Original Research Article

Microcurrent Frequencies' Effect on the Cell Membrane Potential

Abstract

Research shows that cellular and mitochondrial (ΔΨm) membrane potentials are strong indicators of cellular physiology. In this paper we review further research suggesting that microcurrent frequencies can positively influence both these membrane potentials. The goal of this research is to show how microcurrent might stimulate physiological potentials in order to support a healthy function of bioelectric fields of cells and organs. In the second part of the article, a study to examine the effects of microcurrent application on the body's response to electric measurements is presented, in particular to a change in voltage-current lag known as a phase angle. The test involved measuring bioimpedance of a person before and after a 30-minute application with microcurrent stimulation. Fifteen healthy subjects were examined through impedance measurements taken on one arm. The results showed a consistent increase in phase angle directly after the stimulation, confirming a widely accepted indication of health improvement on a cellular level. These results are encouraging and justify further investigations on the effect of microcurrent stimulation on the human body in relation to general cellular health and regenerative functions.

Keywords: Cell membrane potential, ATP, Bioelectric, Bioenergetic, Bioimpedance Analysis BIA, Phase Angle PA, Microcurrent Electrical Stimulation

Introduction

Effect of Microcurrent Frequencies on the Bioelectric Field of Cells and Tissues

Mannheimer (Mannheimer 2005) (Hood 2001) examined the effect of a large band of frequencies from 3 Hz to 130 Hz on the electrical potential of cells and tissues. The results obtained from Magnetic Resonance Spectroscopy (MRS) in a randomized double-blind placebo-controlled study, using pulsed biphasic microcurrent, show that specific fluctuating frequencies are positively affecting membrane potentials and the potential of the whole tissue by inducing increased cellular energy and a better bioelectrical "milieu" for the cells. A balanced electrical status is the basis for normal physiological cell function and inter-cell communication through the ECM (Extracellular Matrix) as an interface medium.

In his dissertation, Mannheimer states:

“Dissipation of the electrochemical gradient across the inner membrane stops the action of the F_1F_0 ATPase and hence decreases ATP synthesis (Hood 2001). Recent experimentation has demonstrated that almost all of the torque sufficient to generate ATP synthesis by the Na^+F_0 motor is due to the membrane potential and not pHi (Peter Dimroth 2000) (McCabe 2003). The F_0 motor converts the transmembrane gradient of Na^+ into a rotary Torque (protonation) that releases ATP and in the reverse direction (deprotonation) it functions as an ATP-driven NA^+ or H^+ pump (Peter Dimroth 2000).

It has been shown that the ATP synthesis rate becomes saturated at a frequency that exceeds 3Hz, which relates to the low end of the frequency window, but the maximal rotary speed of the F_0 motor is 130 Hz (Hiroyasu Itoh 2004).

The preceding physiological explanation is now recognized as the mechanism behind ATP synthesis triggered by electrical or electromagnetic micro-amperage stimulation at the cellular level.”

Mannheimer is referring to the positive effect of microcurrent frequencies on the membrane potential of mitochondria (where ATP synthesis takes place); a corresponding effect can be expected for cell membrane potential, which is closely related to the mitochondria’s membrane potential since cell membranes act as a “storage battery” for the distribution of electrons used to induce subcellular enzymatic reactions based on cell membrane depolarization events. Frequency-receptors mediate 2nd messenger systems like Ca_2^+ cAMP, etc., which then electrically and chemically activate mitochondrial membranes for ATP synthesis (Sten Orrenius 2015). Similar to the cell membrane, mitochondrial membrane potential generated by the electron-transport chain is the driving force behind ATP synthesis for mitochondrial membranes. This also plays a key role in mitochondrial homeostasis through selective elimination of dysfunctional mitochondria and is an essential component of mitochondrial calcium homeostasis. In fact, a distinctive feature of the early stages of apoptosis is the disruption of normal mitochondrial function. A collapse in the mitochondrial membrane and redox potential may induce unwanted loss of cell viability, thus paving the way for unhealthy tissues.

Successful modeling of the effect of an external electric field and microcurrent (up to 1000 µA) on cell membrane potential and ATP production has been reported by Lohrasebi, confirming that microcurrent induces an increase of the rotary frequency of the F0 motor, depending on the intensity of the electrical current (A. Lohrasebi 2008). This causes an increase in cellular potential and ATP production. As stated by Mannheimer:

“It will be seen that the application of the field, or the current, on the one hand, transforms the elasticity behavior of the cell membrane, and on the other hand introduces changes in the transmembrane potential, i.e. both the field and current have an effect on the production of the ATP molecules via influencing the dynamics of the membrane.”

“The results from all these experiments show an increase in the production of the ATP molecules as a result of the application of either an external electric field to the cell membrane or the stimulation of the membrane by an external microcurrent.

> "Summing up our results, we can state that when a constant electric field is applied to the membrane, the transmembrane potential can change – i.e. increase or decrease – and the surface tension of the membrane is reduced. Both these effects influence the production of the ATP molecule. Furthermore, at low voltages, the influence of the transmembrane potential is more pronounced than the influence of the change in the membrane surface tension. Moreover, we have found that when an electric current is applied, rather than a field, the rotational frequency always increases, promoting a corresponding increase in the ATP production." (A. Lohrasebi 2008)

According to Mannheimer, pulsed electric currents with specific frequencies influence cellular energy and electrical potential of cells and tissues in a positive way. Due to the close correlation of ultra-weak cell radiation to the bioelectricity of cells and tissues, the same microcurrent frequencies also positively influence the quantum field level of the entire electromagnetic network in the human body. Regarding cell radiation, F.A. Popp examined the coherence of ultra-weak biological electromagnetic emission as an indicator of coherent information exchange and communication at a cellular level. Interestingly, the frequency distribution of electrical potential on the skin corresponds to the coherence of the photons emitted by the same organs located below the skin (F.A.Popp 2002). This indicates that there is a close relationship between the ultra-weak cell radiation and the bioelectricity of cells and that of relative zonal tissues.

A harmonizing effect of microcurrent frequencies on the bioelectric field of the organism can be expected as a result of the increased coherence in the electromagnetic quantum field of the entire body.

The Cell Membrane Potential as the Basis of the Bioelectric Field

The electrical parameters of the cell in relation to electrical potentials of other physiological structures of the bodies of animals and humans were extensively studied by Becker (R O Becker 1965) and Nordenstrom (Nordenstrom 1983). There exist voltage potentials across all cellular membranes. Various tissues possess different electrical characteristics. In the last decades, it has been proven that all tissues produce or carry electrical potentials of different amplitudes (Tyler 2017). When the electrical potentials of several cells in a tissue are combined, a much higher voltage is generated and it can be measured in several ways as for example:

- on the surface of the brain using Electroencephalography (EEG)
- on muscles using Electromyography (EMG)
- on the heart using Electrocardiography (ECG)

Nordenstrom (Nordenstrom 1983) and Becker (Becker 1985) conducted extensive research on how electrical potentials of cell groups and tissues are responsible for different diseases or dysfunctions such as, among others:

- the decreased wound healing capacity
- dysfunctional immune system reaction
- ischemic pain caused by tissue hypoxia and acidosis

- inflammatory processes

Increased electrical conductivity has also been confirmed by several researchers through measurements of specific anatomical positions known as acupuncture points, well known in the classical Chinese representation of the bioelectric blueprint of the body (Lee 2005). Two Japanese researchers—Yoshio Nagahama (Nagahama 1950) and Hiroshi Motoyama (Motoyama 1997), as well as Langevin and Yandow (Langevin 2002), concluded that the meridian system is located in the electrical properties of the superficial fascia. Motoyama has demonstrated that what is called “Chi energy” in traditional Chinese Medicine is not simply the movement of ions through tissue, but is rather connected to the current of electrons in the tissues through anatomical connective tissue plans and related to amplitude and frequency of this electrical current.

The most important discovery brought by Becker was that injuries produce a so-called physiological “current of injury.”, meaning that an open wound reduces the electrical potential, allowing the tissues to become uncharged. He demonstrated that this effect can be counteracted by applying an electrical current of certain frequencies to wounded tissues in order to correct the electrical potential of the cells, triggering repair and restoring healthy cellular functions. Becker also demonstrated that increased microcirculation and inflammation locally cause reduced electrical resistance and an increased concentration of tissue NaCl. Decreased resistance allows higher electrical charges to move towards wounded areas. This interference with the sodium ion pump mechanism within the cells reduces their capacity to produce ATP, the very chemical energy that constitutes energy supply to the cells (Diamond 2001). Due to this lack of electrons in the extracellular space, decreased cell membrane potential, and reduced ATP production, cell membrane transport mechanisms through ion channels are degraded. When an ion channel is disturbed, the normal transport of nutrients to the cells and the disposal of metabolic waste is quickly impaired. Eventually, the decreased electrical cell membrane potential results in a quick cellular efficiency decline. When the cell membrane’s potential is restored, permeability increases, and a faster transfer of fluids and nutrients into the cells is achieved. This effect occurs when an electrical microcurrent with specific lower frequencies is applied to the disrupted area (Mannheimer 2005). According to Mannheimer, this effect depends on the frequency modulation of the microcurrent. Frequencies modulated onto an ultra-weak magnetic field can positively influence the cell membrane (Bauréus Koch CL 2003).

According to Robert Becker’s research colleague Arthur Pilla, any change in the environment of the cell that causes an increase or decrease of the membrane’s electrical potential can potentially alter cell function (Pilla 1983). He concludes that a cell can be stimulated with specific frequencies to restore the lost potential. A “window effect” has been discovered in this regard, expressing that a certain range of frequencies and amplitudes has the strongest effect (Escobar 2020) (Grosse 1992).

Early research by Nordenstrom and Becker has been confirmed by several more recent studies and publications dealing with cell membrane potential in different pathologies (Levin 2007).

Ming Yang and William J. Brackenbury (Yang 2013) published a "cell membrane potential scale" in mV, comparing the membrane potential of healthy cells with those of tumor cells. They collected their data from Binggeli and Weinstein (Binggeli 1986) and Fraser (Fraser 2005) and Yang et al. (2012).

Similar research conducted on tissues affected by ischemic pain and inflammation confirmed that during these pathological phases, a decreased cell membrane potential was present (Issberner 1996).

Michael Levin (Levin 2007) reviewed research on the influence of the cell potential and related bioelectrical parameters for the regeneration of cells. This paper graphically displays the multiple effects on cell electricity and shows another similar graph to scale the potentials of different kinds of healthy and pathological cells.

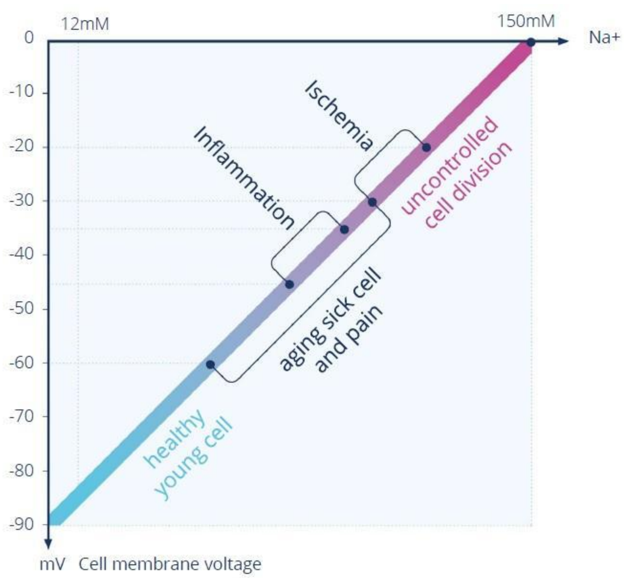

Figure 1 combines these findings with the original concept of Nordenstrom and Becker to develop a scale of the cell membrane potential and the sodium chloride concentration (Noma 1975) in the cell, relative to different pathological states. This diagram represents aging and pathological processes of the cell in relation to its bioelectric emission. A therapeutic process using frequency-modulated-microcurrent might support the cell membrane potential and thereby balance order, consistency and distribution of electrical potential, to achieve a coherent bioelectrical field.

Figure 1: Cell membrane potential versus concentration of Na^+-Ions as summarized from previously mentioned sources

Study design and Methods

Measurement

In this study, 15 subjects have been measured using the VitalSensor BIA-PAD Bioimpedance Analyzer, with the measurement current being set at 50 kHz. Electrodes were placed in a tetrapolar configuration Fig. 2 (left). Localized measurements were performed on the forearm with a distance of 20 cm between proximal electrodes. A distance of 1.5 cm is allowed between the distal and proximal electrodes. The subjects were instructed to refrain from food intake an hour before the measurement. Four distinct measurements were taken with the subjects in Fowler's position (a standard semi-sitting position at 45-60 degrees with straight knees), two before microcurrent application and two afterward. Each pair of measurements were interrupted by 5-minute intervals.

Figure 2: Electrode placement for BIA measurements (left) and microcurrent application (right)

Microcurrent application

Microcurrent applied during each session had a frequency of 50 Hz and the amplitude varied between 50 and 400 µA (randomly selected per subject).

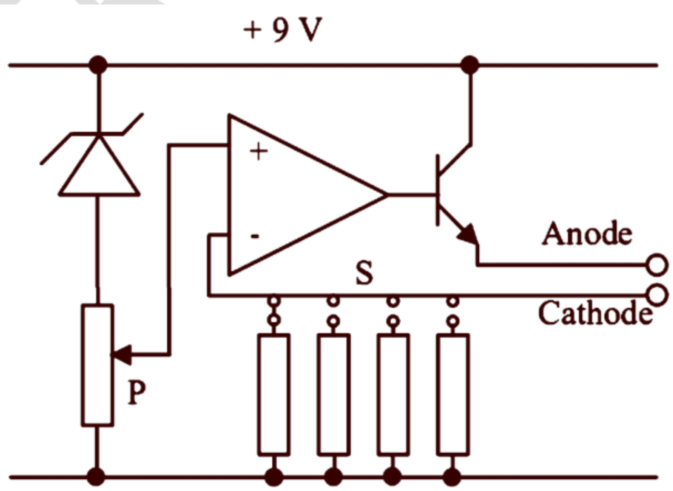

Figure 3 Schematic of the microcurrent application circuit used by a much cited study on microcurrent assisted ATP production (Cheng 1982)

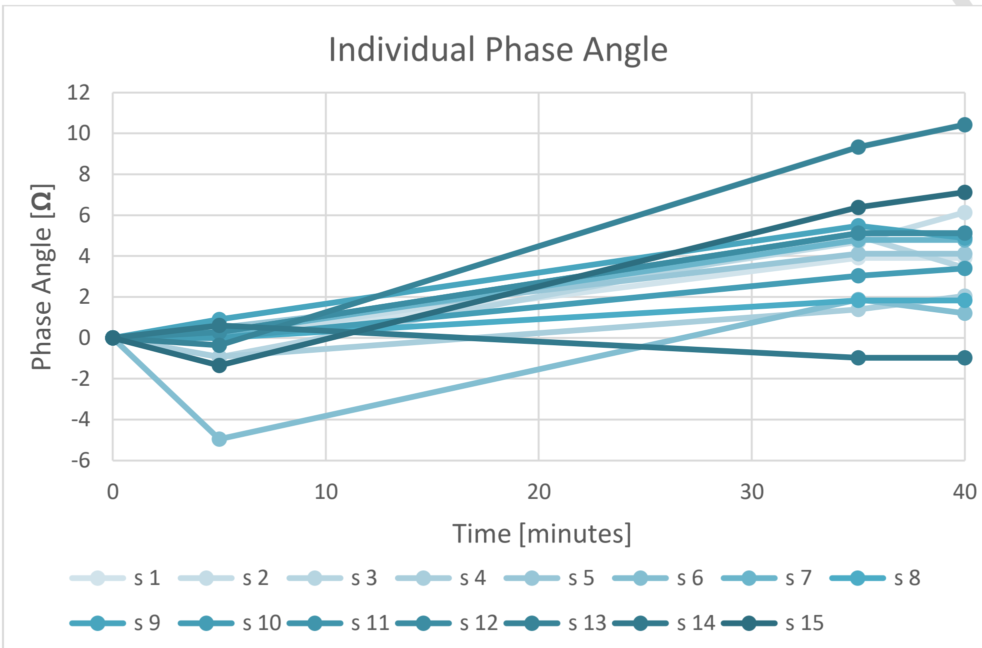

Figure 4: Results from measuring the PA for 15 subjects (s) before (at 0 and 5 minutes) and after (at 35 and 40 minutes) the microcurrent application.

As shown in Figure 4, a typical session presented a steady or even slightly decreased PA level between the first and second measurement during the first 5 to 10 minutes of rest in the experiment position. This shift can also be attributed to bodily fluids readjusting from being upright to the reclined Fowler's position.

Cumulative percentage of change in the subjects' PA level as a result of microcurrent application shows a relative change in PA across four BIA measurements, two before applying microcurrent and two measurements afterward. Following the 30-minute current application in a range between 50 and 400 µA, all but one of the subjects (93.3 %) showed a significant increase in the PA with an average of 4.4 % and a median of 4.6 % raise per subject. After microcurrent application, all subjects remained at rest. In this last phase, PA remained unchanged at an increased value.

	M1 (0 min)	M2 (5 min)	M3 (35 min)	M4 (40 min)

sub 1	10.21	10.21	10.61	10.61
sub 2	11.91	11.91	12.47	12.64
sub 3	8.45	8.37	8.87	8.74
sub 4	10.78	10.68	10.93	11
sub 5	6.08	6.11	6.33	6.33
sub 6	7.47	7.1	7.61	7.56
sub 7	10.03	10.05	10.51	10.51
sub 8	14.17	14.17	14.43	14.43
sub 9	10.03	10.12	10.58	10.52
sub 10	11.19	11.19	11.53	11.57
sub 11	7.22	7.24	7.59	7.59
sub 12	7.22	7.24	7.59	7.59
sub 13	8.25	8.22	9.02	9.11
sub 14	8.2	8.25	8.12	8.12
sub 15	8.15	8.04	8.67	8.73
average	**9.29**	**9.26**	**9.65**	**9.68**

Table 1. PA results for 15 subjects at measurements before (m1-2) and after (m3-4) microcurrent application and the percentage change in PA value between the m2 and m3 measurements

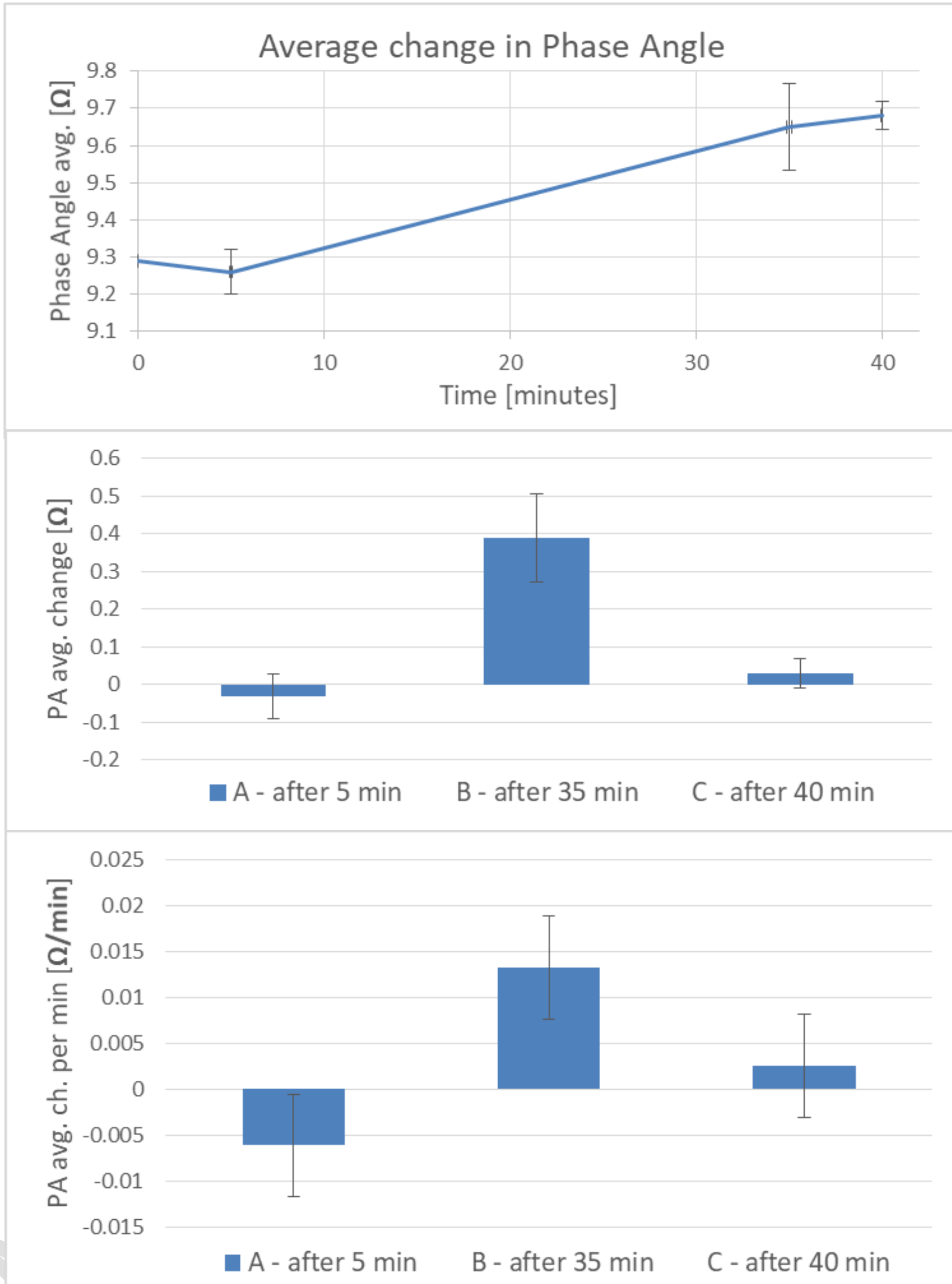

Figure 5. Average change in PA between 4 measurements in 15 sessions with different participants (top). Changes during the respective observational period (middle) A: after an initial rest and prior to application of microcurrent; B: after the application pf microcurrent; C: after post-application rest and respective change per minute (bottom).

Experimental results and Discussions

Bioimpedance Phase Angle

Bioimpedance Analysis (BIA) is a low-cost, noninvasive and reliable method, frequently used as a body mass index (BMI) assessment. BIA is considered to be an accurate predictor of cellular health, as it indicates the cell membrane's integrity and proper function (A. R. Streb 2020). Significant variations derive from changes caused by local and systemic inflammation, swelling, and local or systemic infection (T. K. Bera 2011) (A. D. Bauchot 2000). BIA has been also experimentally tested as a novel test biomarker for detecting cancerous cells since these produce uncontrolled intensified growth, vascular development and increased blood supply. Cancer cells display much lower impedance than of normal cells (Bera 2014).

Phase Angle (PA) ϕ is a component of bioimpedance, or more precisely the arctangent of the ratio between reactance (X) and resistance (R).

$$\phi = tan^{-1}\frac{X}{R}$$

The main contributions to resistance are the water and electrolyte content of tissues (both intra- and extracellular), and its value is constant across the frequency spectrum. Reactance is frequency-dependent and originates from the cell membrane's capacitance. It varies depending on the cell membrane’s integrity, function, and chemical composition (O. Di Vincenzo 2019).

PA measures the shift between the applied current and voltage caused by the cell membranes and tissue interfaces. The healthier the cell, the more voltage is delayed in relation to current and, as shown in many BIA study cases, the higher the PA value the greater the cell’s health (H. C. Lukaski 2017).

Microcurrent stimulation

In recent years there has been a growing trend to advance non-invasive methods addressing health improvement, preservation, and prophylaxis. Electro-stimulation therapy has been increasingly used as an adjuvant in physical rehabilitation, post-operative treatments, exercise, and athletic performance enhancement. Microcurrent stimulation is a valid candidate and an appropriate example for electrical stimulation utilizing weak electrical currents (in the range of microamperes), dosed to intensities similar to those occurring endogenously in tissues and cells that instigate regenerative mechanisms (Isseroff 2012). The role of specific microcurrents and frequencies and their role in overall health improvement is currently being actively researched. Shane Gilroy used BIA measurements to study the effects of microcurrent stimulation on the body's bioimpedance, showing moderate to significant positive changes in phase angle in 91 % of 34 subjects treated with frequency-specific microcurrent (Gilroy 2014).

Conclusion

Our presented study showed strong evidence that microcurrent stimulation positively affects PA, an overall indicator of cellular health. It is a promising outcome that opens the way for further investigation with different parameters to be applied to microcurrent stimulation and a wider investigation for electrical measurement techniques. Results obtained after Bioimpedance Analysis can be frequency-dependent and might vary when measured after several hours post-treatment. Additional studies with multifrequency impedance analysis such a Bioimpedance Spectroscopy are proposed for further investigation to obtain more complete characteristics of the observed positive phenomenon.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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