International Journal of Engineering &Technology, 7 (4) (2018) 6539-6543

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.28327
Research paper

INFLUENCE of ovarian cycles on body composition using MFBIA

Er. Poonam Khalsa [1] *, Dr. Jayanand Manjhi [2]

[1] PhD Scholar at Department of Biomedical Engineering, Shobhit Institute of Engineering & Technology ,Modipuram Meerut India
[2] Department of Biomedical Engineering & Technology Modipuram, Meerut India
**Corresponding author E-mail: poonamkhalsa4@gmail.com*

Abstract

Multi- Frequency Bioelectrical Impedance Analysis (MFBIA) is a technique used to estimate the body composition. MFBIA helps to evaluate the water and fat percentage in the body. In MFBIA, different frequencies (0, 50, 100, 200 to 500 kHz) are used to evaluate Fat Free Mass (FFM), Total Body Water (TBW), Intracellular Water (ICW) and Extracellular Water (ECW) content. The main objective of the study is to evaluate the outcome of the ovarian cycle on the composition of the body, with the help of 720 MFBIA and 520 MFBIA. Experiments are conducted on forty-four college-aged women of appropriate age and body mass (Age=21.4 ± 1.1 years; Body Mass Index = 24.4 ± 3.8 kg/m2). Body compositions of the women are assessed using 720 MFBIA and 520 MFBIA analyzers during all the phases of ovarian cycle namely ovarian, follicular, early and late luteal phase. The research study indicates that 720 MFBIA is better tool than 520 MFBIA to study the effect of ovarian cycles on body compositions.

Keywords: *MFBIA; In Body 520; In Body 720; Ovarian Cycle.*

1. Introduction

Bioelectrical impedance analysis, (BIA) is a non-invasive and a low-priced method to evaluate a person's body composition [1]. This process does not require intense technical skills. This means it can be easily handled [2]. The BIA method sends the electric current through the body and evaluates the body composition by calculating the impedance or resistance to current flow [3]. Fat-free mass is highly conductive as it offers little resistance to current flow [4]. Low resistance is due to the presence of high electrolyte and water content in fat-free mass [5]. Adipose tissue is less conductive as it offers high resistance to current flow. High resistance is due to the presence of less water content and electrolytes [6]. The present day contact electrode BIA analyzers differ significantly from the traditional BIA analyzers. The traditional BIA analyzers placed gel electrodes at precise anatomical locations. The Contact electrode BIA analyzers, evaluates percent body fat along with fat-free mass by automatic calculations, based on pre-programmed prediction equations [7, 8]. These equations calculated impedance along with information such as height, body mass, gender, age and body type to evaluate the body composition values [9].

BIA analyzers are categorized as single or multi-frequency on the basis of the electrical current(s) used to calculate impedance of the body tissues. Single-frequency analyzers normally penetrate electrical current of 50 KHz in the body to evaluate whole-body or composition of segmental tissues [10].MFBIA differs from single frequency bioelectrical impedance analysis in that the bioimpedance data is received at different frequencies. Bioimpedance data at different frequencies allows the measure of ECW at low frequencies (1 to 5 kHz) and TBW at high frequencies (100, 200, or 500 kHz) [11].



Fig. 1: In Body 720 Device [27].

Intracellular water can be calculated by subtraction of the two calculated water compartments namely TBW and ECW [12]. In body, the 720 device is a tetra polar multi-frequency BIA analyzer. For measurement, it utilizes the gradual electric current frequency of 1, 50, 200, 500 and 1000 kHz [13]. It is a digital scale analyzer which uses eight point touch electrodes for measurement. It calculates segmental impedance of the legs, arms and the trunk. The impedance is measured at 1, 5, 50, 250, 500, and 1000 kHz [14]. In this system, eight electrodes are in touch with the body, two in each hand and foot. Body mass along with five segmental impedance calculations (right arm, left arm, trunk, right leg and left leg) are measured automatically by the device [15]. The volunteer stands straight and holds the hand electrodes by naked feet which are positioned accurately on contact electrodes of the MFBIA scale-like platform [16].

In Body 520 Body device can also be used to evaluate Multi-frequency Bioelectrical impedance [17]. When an electrical cur-

Copyright © Er. Poonam Khalsa, Dr. Jayanand Manjhi. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

rent travels through the body, certain resistances and reactances develop which can be determined with the help of 520 MFBIA. These readings help to analyze the body composition [18]. In Body 520 is a multi-frequency analyzer which partitions the body into five parts, namely, two arms, two legs and a trunk. The electrodes are positioned below the patients feet on the platform, on the palms, and on the thumbs connected to the handles of the device [19]. Age, height, and gender have to be entered manually after the determination of weight by a scale situated within device. Patients skin which is in touch with the 74 electrodes helps us to determine many variables like TBW, segmental impedance, EBW and ICW. Body mass and impedance can be calculated automatically through the manufacturer software [20]. Equations present in the manufacturers' proprietary software can calculate fat free mass along with body fat percentage. Before each evaluation, the electrodes are thoroughly cleansed with In Body 520 provided tissues. After the device obtains the volunteer's weight, the volunteer is then informed through the software to stand fully straight, arms extended and not touching body sides and to refrain from moving or talking until the evaluation is completed [21].



Fig. 2: In Body 520 Devices [28].

All the Multi-frequency analyzers send a number of frequencies, varying from 1-1000 kHz, through the body to obtain body composition dimension [22]. At 50 kHz, single frequency analyzers provide total body water estimates but are incompetent to differentiate between IBW and EBW [23]. On the other hand, multi-frequency analyzers can distinguish between intracellular and extracellular body water content [24]. Earlier researches have revealed that impedance is altered by aspects that produce change in electrolytes or body fluids [25]. To manage fluid shifts and to develop the measurement accuracy, explicit pre-testing guidelines have been approved before using BIA technology. For example, it is suggested that clients should abstain from eating, drinking, exercise, and taking diuretic medication before assessment. It is also suggested that women should not be tested during the water retaining phase of the menstrual cycle [26]. The ovarian cycle consists of series of events that leads to oocyte maturation. Furthermore, if fertilization occurs, the uterus is prepared for an embryo [27]. Temporary weight gain can be seen in some women, during the ovarian cycle due to increase in water retention. However, earlier data to examine the impact of the ovarian cycle on MFBIA measurements via traditional, gel-electrode technology have disclosed small or no impact [28]. Given the current advancements in BIA contact-electrode technology and the popularity of these devices, it is essential to examine the possible impact of the menstrual cycle on MFBIA measurements.

2. Literature review

Previously, a lot of research has been done in this field. Some of the important and relevant research related to the study is described in this section.

Emily A, et al. 2018, described that BIA is relatively inexpensive technique to determine body composition. BIA manufacturers advised refraining testing women when they perceive to retain water during the ovarian cycle. The objective of the study was to scrutinize the effect of the ovarian cycle on body composition with the help of contact-electrode BIA analyzers. Forty-three college-aged women of appropriate age and body mass were considered in this research (age=21.5 ± 1.3 years; body mass index = 24.5 ± 3.8 kg/m2). The body composition of women was assessed through four dissimilar contact-electrode BIA analyzers.

The assessment of body composition was done during the menstrual cycle phases namely menstrual, follicular, early and late luteal. Despite of different BIA analyzer utilized for assessment, no noteworthy alterations in body composition measures were observed within cycle phases. From the study, it was concluded that the contact-electrode BIA devices used in this research can be utilized at any time during a women menstrual cycle without the change in body composition values. [25]

Feldmar, et al. 2009, explained a new technique of the multiple-frequency bioimpedance analysis (MFBIA) for patients with controlled ovarian hyper stimulation (COH) .The MFBIA has helped to predict and to diagnose severe forms of ovarian hyper stimulation syndrome (OHSS).53 patients were recruited in this study. The surface body impedances at 1, 5, 50 and 100 kHz were determined. Study group involved 13 patients with advanced OHSS grade III.-V. The control group is comprised of 40 women undergoing COH without matured OHSS. MFBIA devices were used to measure impedances .The decline of the impedance values amid the day of oocyte retrieval and the day of embryo transport considerably increased comparative risk of OHSS grade III.-V progress. 5 kHz (9.08 $p<0.0001$) frequency gave the best correlation. The study has suggested that the analytical value of MFBIA in OHSS improvement is better than the amount of retrieved oocytes (>20 oocytes-RR 5, 71). Decrease in impedances has revealed the increase in uncertainty of OHSS development. For the impedances at 5 kHz, highest predictive values of OHSS were observed. [26]

Silva et al. 2018, compared the entire-body bio-impedance computed values achieved from MFBIA spectroscopy (BIS, Xitron 4200) at a 50 kHz frequency measured by a 1-∅, singe frequency tool utilized for active as well as elite athletes. The experiment comprises of 126 numbers of active males participated in sports having age lies between (20 to 39 years) and female athletes whose age lies between 18 to 39 year. It has been observed that bioimpedance measurements from current single and multilevel devices have not been used in place of one another. Due to the methodological and biological factors, there was no consensus between devices for the determination of the individual values of R, X_c, Z and ∅, which is a highly active population [27].

Carrion et al. 2019, examined the effect of three BIA in athletic young adults. There are total 51 number of participants in which 26 are men and 25 are women have been assessed for determining fat by utilizing arm- arm bi-polar solitary frequency device, leg-leg solitary frequency device. PBF has been measured randomly, equally with three devices. Recurrent events ANOVA found significant differences in PBF assessments ($p <0.001$) between all devices. Pearson Correlations measured between arm to arm and MFBIA in case of male and female is and moderate relationship between leg-leg BIA and MFBIA. This information shows a strong contract between each of the three devices, and any of them can be used to track the PBF changes over time. However, significant differences in PBF values between devices suggest best practice for body composition monitoring to be used consistently over time for a valid device evaluation [28].

Beato et al. 2019, have examine the effects of Bariatric surgery on women body composition (BC). For experiment data from 20 class-III obsene female having age 24 to 34 years, boly mass liese between 42 Kg/m2 to 47 Kg/m2 undergo for gastric bypass surgery have been considered. The experiment has been conducted by in body 230 and DLW before 6 months and after 6 months of surgery. The accuracy in terms of root mean square error has been

examined. The mean square error of − 1.40 to 0.06 kg has been observed [29].

Ryo et al. 2014 demonstrated the influence of short term calorie constraint and work out on variation in VFA determined by Computed tomography (CT) and abdominal BIA. From the experimental analysis it has been observed that the short term intrusion decrease visceral fat which results in enhancement of metabolic cardiovascular risk issues. The Visceral fat is placed in the mesenteric and omentum that delivers fat free acid to the liver through the portal vein [30].

Dixon et al. 2013 have utilized BIA technique to analyze the influence of meal on impedance as well as on percentage body fat. For this purpose, the authors have considered 43 adults comprises of 23 female and 20 male having age ranges from 18.5 years to 21.1 years with body mass index of 20.2 Kg/m2 to 28 Kg/m2. The experiment has been conducted by considered three different BIA analyzers named as Leg- leg, segmental and multi-frequency BIA. It has determined that after 20 minutes of eating meal leg to leg BIA, segmental BIA and Multi frequency BIA have been increased by 0.8 Kg, 0.8 Kg and 0.7 Kg respectively [31].

3. Proposed work

In the present study, In Body 520 and In Body 720 devices are used to study the effect of ovarian cycles on body compositions. To continue with the process, many female volunteers took part in the study. Body compositions of the women are assessed during all the phases of ovarian cycle namely ovarian, follicular, early and late luteal phase.

3.1. Participants

Forty-four middle-aged female volunteers took part in the study. Each volunteer visited laboratory four times for testing, separated by a time of exactly one week, with each visit lasting less than 30 minutes. For all body composition measurements, female volunteers were advised to wear t-shirt and shorts. Wall-mounted stadiometer and digital scale were used to measure Height (cm) and weight (kg). Women volunteers were asked to follow the approved guidelines (8):

a) Within twelve hours of the scheduled test, no physical activity should be performed;
b) Within two hours of the test, eating or drinking is not permitted;
c) Bladder should be emptied thirty minutes prior to the test;
d) Within forty eight hours of the test, no alcohol consumption is permitted;
e) Within seven days of the test, no diuretic medications are allowed.

3.2. Protocol

In Body 520 and In Body 720 devices are used to measure MFBIA. The In Body 520 measures the segmental impedance across both the legs, arms and the trunk at 5, 50, and 500 kHz. The In Body 720 measures the segmental impedance across both the legs, arms and the trunk at 5, 50 and 500 kHz. Eight electrodes are in touch with the body, two in each hand and foot. Segmental impedance measurements of right arm, left arm, trunk, right leg, left leg and body mass are automatically calculated whereas the volunteer stands straight holds the hand electrodes by bare feet positioned accurately on the contact electrodes of the MFBIA scale-like platform.

Each female volunteer has finished a two-month calendar to report the start and end of their two preceding ovarian cycles. These details were used to determine the average cycle length and the targeted dates for all testing visits.

The process of Testing was performed during the ovarian (cycle days 1–7), follicular (cycle days 8–14), untimely luteal (cycle days 15–21) and late luteal (cycle days 22–28) phases. Each female volunteer has finished a prescreening questionnaire to conclude birth control medication use before testing.

3.3. Statistical analysis

Data were measured with Sigma Plot Version 13.0. Each value is depicted as; mean ± standard deviation. Each of the four phases of the ovarian cycles is considered to evaluate body composition variables for each female volunteer. For the determination of consequence in the variables for different phases of the ovarian cycle, a repeated measure ANOVA was used. The significance level was $p \leq 0.05$ for all analysis.

4. Results

In this study, 44 middle aged females were considered to study ovarian cycles with the help of MFBIA analysis tool. In Body 720 Device and In Body 520 Device were used to analyze body composition of women during various phases of ovarian cycle.

The females of appropriate number, age, height, weight, body mass and ovarian cycles length were considered as illustrated in Table 1. All values are Mean± Standard Deviation.

4.1. Body composition analysis using in body 520 device

Body compositions of the women were assessed using 520 MFBIA analyzers during various ovarian cycle phases. The phases include ovarian (cycle days 1-7), follicular (cycle days 8-14), untimely luteal (cycle days 15-21) and late luteal phase (cycle days 22-28). Many variables like Body Mass (kg), Body Fat (%), Lean Body Mass, Fat Mass, ICW, ECW, and TBW were determined. The segmental impedance for legs, arms and the trunk at 5, 50, and 500 kHz were also determined.

Table 1: Characteristics of the Study Participants

N	44
Age (years)	22.2±1.1
Height (cm)	162.2±6.7
Weight (kg)	64.2±10.9
Body Mass (kg/m2)	24.6±3.7
Length of Ovarian Cycles	28.0±3.5

Table 2: Body Composition Values Measured Using in Body 520 Analyzers During Various Ovarian Cycle Phases

	Ovarian cycle	Follicular phase	Early phase	Late luteal phase
Body Mass(Kg)	64.1±11.0	64.0±10.9	64.2±10.9	64.2±11.1
Body Fat (%)	27.8±8.1	27.8±8.1	27.6±7.9	27.7±7.8
Lean Body Mass(Kg)	45.9±6.1	45.9±6.0	46.1±6.0	46.0±6.1
Fat Mass(Kg)	18.2±8.1	18.1±8.0	18.1±7.9	18.2±7.9
Intracellular Water(Kg)	21.3±2.9	21.3±2.9	21.5±2.9	21.5±2.9
Extracellular water(Kg)	12.6±1.8	12.6±1.8	12.8±1.8	12.8±1.9
Total Body water(Kg)	33.9±4.7	33.9±4.7	34.3±4.7	34.3±4.8
5(ohms)	1497.0±160.1	1492.7±143.5	1496.0±168.8	1486.4±160
50(ohms)	1325.9±144.8	1321.6±132.3	1325.3±146.3	1319.4±145.4
500(ohms)	1136.4±120.6	1131.6± 120.0	1135.4±130.2	1131.7±129.8

4.2. Body composition analysis using in body 720 device

Body compositions of the women were also assessed using 720 MFBIA analyzers during various ovarian cycle phases. The phases include ovarian (cycle days 1-7), follicular (cycle days 8-14), un-

timely luteal (cycle days 15-21) and late luteal phase (cycle days 22-28). Many variables like Body Mass (kg), Body Fat (%), Lean Body Mass, Fat Mass, ICW, ECW and TBW were determined. The segmental impedance for legs, arms and the trunk at 5, 50, and 500 kHz were also determined.

Table 3: Body Composition Values Measured Using in Body 720 Analyzers During Various Menstrual Cycle Phases

	Ovarian cycle	Follicular phase	Early phase	Late luteal phase
Body Mass(Kg)	64.2±11.0	63.9±10.9	64.3±10.9	64.3±11.0
Body Fat (%)	29.1±7.9	28.9±7.9	28.7±8.0	28.9±7.8
Lean Body Mass(Kg)	45.8±6.4	44.9±5.8	45.4±5.9	45.5±5.4
Fat Mass(Kg)	18.4±8.0	19.0±8	18.9±8.4	18.6±8.1
Intracellular Water(Kg)	21.2±3.1	21.1±2.9	21.2±2.7	21.0±2.6
Extracellular water(Kg)	12.6±1.8	12.4±1.7	12.8±2.7	12.5±1.7
Total Body water(Kg)	33.8±4.9	33.5±4.6	34.0±5.4	33.5±4.3
5(ohms)	1316.4±136.6	1323.6±1329.4	1318.7±151.9	1312.9±143.5
50(ohms)	1132.4±133.3	1147.2±115.6	1142.9±133.2	1140.5±126.0
500(ohms)	1098.2±134.0	1108.1±108.9	1108.9±129.0	1106.9±121.7
Whole body-phase angle	7.06±1%59o	7.05±1%58o	7.04±1%58o	7.06±1%59o

During this study, ANOVA tests were executed and observed body compositions variables were evaluated for four phases of ovarian cycles. Significance level was $p \leq 0.05$ for all analysis.

4.3. Phase angle depiction by in body 720 device

In Body 720 device is advantageous over In Body 520 as it provides the facility for calculating segmental readings for various body phase angles. Values of Phase angle for various body segments are calculated and it is observed that trunk area of body (TR) has maximum phase angle. Minimum phase angle is observed in left arm.

In Body 720 Device also helps to calculate Whole Body Phase Angle, which is not possible in case of In Body 520 Device. Whole body phase angle is almost similar for all phases of ovarian cycles. The average of whole body phase angle for all phases is observed at 7.05±1%58o.

Table 4: Segmental Reading for Phase Angle in Body 720

RA	6.8
LA	6.5
TR	9.2
RL	7.9
LL	7.2

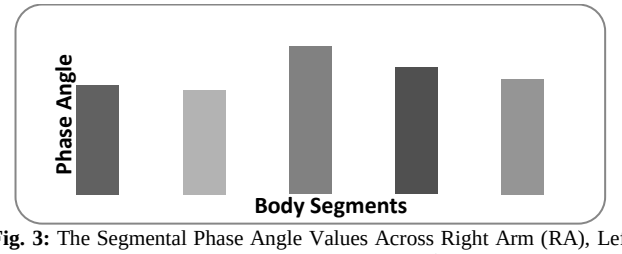


Fig. 3: The Segmental Phase Angle Values Across Right Arm (RA), Left Arm(LA), Trunk(TR), Right Leg (RL) and the Left Leg(LL) Determined by the Device in Body 720.

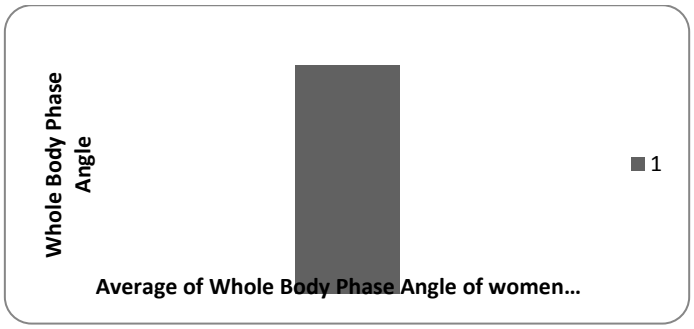


Fig. 4: Average of Whole Body Phase Angles in Various Stages of Ovarian Cycles.

4.4. Determination of visceral fat area (VFA) by in body 720 device

In body 720 device, different frequencies 5 kHz, 50 kHz and 500 kHz are used and it is observed that during the ovarian cycle visceral fat area ranges from 16.8 to 171.6cm2. Sensitivity at VFA ≥110 cm2 is calculated by using regression equations. ($P \leq 0.05$ mean age 22.2±1.1). The data VF ≥110cm2 is applicable for women of North India, as women considered in this study are from North India. It is not possible to determine visceral fat area with the help of In Body 520 MFBIA.

5. Conclusion

This study concludes that in body 720 MFBIA Reactance is easy to determine as compared to in body 520 reactance. In body 720 device is more accurate to determine segmental water body analysis, Body cell mass (BCM), whole body phase angle, segmental phase angle and visceral fat area. It has been concluded that the heath is reciprocal to the higher the value of phase- angle and the Phase Angle decreases with age. The average whole body phase angle is 7.05±1%58o as depicted by in body 720 MFBIA. High reactance values have demonstrated that the human body cells can store more energy and low reactance values demonstrate that the cells are store less energy. This proves that In Body 720 MFBIA is better tool to study ovarian cycle than In Body 520 MFBIA.

References

[1] VH. Heyward, DR. Wagner, "Applied Body Composition Assessment. Human Kinetics", *Champaign*, IL: pp. 87–98, 20004.

[2] HC. Lukaski, "Assessing regional muscle mass with segmental measurements of bioelectrical impedance in obese women during weight loss", *Ann NY Acad Sci*. Vol.904, No. 1, pp.154–158, 2000. https://doi.org/10.1111/j.1749-6632.2000.tb06440.x.

[3] S. z. yanovski, v. s. hubbard, s. b. heymsfield, & h. c. lukaski, "bioelectrical impedance analysis in body composition measurement: National institutes of health technology assessment conference statement", *The American journal of clinical nutrition*, Vol. 64, pp. 524-532, 1996. https://doi.org/10.1093/ajcn/64.3.524S.

[4] C. Nunez, D. Gallagher, M. Visser, F. Pi-Sunyer, Z. Wang, SB. Heymsfiel, "Bioimpedance analysis: evaluation of leg-to-leg system based on pressure contact food-pad electrodes," *Med Sci Sports Exerc*. Vol.29, pp.524–531, 1997. https://doi.org/10.1097/00005768-199704000-00015.

[5] SB. Heymsfield, TG. Lohman, Z. Wang, SB. Going, "Human Body Composition. Human body composition, Vol. 918, Human kinetics in 2005.

[6] CB. Dixon, B. Masteller, JL. Andreacci, "The effect of a meal on measures of impedance and percent body fat estimated using contact-electrode bioelectrical impedance technology," *European journal of clinical nutrition*, Vol. 67, 950-955,2013. https://doi.org/10.1038/ejcn.2013.118.

[7] VH. Heyward, DR. Wagner, "Applied Body Composition Assessment", *Human Kinetics; Champaign*, IL: pp. 87–98, 2004.

[8] AC. Buchholz, C. Bartok, DA. Schoeller, "The validity of bioelectrical impedance models in clinical populations", *Nutrition in clinical practice*, Vo. 19:433–46, 2004. https://doi.org/10.1177/0115426504019005433.

[9] KS. Cole, "Permeability and impermeability of cell membranes for ions", *Cold Spring Harbor Symp Quant Bio*. Vol. 8, pp.110–22, 1940. https://doi.org/10.1101/SQB.1940.008.01.013.

[10] P. Kutáč, & M. Kopecký, "Comparison of body fat using various bioelectrical impedance analyzers *in university students*," *Acta Gymnica*, 45(4), 177-186, 2015. https://doi.org/10.5507/ag.2015.021.

[11] M. R Miller, L. Toby Chambers, P. Stephen Burns, "Validating In Body® 570 Multi-frequency Bioelectrical Impedance Analyzer versus DXA for Body Fat Percentage Analysis", *Research Journal of the American Society of Exercise Physiologists*, Vol. 19 , No. 5, 2016. https://doi.org/10.1249/01.mss.0000487979.68551.d7.

[12] T. N. Garlie, J. P. Obusek, B. Corner, & E. J. Zambraski,, "Determination of Percent Body Fat Using 3D Whole Body Laser Scanning: A Preliminary Investigation", *Army Natick Soldier Center Ma*, 2006..

[13] UG. Kyle, I. Bosaeus, De Lorenzo AD, P. Deurenberg, M. Elia, JM. Gomez, BL. Heitmann, L. Kent-Smith, JC. Melchior, M. Pirlich, H. Scharfetter, AM. Schols, C. Pichard, "Bioelectrical impedance analysis – part l: review of principles and methods," *Clin Nutr*, Vol. 23, No. 5, pp. 1226-1243, 2004. https://doi.org/10.1016/j.clnu.2004.09.012.

[14] MR. Esco, RL. Snarr, MD. Leatherwood, NA. Chamberlain, ML. Redding, AA. Flatt, JR. Moon, HN. Williford, "Comparison of total and segmental body composition using DXA and multi-frequency bioimpedance in collegiate female athletes," *The Journal of Strength & Conditioning Research* VOl. 29, No.4, pp.918-925, 2015. https://doi.org/10.1519/JSC.0000000000000732.

[15] P. Deurenberg, JA. Weststrate, I. Paymans, van der Kooy K, "Factors affecting bioelectrical impedance measurements in humans", *European Journal of Clinical Nutrition*, Vol. 42, No. 12, pp. 1017-1022, 1988.

[16] CB. Dixon JL. Andreacci, C. Ledezma, "Effect of aerobic exercise on percent body fat using leg-to-leg and segmental bioelectrical impedance analysis in adults," *nternational Journal of Body Composition Research*, Vol. 6, No. 1, pp. 27-34, 2008.

[17] CB. Dixon, B. Masteller, JL. Andreacci, "The effect of a meal on measures of impedance and percent body fat estimated using contact-electrode bioelectrical impedance technology", *European journal of clinical nutrition*, Vol.67, No. 9, pp. 950-955. https://doi.org/10.1038/ejcn.2013.118.

[18] T. Gomez, P. A. Mole & A. Collins, "Dilution of body fluid electrolytes affects bioelectrical impedance measurements. Research in Sports Medicine, an International Journal, vol. 4, No.4, pp. 291-298, 1993. https://doi.org/10.1080/15438629309511993.

[19] CO. Mitchell, J. Rose, B. Familoni, S. Winters, F. Ling, "The use of multifrequency bioelectrical impedance analysis to estimate fluid volume changes as a function of the menstrual cycle," In *Human Body Composition pp.* 189-191, 1993. https://doi.org/10.1007/978-1-4899-1268-8_43.

[20] M. Damavandi, "Effect of modeling methods on the body and head-neck-trunck moments of inertia calculations in individuals of different morphology, 2008.

[21] S. C. Teilmann,, C. A. Clement, J. Thorup, A. G. Byskov,, & S. T. Christensen,, "Expression and localization of the progesterone receptor in mouse and human reproductive organs," *Journal of Endocrinology*, Vol.191, No. 3, pp. 525-535, 2006. https://doi.org/10.1677/joe.1.06565.

[22] WC Chumlea, AF. Roche, S. Guo, B. Woynarowska, "The influence of physiologic variables and oral contraceptives on bioelectrical impedance," *Human biology*, Vol. 59, No. 2, pp. 257-269, 1987.

[23] CN. Gleichauf, DA Roe, "The menstrual cycles effect on the reliability of bioimpedance measurements for assessing body composition", *The American journal of clinical nutrition*, Vol.50, No. 5, pp. 903-907, 1989. https://doi.org/10.1093/ajcn/50.5.903.

[24] C. H. González-Correa & J. C. Caicedo-Eraso, "Bioelectrical impedance analysis (BIA): a proposal for standardization of the classical method in adults", *In Journal of Physics: Conference Series*, Vol. 407, No. 1, p. 12-18 IOP Publishing, 2012. https://doi.org/10.1088/1742-6596/407/1/012018.

[25] Dixon, And L. Joseph Andreacci, "The Effect of the Menstrual Cycle on Body Composition Determined by Contact-Electrode Bioelectrical Impedance Analyzers,"*International Journal of Exercise Science*, Vol. 11, No. 4, pp. 625-632, 2018.

[26] P. Feldmár, M. Hrehorcák, I. Malá, Suchová, K., Halaska, M., Chmel, R., & Rob, L, "Bioimpedance analysis--a new method in prediction and early detection of ovarian hyper stimulation syndrome," *Ceska gynekologie*, *Vol.* 74, No. 1, 8-12, 2009.

[27] https://www.alibaba.com/product-detail/High quality-body-composition-fat-analysis_1388600607.html.

[28] http://www.stage3fitness.com/inbody-assessment/

[29] A. M. Silva, C. N. Matias, C. L. Nunes, D. A. Santos, E. Marini,, Lukaski, H. C., & Sardinha, L. B., " Lack of agreement of in vivo raw bioimpedance measurements obtained from two single and multi-frequency bioelectrical impedance devices", *European Journal of Clinical Nutrition*, Vol.1, 2018. https://doi.org/10.1038/s41430-018-0355-z.

[30] B. M. Carrion, A. Wells, J. L. Mayhew, & Koch, A. J., "Concordance Among Bioelectrical Impedance Analysis Measures of Percent Body Fat In Athletic Young Adults", *International Journal of Exercise Science*, Vol.12, No.4, pp. 324-331, 2019.

[31] G. C. Beato, M. N. Ravelli, A. H. Crisp, & de Oliveira, M. R. M., "Agreement between body composition assessed by bioelectrical impedance analysis and doubly labeled water in obese women submitted to bariatric surgery, "*Obesity surgery*, Vol. *29*, No. 1, pp.183-189, 2019. https://doi.org/10.1007/s11695-018-3505-4.

[32] M. Ryo, K. Kishida, T. Nakamura, Funahashi, T., & Shimomura, I., "Short-term intervention reduces bioelectrical impedance analysis-measured visceral fat in type 2 diabetes mellitus," *Diabetes research and clinical practice*, Vol.103, No.3, e27-e29, 2014. https://doi.org/10.1016/j.diabres.2013.12.046.

[33] C. B. Dixon, B. Masteller, & J. L. Andreacci, "The effect of a meal on measures of impedance and percent body fat estimated using contact-electrode bioelectrical impedance technology", *European journal of clinical nutrition*, Vol.*67, no.*9, pp. 950, 2013. https://doi.org/10.1038/ejcn.2013.118.