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Bioelectrical Impedance Analysis in Body Composition

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Abstract

The characteristic of measurement method of bio-impedance has demonstrated to be of non-invasive nature henceforth is a significant aim for accepting this method in medical investigation. BIA is an energetic and valuable technique for determining the total configuration of the body. Investigation of Bio-impedance shows an energetic role in the valuation of well-being and nutritional value of the body. By altered united circuits dissimilar methods for extent of body composition is obtainable in this paper.

Keywords: A.C. rectification, bio-impedance, bio-impedance analysis, non-invasive measurements, I/Q demodulation

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INTRODUCTION

Proportion of body composition is toughly related with people's bodily health and its variations are of abundant implication for nutritional status and disease prevention, but its exact dimension is problematic. Bioelectrical impedance analysis (BIA) can notice bioelectrical impedance complete electrodes positioned on the surface of body and attain the correlative physiological info to examine body composition. Educations have revealed that BIA is a comparatively suitable, quick, non-invasive and correct method to degree body composition advanced nearly 20 years, which has lively request forecasts, the mentions therein. One of the most important factors to measure body composition by BIA is to establish proper impedance model. Presently the maximum broadly used model is five-segment impedance model. For extra results on this. This model distributes body into five parts containing limbs and trunk, regarding trunk as a whole. The advantage of this model is that it has taken the impedance differences of different body parts into account, having solved the technical problem that whole-body impedance model measures overall impedance to some extent; however, it is unable to accurately measure the impedance distribution in the trunk, such as the impedance of abdomen and chest. In allusion to defects of five-segment impedance model, the literature have proposed the trunk subdivision BIA, subdividing the trunk to obtain the improved impedance model, but this literature did not provide effective calculation method. Therefore, how to establish an accurate impedance calculation method is the key for further research.

Established on this, we have suggested the impedance analysis technique based on eight-segment impedance model, using the eight-electrode measurement technique to acquire conforming voltage value when dissimilar weak alternating current is approved into the body to estimate the impedances of conforming segments. For extra consequences on this topic. Lastly,

the impedance investigation technique founded on eight segment model is certified concluded theoretical source and experimental substantiation.

BIO-IMPEDANCE ANALYSIS PRINCIPLE

Bio-impedance is the reaction of a living creature to remotely connected electric current. Bio-impedance is a measure of the restriction to the stream of that electric current through the tissues, the inverse of the electrical conductivity. The bio-impedance estimation of human body has demonstrated extremely valuable as a non-intrusive strategy for measuring body organization and blood stream.

TECHNIQUES OF BODY COMPOSITION ANALYSIS

Body composition is acquired by determining the impedance at numerous points on the body and thus identical the consequence in a table containing of both the impedance dignified and the body composition. This table is actuality generated by dissimilar manufacturer and is typically grounded on sex, weight, age group and other parameters. Z (f) is a function of the excitation frequency and is symbolized by polar or Cartesian notations

$$Z(f) = |Z(f)| \cdot e^{j\theta(f)}$$
$$Z(f) = R(f) + jX((f)$$

Where,

$$|Z| = \sqrt{R^2 + X^2}$$
$$\theta = arctg\left(\frac{X}{R}\right)$$

The AFE4300 is an IC settled by Texas Instruments and delivers two options for body impedance measurement specifically I/Q demodulation and ac rectification. Both, I/Q demodulation and ac rectification work on the norm of inserting a sinusoidal current into the body and gauging the voltage drop crossways the body. The circuit that injects the current into the body is the same for both the techniques. The difference lies in how the voltage measured across the impedance is processed to obtain the final result

EIGHT-SEGMENT IMPEDANCE MODEL

Though the impedance of trunk is about numerous tens Ω while the limbs' is about 200Ω, the trunk comprises nearly 40% of body arrangement, the orientations therein [11]. In calculation, the upper part is chest, whose fat distribution is mostly medical fat, while the lower part is abdomen, whose fat dissemination is mostly instinctive fat, the references therein [12]. Consequently, in edict to confirm the correctness of trunk impedance dimension, it is inaudible required to differentiate between upper part (chest) and lower part (abdomen) in body composition capacity.

Eight-segment impedance model is shown in Figure 1. On the basis of the five-segment impedance model, the Eight-segment model subdivides the trunk and finally divides body into right arm R_1 , left arm R_3 ,right leg R_6 , left leg R_8 , right longitudinal trunk R_4 , left longitudinal trunk R_5 , upper trunk R_2 and lower trunk R_7

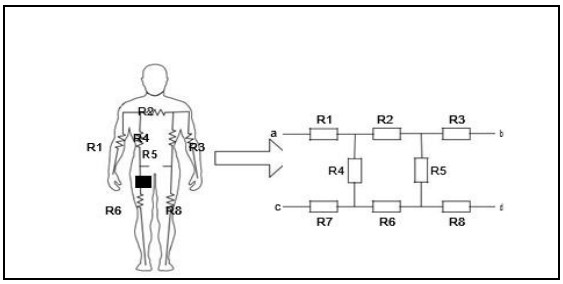

Fig. 1. *Eight-Segment Impedance Model.*

ANALYSIS METHOD OF EIGHT-SEGMENT MODEL

Calculation Method of Eight-Segment Model

As revealed in Figure 1, the capacity model in this revision is a four-port impedance network. Eight-electrode quantity technique is used; specifically, each of left hand, right hand, left foot and

right foot is located two electrodes, one is current electrode and the added is voltage electrode. Current incentive is directed into body over two current electrodes, and the incentive-measurement voltage is sedate over and done with two voltage electrodes, then the consistent impedances can be considered finished the measured voltage. The electrodes distribution and the current elegant finished the body in dissimilar incentive-measurement modes are depicted in Figure 2. Where 1-8 are eight electrodes; I(t) is the Current incentive; V(t) is the corresponding measured voltage.

As depicted in Figure 2, take Figure 2-a for instance, when the current is directed to right hand and right foot, the current runs through right arm, trunk and right leg; if currently the voltage is dignified amid right hand and right foot, we can get conforming arm, trunk and right leg voltage. There are completely 36 pairs grouping of this kind, as depicted in Table 1, where I is the incentive current, and V is the measured voltage.

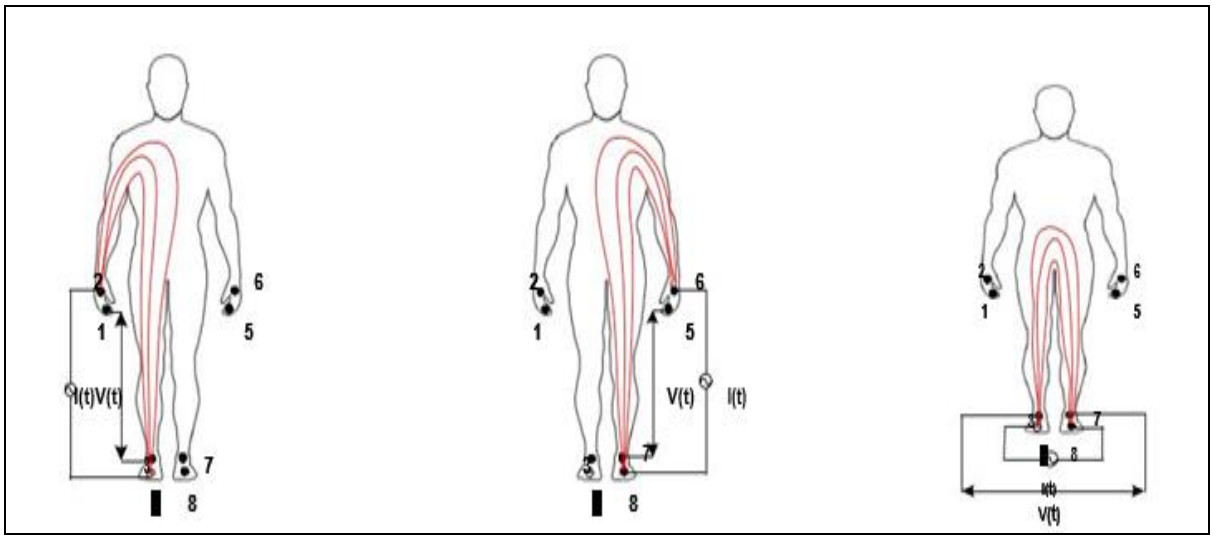

Fig. 2. *Electrodes Distribution and the Current Flowing Through Body.*

Table 1. *Incentive-Measurement Port Of Eight-Segment Model*

Measurement Incentive	**ab**	**ac**	**ad**	**bc**	**bd**	**cd**
Iab	Vab1	Vac1	Vad1	Vbc1	Vbd1	Vcd1
Iac	Vab2	Vac2	Vad2	Vbc2	Vbd2	Vcd2
Iad	Vab3	Vac3	Vad3	Vbc3	Vbd3	Vcd3
Ibc	Vab4	Vac4	Vad4	Vbc4	Vbd4	Vcd4
Ibd	Vab5	Vac5	Vad5	Vbc5	Vbd5	Vcd5
Icd	Vab6	Vac6	Vad6	Vbc6	Vbd6	Vcd6

Table 2. *The Effective Measurement Model.*

Valid values	**The effective measurement model**					
Current value	Iab-ac	Iab-bd	Iab-cd	Iac-ad	Iac-cd	Iad-bd
Voltage value	Vac1	Vbd1	Vcd1	Vad2	Vcd2	Vbd3

Known from the circuit principles, there are only six effective measurement modes for a four-port network, as shown in Table 2. According to the six effective measurement modes, the corresponding impedance formulas are as follows:

$$(R_1 + \frac{R_2 * R_4}{R_2 + R_4 + R_5 + R_6}) * I = V_{ac1} \quad \text{Eq. (1)}$$

$$(R_3 + \frac{R_2 * R_5}{R_2 + R_4 + R_5 + R_6}) * I = V_{bd1} \quad \text{Eq. (2)}$$

$$\frac{R_2 * R_6}{R_2 + R_4 + R_5 + R_6} * I = V_{cd1} \quad \text{Eq. (3)}$$

$$\frac{R_4 * R_5}{R_2 + R_4 + R_5 + R_6} * I = V_{ad2} \quad \text{Eq. (4)}$$

$$(R_7 + \frac{R_4 * R_6}{R_2 + R_4 + R_5 + R_6}) * I = V_{cd2} \quad \text{Eq. (5)}$$

$$(R_8 + \frac{R_4 * R_5}{R_2 + R_4 + R_5 + R_6} + \frac{R_5 * R_6}{R_2 + R_4 + R_5 + R_6}) * I = V_{bd3} \quad \text{Eq. (6)}$$

Where: Vac1 is the voltage measured between right hand and right foot when current is send between left hand and right hand; Vbd1 is the voltage measured between left hand and left foot when current is send between left hand and right hand; Vcd1 is the voltage measured between left foot and right foot when current is send between left hand and right hand; Vad 2 is the voltage measured between right hand and left hand when current is send between right foot and right hand; $V_{cd\ 2}$ is the voltage measured between left foot and right foot when current is send between right foot and right hand; $V_{bd\ 3}$ is the voltage measured between left hand and left Foot when current is send between left foot and right hand.

As indicated by the eight-fragment show, there are eight impedances to be measured. Not all impedance qualities can be acquired through Eqs (1)- (6), and another two straightly autonomous conditions are expected to get each of the eight-section impedances. Clinical reviews have demonstrated that the reciprocal sides of body are not completely symmetrical, but rather extraordinary parts of body have indicated diverse degrees of symmetry. The symmetry of trunk is poorer because of the uneven conveyance of interior organs, while appendages demonstrate a higher level of symmetry.

A lot of researchers have done examination on body's substantial symmetry and meridian symmetry. As far as physical symmetry, the structure of body is practically symmetrical, for example, eyes, hands and feet. In any case, the obviously symmetrical structure is not precisely unclear. For example, the two-sided half faces are not unequivocally the same, so are the eyes estimate, feet length and even feet range. In places of meridian symmetry, however the regulatory working of meridians has not been perceived in methodology in obsolete Chinese medication, it is justifiable that it conveys assortments of life data somehow to save physiological adjust. In including, meridian lines have low encounter and the impedance of two-sided meridians is adjusted. As an approximation technique

of body composition, limbs can be measured balanced in the nonexistence of distinct limb disorder and visible limb asymmetry, specifically, the impedance values can be measured to be the similar. It is also conceivable that the left and right limb is irregularity due to aplasia or disease; understandable body asymmetry can be modified by other way.

From the above analysis, we may assume:
$R_1=R_3$
$R_6=R_8$

Corresponding to the Eqs (1)-(6), the measured impedance values are:

$X_1 = V_{ac1} / I,$ Eq.(1)
$X_2 = V_{bd1} / I,$ Eq.(2)
$X_3 = V_{cd1} / I,$ Eq.(3)
$X_4 = V_{ad\,2} / I,$ Eq.(4)
$X_5 = V_{cd\,2} / I,$ Eq.(5)
$X_6 = V_{bd\,3} / I$ Eq.(6)

Solve simultaneous Eqs (1)-(8) and assume:

$$m = \frac{X_1 - X_2}{X_4 + X_5 - X_6},\ n = \frac{X - X}{X_3},\ k = \frac{\sqrt{n^2 X_2 + 4mX_3 X_4} - nX_3}{2X_3}$$

Eight-segment impedance values are as follows:

$$R_1 = R_3 = X_2 - kX_3 \quad \text{Eq. (9)}$$

$$R_2 = (m + n + 2k + 1)X_3 \quad \text{Eq. (10)}$$

$$R_4 = \frac{(k+n)(m+n+2k+1)X_3}{m} \quad \text{Eq. (11)}$$

$$R_5 = \frac{k(m+n+2k+1)X^3}{m} \quad \text{Eq. (12)}$$

$$R_6 = \frac{(m+n+2k+1)X_3}{m} \quad \text{Eq. (13)}$$

$$R_7 = R_8 = X_5 - \frac{(k+n)X^0}{m} \quad \text{Eq.(14)}$$

Theoretical Derivation of the Eight-segment Impedance Values

The accuracy of the got recipes (9)- (11) can be checked by hypothetical induction on the grounds that the impedances of various parts are likewise extraordinary hypothetically. In the above examination, we have accepted that appendages are symmetrical; hence, what is required to be confirmed is that whether the relative impedance estimation of the storage compartment and appendages is in accordance with the current hypothesis investigation.

Examines have demonstrated that the impedance estimation of the storage compartment is around a few tens Ω, while the appendages impedance is roughly 200ω. In light of this, the impedance range is:

$0 \le R_2、R_4、R_5、R_6 \le 100\ 200$

$\le R_1、R_3、R_7、R_8 \le 300$

Formula (1)-(2) show: if $R_4 > R_5$, then $X_1 > X_2$; if $R_4 < R_5$, then $X_1 < X_2$ .Namely:

$(X_1 - X_2) * (R4 - R_5) > 0$

Now, substitute R_4 , R_5 with formula (11)-(12) and simplify:
$(X_1 - X_2) * (X_4 + X_5 - X_6) * q > 0$

From $m = \frac{X_1 - X_2}{X_4 + X_5 - X_6}$ and the above in equation, we can get:
$mq > 0$

From formula (5)-(6), we can get:
$X_6 > X_5$

Then, substitute *m*, *n* into p and simplify:
$p = m(X_6 - X_5) > 0$

Contrasted with appendages, the impedance of trunk is much lower. In the eight-fragment show, four trunk resistors R2 , R4 , R5 , R6 are in arrangement, so the impedance of trunk is around the aggregate of four impedances.

Consequently, we can confirm the got equations by contrasting whether trunk impedance is not as much as appendages impedance, to be specific:

$R_2 + R_4 + R_5 + R_6 - R_1 < 0$
$R_2 + R_4 + R_5 + R_6 - R_7 < 0$

Substitute formula (9)-(14) into the above inequations, we can obtain:
$qX_3 / p + mqX_4 / p + q + qX_3 / mp - (X_2 - mX_3) < 0$

$qX_3 / p + mqX_4 / p + q + qX_3 / mp - (X_5 - mX_4 X_3 / p) < 0$

Substitute m , n, $p = m(X_6 - X_5)$, $q = m(X_3 + 2X_4) + X_3 + X_2 - X_1$ into the above inequalities, and regard the All other inequalities as the limitation, then two inequalities can be simplified as:

$m^2 [X_4 (X_5 - 2X_4 - X_3 - 2X_6)] + m[X_3^2 + X_3 (3X_4 + X_6 - X_5)] + X_3 (2X_3 + 2X_4 - X_1 + X_2) < 0\ m^2$

$[(2X_4 + X_3)(X_5 - X_4 - X_6)] + m[X_3^2 + (X_3 + 1)(X_6 - X_5)] + X_3 (2X_3 + 2X_4 - X_1 + X_2) < 0$

The two inequalities are both in the form of $am^2 + bm + c < 0$, and the coefficients meet $a < 0$ and $= b^2 - 4ac > 0$. Known from the mathematical principles, the two inequalities are reasonable.

Now, we can reason that the over two disparities are valid inside the endorsed extend. That is to state, the proposed investigation technique in this paper is right in hypothetical deduction.

EXPERIMENT DESIGN

With a specific end goal to check the accuracy of the impedance investigation technique in light of eight-fragment demonstrate, we have outlined the differentiation confirmation explore between the Body Composition Measurement System in view of the above strategy (hand crafted instruments) and the Tanita Viscan stomach fat analyzer, the references in that.[13-15].

The subjects are 10 sound volunteers, and the related notes are disclosed to them before the trial. Firstly, record the subjects' sexual orientation, age, tallness weight and race. Furthermore, utilize hand crafted instruments to quantify the subjects. At long last, utilize Tanita Viscan stomach fat analyzer to gauge the subjects. The estimation results are appeared in Table 3, where G, A, H, W, separately implies Gender, Age, Height and Weight; G is 1 when sex is male; G is 0 when sex is female; X1-X6 are the deliberate values in recipe (1)- (6); Fat1 is the stomach fat measured by custom made instruments; Fat2 is the stomach fat rate measured by Tanita Viscan.

Table 3. *Characteristic Parameters and Impedance Measurement Value.*

NO.	Parameters				Impedance values						Fat	
	G	A	H	W	X1	X2	X3	X4	X5	X6	Fat1	Fat2
1	1	23	174	76	296.4	306.2	18.6	18.2	190.1	220.2	11.15	16.4%
2	0	22	174	64.4	311.6	321.3	21.9	21.3	188.9	218.3	4.94	7.8%
3	0	26	184	73.6	345.4	355.8	22.4	22.8	235.2	265.8	12.17	17.9%
4	1	25	175	74.8	308.8	318.2	21.7	21.2	184.0	214.2	9.95	11.7%
5	0	24	168	55	327.8	337.3	25.3	25.3	224.3	254.3	6.76	10.3%
6	0	21	180	70.9	378.4	388.8	23.8	23.8	222.8	252.8	15.5	22.9%
7	1	27	173	68.8	318.1	328.2	22.9	22.2	252.3	282.2	9.92	13.7%
8	0	23	174	58.2	338.8	348.1	25.5	25.1	223.6	253.1		8.0%
9	1	21	178	63.2	300.1	310.4	22.0	22.4	201.6	231.4	6.18	10.1%
10	1	28	182	78	298.7	308.9	19.8	19.9	181.9	211.9	5.18	6.9%

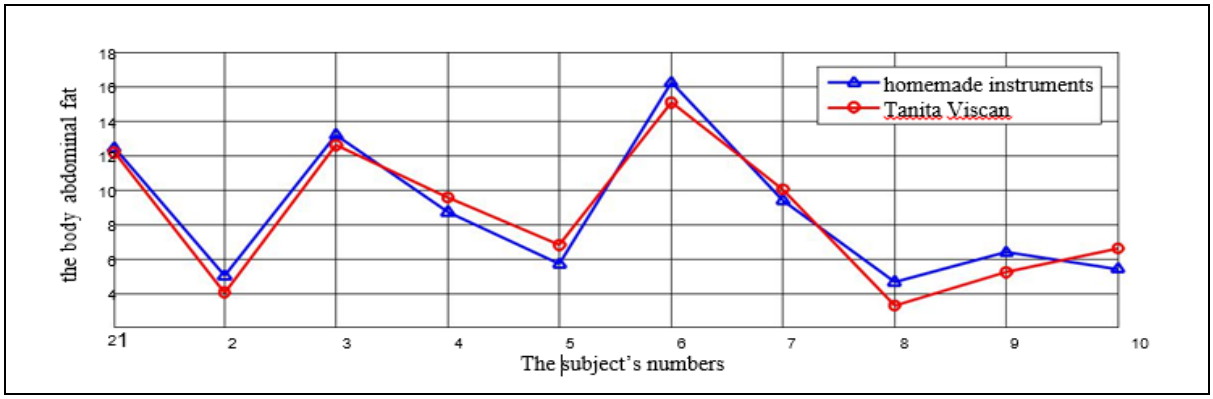

Fig. 3. *The Result Comparison Of The Two Measurement Methods.*

The result1 comparison of the two meters is shown in Figure 3. As Figure 3 shown that, when the abdominal fat content of the subjects is too low or too high, the correlation coefficient of the outcomes measured by the two meters$^{0.5}$ is 0.9544; when the subjects of abdominal fat content is comparatively moderate, the correlation coefficient of the outcomes measured by the two meters increases 0.9751. The results have shown that the body abdominal^{0}05fat contents10 measured15 by20 the two25 meters30have shown35 great40 relativity, 45 especially 50.

CONCLUSIONS

The current trunk subdivision BIA technique has enhanced body impedance show viably, yet there is not an exact computation strategy for this model as of now. As per this, we have proposed the examination technique in view of eight-section impedance demonstrate, which can give more precise impedance values and give another answer for accomplish impedances quicker. Be that as it may, on the grounds that there is not a brought together forecast calculation between body arrangement and bioelectrical impedance yet, body piece projection in light of bioelectrical impedance will turn into the concentration of further research, furthermore will be the commonsense restricting in wide utilization of eight-section impedance demonstrate investigation strategy.

REFERENCES

1. Rosendale, P. Ryan, Bartok, J. Cynthia, "Air-displacement plethysmography for the measurement of body composition in children aged 6-48 months", Pediatric Research, vol.71, no.6, pp.299-304, 2012.
2. Wilson, P. Joseph, K. Mulligan, B. Fan, "Dual-energy X-ray absorptiometry-based body volume measurement for 4-compartment body composition", A Merican Journal of Clinical Nutrition , vol.95, no. 13, pp. 25-31, 2012.
3. Penny WD. "Comparing Dynamic Causal Models using AIC, BIC and Free Energy", Neuroimage, vol.59, no.6, pp.319-330, 2012.
4. Qin XY. "Nearest neighbor clustering algorithm based on AIC criterion", Systems engineering and
5. Electronics, vol.27, no.5, pp. 257-259, 2005.
6. M. Dehghan and A. T. Merchant, "Is bioelectrical impedance accurate for use in large epidemiological studies", Nutrition Journal, vol.7, no.26, pp.1-7, 2008.
7. B. Chen and X. Zhang, "Research and design of impedance measuring instrument based on the method of multi-frequency and multi-segment",

In Proceeding(s) of the 2009 2nd International Conference on
8. Biomedical Engineering and Informatics, pp.1201-1204, 2009.
9. M. Nagai and H. Komiya, "Estimating visceral fat area by multi-frequency bioelectrical impedance",
10. Emerging Treatments and Technologies, vol.33, no.5, pp.1077-1079, 2010.
11. X. Gao and J. Tang, "Bioelectrical impedance measuring method based on principle of multi-frequency and multi-segment", In Proceeding(s) of International Conference on Advances in Engineering, pp.459-463, 2011.
12. S. Zhao and H. Sha, "A new trunk subdivision model for segmental bioelectrical impedance analysis",
13. Proc. of World Congress on Medical Physics and Biomedical Engineering, Munich, Germany,
14. pp.1151-1154, 2009.
15. M. Jaffrin and H. Morel, "Body composition measurements in limbs using eight-electrode bioimpedance", In Proceeding(s) of the 13th International Conference on Electrical Bioimpedance/8th Conference on Electrical Impedance Tomography, pp.771-774, 2007.
16. H. C. Lukaski, W. W. Bolonchuk and C. B. Hall, "Validation of tetrapolar bioelectrical impedance method to assess human-body composition, Journal of Applied Physiology", vol.60, no.4, pp.1327-1332, 1986.
17. L. W. Organ, G. B. Bradham and D.T. Gore, "Segmental bioelectrical impedance analysis theory and application of a new technique", Journal of Applied Physiology, vol.77, no.1, pp.98-112, 1994.
18. Benton, J. Melissa, Swan, D. Pamela. "Comparison of Body Composition Measurement with Whole Body Multifrequency Bioelectrical Impedance and Air Displacement Plethysmography in Healthy Middle-Aged Women", Health Care for Women International vol.32, no.12, pp.1068-1078, 2011.
19. S. Shaikh and K. J. Schulze, "Bioelectrical impedance among Rural Bangladeshi Women during pregnancy and in the postpartum period", Health Populnutr, vol.29, no.3, pp.236-244, 2011.
20. P. Clarys and P. Deriemaeker, "The influence of stratum corneum hydration on body fat determination by bioelectrical impedance analysis", Skin Research and Technology, vol.18, no.1, pp.55-60, 2012.