ISSN 0044-0507

www.ym-kdham.in

Vol. 48 | Issue 1 & 2 | Jan-Dec 2016

YOGA-MĪMĀṂSĀ

A journal of scientific and philosophico-literary research in Yoga

Published since 1924

Official Publication of
Kaivalyadhama

Medknow

Wolters Kluwer

Original Article

Bio-electrical activity: As a valid variable in yoga research

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Abstract

Background: The claims of ancient yogic text indicate that yoga practice leads to enhanced body awareness; however, the present research tool, as seen in research reviews, to measure such psychophysiological phenomenon aspect of body awareness has not been proven so far. Therefore, this study is taken to propose bio-electrical activity as a suitable experimental variable to quantify the awareness phenomena of yoga practices.

Objective: To explore conceptual plausibility for establishing a suitable cellular electrophysiological variable to quantify body awareness.

Method: The separate reviews of past research literature on both whole-body bio-electrical activity and human information processing (HIP) aspect of body awareness in relation to yoga were explored. The studies which indicate improvement in energy storage, energy circulation, and energy expenditure at cellular and somato-cortical levels were included in this review. Furthermore, studies indicating enhancement in brain abilities such as perception, attention, learning, and motor functions demonstrating that profile of bio-electrical activity may be a suitable parameter common to both quantification of body awareness and whole-body bio-electrical activity were included.

Results: The present study explores the bio-electrical energy dynamics of human consciousness. The bio-electrical response variables, such as impedance (Z), reactance (X_c), and relative arrival time of current (I), and voltage (V), measured as phase angle of the cell, have been proposed to be a valid tool to understand enhancing psychobiological basis of body awareness due to yogic practices.

Conclusion: The bio-electrical measure of cell activity reflects HIP aspect of awareness from cellular level to whole-body level.

Key Words: Bio-electrical activity, human consciousness, human information processing, psychobiology, yoga

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INTRODUCTION

Quantification of psychophysiological effects of yoga practices, in general, and that of subjective experiences of yoga, in particular, has been a controversial issue from the viewpoint of objectivity, verifiability, and validity of the related research findings. Similarly, yoga practice effects, related to bio-energy, corresponding to yogic experiences, have also been meagerly understood so far. Therefore, this study proposes a need for linking the energy-dependent cell sensitivity response with varying energy dynamics of the body. The extent of cell sensitivity response of the whole body, on vegetative

Access this article online	
Quick Response Code:	Website: www.ym-kdham.in
	DOI: 10.4103/0044-0507.198704

How to cite this article: Kulkarni DD, Bhogal RS, Verma A, Shete SU. Bio-electrical activity: As a valid variable in yoga research. Yoga Mīmāṃsā 2016;48:13-7.

level, is proposed to be directly proportional to the extent of the whole-body awareness.

This study attempts to suggest a possible role of cellular electrical activity in higher yogic practices such as meditation and pranayama. The cellular electrical activity is indicative of an interaction between cellular sensitivity and whole-body awareness. The understanding of this connectivity may prove to be helpful if we wish to establish the psychophysiological relationship between the energy dynamics and body awareness. As well, knowing the bio-electrical variable seems necessary to detect the exact nature of cellular sensitivity in a human system. The interaction between the body awareness and the cellular energy, on vegetative level, has been reported through measures of electrocardiogram (ECG), electroencephalogram (EEG) evoked potentials, electrodermal responses, and galvanic skin resistance (GSR) (Clinton, 1967). The above-mentioned references have amply indicated a possible correlation between body's electrical activity and specific physical and mental states, in higher yoga and meditational practices (Cahn & Polich, 2006; Kasamatsu & Hirai, 1966). However, the above studies have not established the electrical connectivity between the cellular activity and whole-body awareness responses. It was, therefore, hypothesized that the body awareness is an outcome of the integrated network dynamics of the whole-body cell sensitivity, regulated by the bio-electrical energy dynamics.

METHOD

For this conceptual study, the investigators identified various earlier studies indicating improvement in energy storage, energy circulation and energy expenditure at cellular and somato-cortical levels. Further, studies that explored variables such as perception, attention, learning and motor functions were analyzed to develop the concept of using bio-electrical activity as a variable in yoga research.

RESULTS AND DISCUSSION

The concept of awareness dynamics is, perhaps, too abstract for a modern physiologist to comprehend. However, the method adopted by the past researchers on correlating the bio-electrical variables with nutrition (Pinheiro, Esteves de Oliveira, Duarte, Esteves, & Bressan, 2011), in the context of cellular behavior, using alternating current (AC) stimulation (Grimnes & Martinsen, 2000), has prompted the present investigators to propose bio-electrical response as a valid variable in yoga research. Such an approach may help, plausibly, perceive interlink between the body awareness and the bio-electrical activity related to the cell response (Hillyard & Picton, 1979). It may help quantify body awareness within the framework of the increment in energy detection (IED) model of the human information processing (HIP) (Green & Swets, 1966). The quantification of body awareness through IED has already been proposed in case of the yogic relaxation in *Shavasana* (Kulkarni & Bhogal, 1991; Kulkarni, 1998; Kulkarni, 2002). This approach may also help establish a link between the cellular sensation and the cellular electrical activity of the brain (Grimnes, 1983). Modulation of cortical EEG responses due to meditation effects further supports the reasoning proposed above (Tikhe, Nagendra, & Muralidhar, 2011).

Increment in energy detection model of human information processing: A connectivity of cells' bio-electric response to body awareness

HIP proves to be the very fabric of stimulus response function. It consists of five main steps, namely, detection, discrimination, decision, memory, and execution (Cowan, 1988; Desmedt, 1980; Ruchkin, Sutton, & Mahaffey, 1987; Duncan-Johnson & Donchin, 1982; Hillyard & Kutas, 1983). Its relevance in understanding the nature of yoga practices, however, has been first proposed by Kulkarni (1997). It is, plausibly, applicable to both cellular and system levels of human behavior, including its relation with brain and immune system (Edelberg, 1977). The possible modulation of brain and immune system, through yoga practices, has been proposed by Kulkarni & Bera (2009). The connecting medium to sustain a communication among cells, organs, and systems is essentially electrical in nature. Therefore, every cell to cell and cell to whole-body communication exhibit different modes of electrical communication (Clinton, 1967). The electrical property of cells seems to shape the body tissues and may trigger organogenesis (Beane, Morokuma, Adams, & Levin, 2011). As well, the role of electrical stimulation, in prevention of cancer cell formation (Chernet & Levin, 2013), suggests its implications in yoga for generating curative nature of bio-electrical response, at the vegetative level. Generally, cell to cell and cell to system communication exhibit an electrical communication. They are direct current (DC) and alternating current (AC) electrical responses. The AC is characterized by wave pattern with alternating crests and troughs, while the DC contains only crests. The electrical responses evoked by chemical or mechanical means vary from millivolt (one thousandth of a volt) to microvolt (one thousandth of one millivolt) within and outside the body. The example of DC type is the GSR elicited by the sweat gland dermal activity and is often modulated by the mental states. The majority of communication within the body is of AC nature, such as EEG and evoked response in the brain, ECG in heart, and EMG in skeletal and smooth muscle activity (Clinton, 1967). These vital organs also function under awareness domain at the will of the subject (Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 2012). Therefore, investigating the whole-body functions, under the influence of AC source, may provide a vital link to connect the cellular sensitivity (Grimnes, 1983) to the whole-body awareness, perceived at the cortical level.

The role of IED model in body awareness phenomenon is proposed to be based on the principles of signal detection

theory (Green & Swets, 1966) in deriving psychophysical threshold response (Kandel et al., 2012). The relevance of IED model in yogic practices is also well established, such as low detection function of attention post-*Shavasana*, measured in terms of skin millivoltage responses (Kulkarni, 1998; Kulkarni, 2002). The understanding of cell sensitivity to energy-dependent changes upon AC stimulation, as reported in earlier studies, in the context to nutrition and energy demands, could be viewed as drift in perceived cellular sensation by IED functions (Martinsen, Grimnes, & Piltan, 2004) that contribute to whole-body awareness. The underlying five stages of HIP are a function of neural electrical activity, viz., attention, perception, cognition, and memory functions, inferred from evoked potential responses. Therefore, it seems clearly established that the role of bio-electrical activity on the cortical level is the function of energy-mediated body awareness phenomenon. Thus, applying similar principles of bio-electrical activity through AC current stimulation on body tissues to reveal bio-energetic responses (Kyle et al., 2004) could lead to understand the sensitivity of electrical response elicited by the cell. This might contribute to the detection of cell sensitivity as a unit response that interconnects the whole-body awareness. The bio-energetic response can be understood from the mathematical model of cell electrical response.

Mathematical description of bio-electrical response

The mathematical model of cell electrical response may lead to understand the awareness component through attention dynamics by the energy detection model of HIP. Since attention and perception overlap with neural electrical activity, as well as consciousness components (Hillyard & Picton, 1979), the energy content, expenditure, and storage are common to both cell sensitivity response and HIP-mediated body awareness. The underlying regulatory process monitoring energy expenditure and storage responses reflects cell sensitivity that links to body awareness. Therefore, the cell sensitivity serves as a unit of whole-body awareness component. The whole-body response to DC stimulation depends on the cell opposing DC flow. It purely depends on the resistance (*R*) of cell membrane. The whole-body response to AC stimulation (*I*) also exhibits similar opposition to AC flow but with a complex resistance response elicited by the cell membrane. It is referred as impedance (*Z*) that depends on the opposition by the cell to discharge ions from the cell membrane.

The property of cell to charge and discharge electrical activity is referred as capacitance and the ability of cell to oppose AC flow, so as to prevent discharge of stored ions, is termed as reactance (X_c). Therefore, the descriptive mathematical model of whole-body response stimulation is a result of the complex interaction of three components of cell electrical properties, namely, *R*, *Z*, and X_c. The X_c implies energy expenditure and storage capacity of the cell due to K^+ and Na^+ ionic mobility (BIA-how it works, n.d.; Grimnes & Martinsen, 2000) due to dielectric properties of the cell (Gabriel, Lau, & Gabriel, 1996) that acts as capacitance that, in turn, stores and discharges energy. This depends on the electrical response to AC (*I*) stimulation which is referred to as voltage (*V*) or potential energy required to prevent entry of I.

The response *V* is also alternate in nature and varies according to different proportions of *Z*, *R*, and X_c. The *V* responses are frequency dependent (Grimnes & Martinsen, 2008) and are characterized according to the range of bio-impedance in different body regions (Grimnes & Martinsen, 2000) tested upon three ranges of frequencies of *I*, such as low (10–50 Khz), mid (50–1 Mhz), and high (1–10 Mhz) frequency. Different frequencies of AC simulations exhibit different magnitude of *Z* through varying *R* and X_c components of cell properties (Gabriel et al., 1996). The three components, viz., *Z*, *R*, and X_c, vary as per body composition such as fat content, cell mass, and water content (Hills & Byrne, 1998). The onset of *V* response time (*t*), with reference to *I* stimulus onset, induces change in *Xc* that determines the magnitude of energy expenditure (BIA-how it works, n.d.) and indirectly reflects the cell response sensitivity (Grimnes, 1983).

The cell may exhibit voltage responses in three different timings to *I* stimulation. The conditions are as follows:

- Cells' *V* response is ahead of current *I* stimulus or *I* leads the *V*
- Both cell *V* response and *I* stimulus arrive simultaneously without time delay and are perfectly synchronized in phase
- Cell *V* is behind *I* stimulus, or *I* leads the *V* response.

The above varying arrival time "*t*" is also mathematically interpreted as spatial shift of periodic sinusoidal wave. The spatial shift of periodic sinusoidal wave of both *I* and *V* is expressed in degrees or radians and is referred as phase angle which is defined, mathematically, as ratio of difference in voltage response versus difference in stimulus current ($\Delta V/\Delta I$). The phase angle is computed as X_c/Z. It is also proportional to delay time "*t*" upon inverse of frequency multiplied by 36° (Clinton, 1967). The phase angle depends on time "*t*" of *V* response that could be (a) ahead of arrival time of *I*, (b) time "*t*" of *V* is identical with the arrival time "*t*" of *I*, or (c) delayed time "*t*" of *V* response with reference to arrival time of *I*. These relations reflect phase angle and the extent of bio-energy storage and expenditure.

The lowered phase angle in condition (a) with respect to "*t*" having voltage response ahead of AC stimulation indicates enhanced energy expenditure or decreased energy storage (Hills & Byrne, 1998). The phase angle, as per condition (b), having zero delay of "*t*," refers to 90° in-phase which indicates equal rate of energy expenditure and storage (Muller, Bosy-Westphal, Later, Haas, & Heller, 2009). The larger phase angle of cell voltage response

(c) is when cell voltage response is behind the arrival time of AC stimulation, which is 90° out of phase and refers to enhanced energy storage and decreased energy expenditure (Muller et al., 2009). It is similar to the mechanism proposed during *Shavasana* practice, enhancing signal power by addition of signal to pedestal by 90° out of phase (Kulkarni & Bhogal, 1991). It implies the relevance of neurophysiological signal processing aspect of regulation of body awareness through yogic practices.

The relevance of application of phase angle estimation has been reported by various workers such as enhanced phase angle and reactance in winning team of volleyball match of healthy athletes (Cerit, Akdag, Dasdag, Karakoc, & Celik, 2010). The implication of phase angle measure can be seen distinguishing physiological differences in nourished and undernourished children (Scalfi, Marra, Caldara, Silvestri, & Contaldo, 1999) and in many other clinical studies (De Oliveira, dos Santos, & de Mello, 2012). The preliminary trial studies in *Shavasana* practice have revealed an increased phase angle as an indicator of energy conservation (Kulkarni, Shete, & Thakur, 2012). It amply suggests the future utility of bio-impedance profile of variables such as *Z*, *X*c, and phase angle may serve as biomarkers for understanding psychophysiology of yoga effects that could, plausibly, explain psychobiology of body awareness aspect ranging from cellular to cortical level.

CONCLUSION

The study concludes that the measure of bio-electrical variables, specifically the bio-impedance profile-related variables such as *X*c and phase angle, seems to be effective tools to assess psychophysiology of yoga and meditation effects on cellular and higher brain functions so as to address the underlying meditation and yogic effects in regulating psychobiology of human consciousness-mediated energy dynamics.

Acknowledgment

We are grateful to Swami Maheshanandji, Director of Research, Kaivalyadhama, and Shri O. P. Tiwari, Secretary, Kaivalyadhama, S. M. Y. M. Samiti and Shri Subodh Tiwari, CEO, Kaivalyadhama, for giving a constant encouragement to complete research activities.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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