weight or body fat, given the characteristics of cellular capacitance (therefore phase angle)
- + It is also widely accepted that male phase angle tends to be significantly higher than females, due to differing physiology (i.e. fat to lean ratios).

"Phase Angle, BIVA and the Prediction Marker™ are obtained directly from resistance, reactance or impedance, and evidence in the literature indicated that they could be used as prognostic or nutritional markers."

ESPEN, "Blue" Book, *Basics in Clinical Nutrition* Fourth Edition Page 20 (2011)

A PROGNOSTIC INDICATOR

Phase Angle is commonly accepted as a prognostic indicator of morbidity and mortality. As health status changes, so does the relationship between Intra/extracellular water. With bioelectrical impedance analysis measurements, volume of TBW can be ascertained from the resistance, in turn reactance reflects the ability of the cell membrane to act as an imperfect capacitor. Therefore the phase angle is an indicator of the intra and extra cellular area. This relationship is represented by changes in the phase angle. A low phase angle is associated with a reduced survival time, conversely a higher phase angle is associated with improved cellular health.

This has been demonstrated in various population groups including oncology, HIV, liver cirrhosis, COPD, heart failure, haemodialysis and sepsis.

Additionally, muscle strength and phase angle correlate which is suggestive of a lower phase angle being associated with decreasing functioning status.

NUTRITIONAL STATS

Many research papers have examined the relationship between phase angle and malnutrition and have found a correlation between low phase angle and higher nutritional risk. Population groups used in both research and clinical practice include nephrology, HIV, oncology and surgical patients.

Bioelectrical Impedance Analysis is becoming a preferred method to establish and monitor malnutrition. Alternative methods, such as blood tests, arm circumferences and skin-fold tests are time consuming, require training and maybe affected by other nutritional changes. Traditional methods may also miss subtle changes in body cell mass (intracellular water and metabolic tissue).

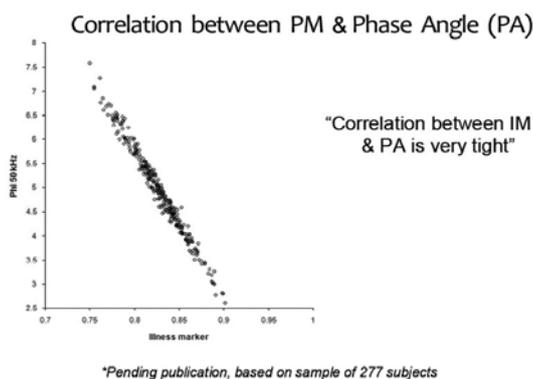
Malnutrition is characterised by changes in the integrity of the cellular membrane, marked by fluid shifts. Study of phase angle, as a reflection of water distribution between ICW/ECW water, is an easy, quick, non-invasive way to ascertain nutritional status.

AN ALTERNATIVE METHOD

THE PREDICTION MARKER™

The Prediction Marker or impedance ratio, is simply the ratio of raw impedance values. We know that at a low frequency this is not strong enough to penetrate the cellular membrane and therefore gives the extracellular water. Higher frequencies allow penetration of the cellular membrane and therefore give total body water. The Prediction Marker is simply the ratio between the high and low frequencies. This is considered a more 'pure' form of data, and as a direct measurement, i.e. devoid of complex numbers and equations. Many research papers have recognised this as a substitute for phase angle and it is thought to be more accurate in oedematous patients as phase angle only uses 50 kHz.

Recent research papers on the Prediction Marker suggest that not only is the correlation between the Prediction Marker and phase angle 'very tight' but that it is also easier to use in a clinical situations as well as easier to understand and explain the origins of the data. As with phase angle, the Prediction Marker is a non-invasive, objective, direct, quick method to determine nutritional status and morbidity risks in patients. It can also be used on any population, age or gender and is independent of weight or height.



GLOSSARY

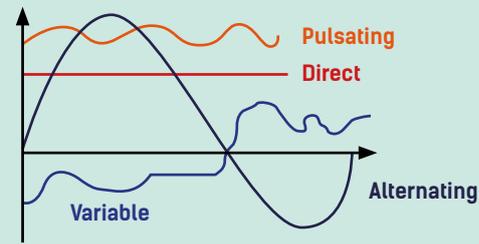


Illustration of different types of current

ELECTRICAL CIRCUITS 101

An electric circuit, in this case the body, is simply a path in which the electrons from a voltage or current supply flow. The voltage is often considered to be the cause, whilst the current is the effect. In other words, the voltage is a measure of energy carried by the charge and the current is the rate of flow of the charge.

There are various types of electrical current (shown above). Bioelectrical Impedance Analysis uses an alternating current (AC), this means that an AC also flows in a reverse direction, while, for example a direct current (DC) only flows in one direction. The data received is measured in the form of impedance. Impedance consists of resistance, capacitive reactance (reflective of capacitors in the circuit) and inductive reactance (reflective of inductors). BIA is concerned with capacitive resistance which reflects how the electrical charge builds up and how it is subsequently discharged. This information is then used to understand the type of cellular opposition that the current encounters. Resistance is an imaginary number derived from a mathematical equation, whereas reactance, the 'real' element of capacitance, reflects the cells opposition to the flow of the electrical current and is only present with AC type devices.

TERMINOLOGY

Body Cell Mass (BCM): Metabolic active tissue - intracellular fluid and metabolic tissue.

Demodulators: This is an electronic circuit that is used to translate the information from a carrier wave, i.e. the sinusoidal wave from the voltage and current flow.

Extracellular Mass (ECM): Metabolic Inactive tissue - extracellular fluid, fat, skeletal mass (bone and tendons).

Viscosity: a measure of resistance in fluid, the denser the fluid the higher the viscosity.

Dielectrics: An electrical insulator, therefore a poor conductor of electricity.

Clinical Nutrition **31**
(2012) 854-861

“Bioelectrical phase angle and impedance vector analysis – Clinical relevance and applicability of impedance parameters”

“PhA, a superior prognostic marker, should be considered as a screening tool for the identification of risk patients with impaired nutritional and functional status, BIVA is recommended for further nutritional assessment and monitoring, in particular when calculation of body composition is not feasible.”

Anja Bosy-Westphal, et al.
Institut für Humanernährung und Lebensmittelkunde, Christian-Albrechts-Universität Kiel, Germany; Institut für Ernährungsmedizin, Universität Hohenheim, Stuttgart, Germany

Clinical Nutrition **32** (2013) 294-299

“Low Phase Angle determined by bioelectrical impedance analysis is associated with malnutrition and nutritional risk at hospital admission”

“There is a significant association between low PhA and nutritional risk, LOS and non-survival. PhA is helpful to identify patients who are at nutritional risk at hospital admission in order to limit the number of in-depth nutritional assessments.”

Claude Pichard, et al.
Clinical Nutrition Department, Geneva University Hospital, Geneva, Switzerland.

European Journal of Clinical Nutrition **68**,
683-689 (June 2014)

“A low bioimpedance phase angle predicts a higher mortality and lower nutritional status in chronic dialysis patients”

“These results suggest that bioelectrical impedance analysis and phase angle measurements are a useful tool for identifying dialysis patients at high risk for malnutrition and/or increased mortality.”

Francis Dumler MD
Division of Nephrology, William Beaumont Hospital, Royal Oak, MI, USA

ABOUT BODYSTAT

Bodystat Ltd, based on the Isle of Man (British Isles), has been established since 1990 and is a registered ISO 13485:2003 company. We specialise solely in BIA Technology and are dedicated to expanding the knowledge of this to improve health and well-being. We have an extensive range of research papers (available on our website) dedicated solely as non-commercial, free materials for educators.

Our devices are manufactured in Europe, made to the highest specifications and use only the best electrical components. The high quality of our devices ensures accurate results that are both reproducible and reliable.

Bodystat Limited

Ballakaap • Ballafletcher Road
Cronkbourne • Douglas
Isle of Man • IM4 4QJ • British Isles

Tel: **+44 (0) 1624 629571**
Fax: **+44 (0) 1624 611544**
Email: **info@bodystat.com**
Web: **www.bodystat.com**

Download free research papers from our website: www.bodystat.com

