MEASURING IMPEDANCE WITH A THIGH–TO–THIGH PATHWAY: ISN'T IT POSSIBLE TO MONITOR ONE'S BODY IMPEDANCE ?

Ki Hwan Hong*, Yong Gyu Lim*, Kwang Suk Park**

* Medical & Biological Engineering Major, Interdisciplinary program, Medical and Biological Engineering Major, Seoul National University, Seoul, Korea
** Department of Biomedical Engineering, College of Medicine, Seoul National University, Seoul, Korea

* honky@bmsil.snu.ac.kr

Abstract
Recently, bio-impednace method is used widely to estimate human body component analysis. So, many people study bio-impedance method. There are several ways to measure one's biological impedance. So many devices use one's wrist-to-wrist path, wrist-to-ankle path, foot-to-foot path, and their combinations as electrical current paths. But they have some problems such that the acquired data cannot show us impedances from his trunk as a big part. So, we propose another way to measure human impedances, especially concentrated on his trunk by skipping human arms and legs. And, non-invasiveness is another advantage of our way.

Introduction

The measurement of human body composition by instrumentation of electrical impedances under some frequencies is a good way to assess one's health. The impedance per unit area and unit length varies due to its material. In case of human body, impedance on adipose tissue differs a lot from other tissues. So, we can calculate the fat tissue's ratio from the whole body.

Applications of bioelectrical impedance analysis (BIA) methods are some of measuring human fatness. To measure and monitor one's body fat, foot-to-foot path, wrist-to-wrist path, wrist-to-ankle path and their combinations are commonly used. But, one's arms and calves have much bigger impedance values than his trunk has, and one's health is much more related in trunk's body fat than arms and legs' one. They say that the data from wrist-to-ankle path contain little amount of body fat from trunk, only about 5-10% to the total impedance [1]. So we propose one's thigh-to-thigh path to bypass the high impedance parts of the body. When the thigh-to-thigh path is chosen, it can be possible to measure one's body impedance without the arm and leg's effects to the whole body impedance.

And, we setup this device on bidet in restroom. So, we can measure the body impedance while the subject is going to the restroom and the body impedance is measured with no consciousness about this measurement. It enables our method to have non-invasive property.

Materials and Methods

The study design was an analysis of data obtained from 9 healthy male persons, the crew of my laboratory. These people underwent some assessments that weight, height, girth of waist and hip and impedances with thigh-to-thigh (TT), wrist-to-ankle (hand-to-foot: HF), foot-to-foot (FF) current paths under 100uA, logarithmically chosen 61 frequencies from 10 kHz to 1 MHz on our impedance system. In this picture at Figure 1 (a), two lower tapes with copper are current-injecting electrodes, and two upper tapes are voltage-sensing electrodes. These are attached on the seat of the bidet in restroom, so we can measure the body impedance while the subject goes to the bathroom.

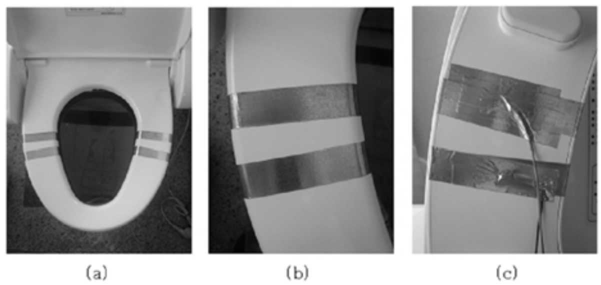

Figure 1: Electrodes on Our Toilet Seat
the whole figure of the bidet seat(a), electrode made of copper tapes on the skin-contact side(b), on the bottom side(c)

At every frequency, the data is measured in 1 second and average it. So, we can keep off from some noises.

This system is calibrated like this way. We subtract the resistance value from a resistor that we know its exact magnitude out of the measured body impedance value and then add the resistor's impedance value on every frequency. So we can eliminate the effects what our system has and any other environment does. This process is summarized on the Function 1.

ISSN: 1727-1983

$$
\begin{aligned}
&(measured\ impedance\ data) \\
&\qquad = (real\ impedance\ value) \\
&\qquad\quad + (unknown\ artifacts) \\
&(measured\ data\ from\ resistor) \\
&\qquad = (real\ impedance\ value\ on\ resistor) \\
&\qquad\quad + (unknown\ artifacts) \\
&\therefore (real\ impedance\ value) \\
&\qquad = (measured\ impedance\ data) \\
&\qquad\quad - (measured\ data\ from\ resistor) \\
&\qquad\quad + (real\ impedance\ value\ on\ resistor)
\end{aligned}
$$

Function 1: formulas for calibration

We calculate correlation coefficients of the data from our measurements and body mass index (BMI index), data and the waist/hip ratio (W/H ratio). The BMI index is calculated like this:

1. Measure one's weight and height.
2. Calculate the BMI index by dividing the weight [kg] into the square of the height [m].

And we can calculate the W/H ratio like this:

1. Measure one's girth of waist and hip.
2. Calculate the W/H ratio by dividing the circumference of waist into the circumference of hip.

Results

Figure 2 shows the impedance data with thigh-to-thigh path from our experiments. According to this data, the data has about 20 ~ 100 ohm range at 10 kHz ~ 1 MHz frequency range.

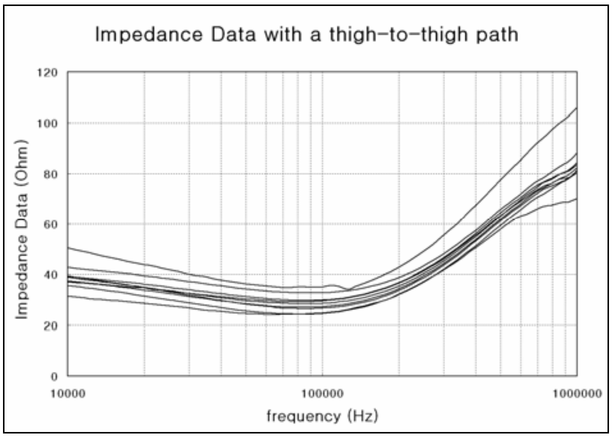

Figure 2: Thigh-to-thigh Data (TT) from our System

Figure 3 shows the impedance data with wrist-to-ankle path from our system. This data has about 300 ~ 700 ohm range (frequency: 10 kHz ~ 1 MHz), much bigger than the data with thigh-to-thigh path.

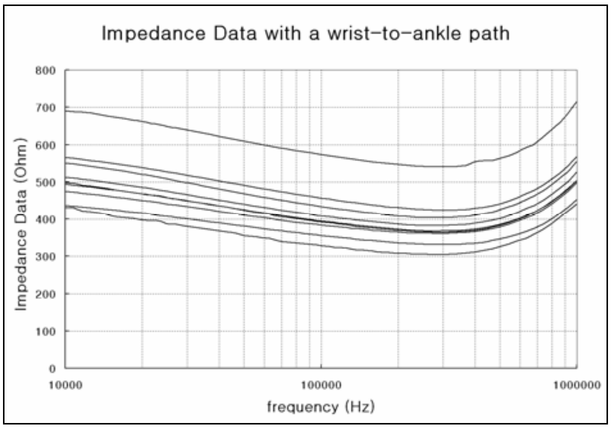

Figure 3: Wrist-to-ankle Data (HF) from our System

Figure 4 shows the impedance data with foot-to-foot current path from our system. This data also has 250 ~ 700 ohm range (frequency: 10 kHz ~ 1 MHz), similar to the data with wrist-to-ankle path.

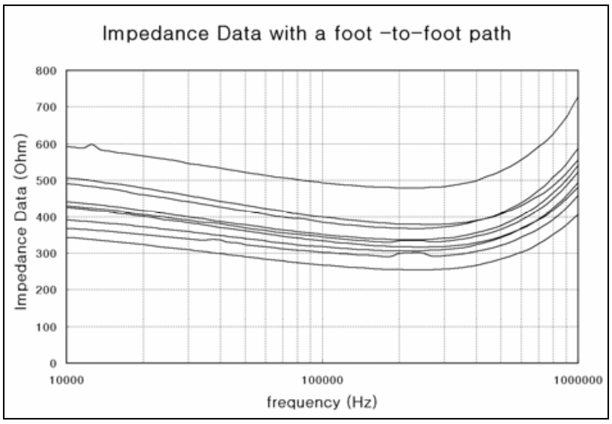

Figure 4: Foot-to-foot Data (FF) from our System

Figure 5 shows correlations between the Body Mass Index (BMI) and impedance data with the three current paths on every frequency. The correlation is calculated under this function:

$$
|\rho_{x,y}| = \left| \frac{Cov(X,Y)}{\rho_x \bullet \rho_y} \right|
$$

ISSN: 1727-1983 © 2005 IFMBE

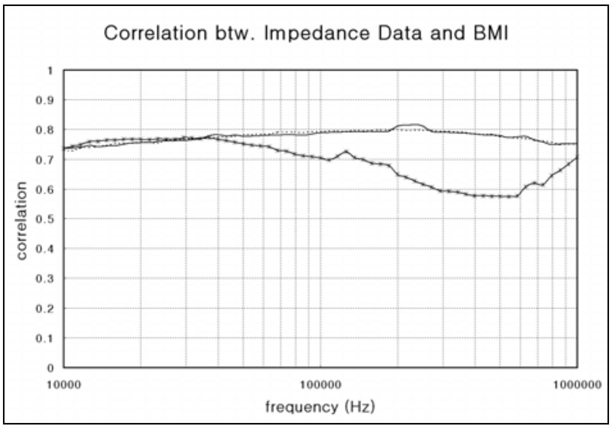

Figure 5: Correlation between BMI and Impedances at each frequency: thigh-to-thigh (-*-), wrist-to-ankle (- - -) and foot-to-foot(——) paths

Figure 6 shows correlations between W/H ratio and the impedance data with the three current paths on every frequency.

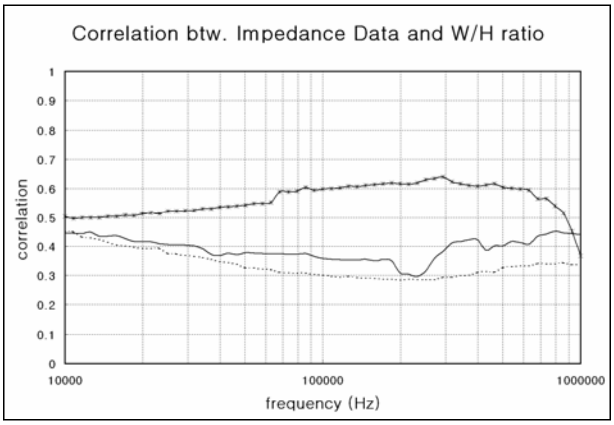

Figure 6: Correlation between W/H ratio and Impedances at each frequency: thigh-to-thigh (-*-), wrist-to-ankle (- - -) and foot-to-foot(——) paths

Discussion

Figure 2 shows impedances with the thigh-to-thigh path from our system on every frequency. According to this graph, the impedance value decreases while the frequency becomes high. And on the high-frequency area, it increases so rapidly. This data has 20 ~ 100 ohm range. At slightly more than 100MHz frequency, measured impedance from one subject looks an error. We think it's because the subject slightly changes his posture. So, his thigh – electrode contact is changed and then returns immediately.

Figure 3 and figure 4 show impedance data with the wrist-to-ankle (Figure 3) and the foot-to-foot (Figure 4) current paths. They have 300 ~ 700 and 250 ~ 700 ohm ranges, in contrast to the data from thigh-to-thigh path.

The reason of these differences between the data with wrist-to-ankle, foot-to-foot path and the data with thigh-to-thigh path is whether the current flows through arms and legs, the high-impedance terms.

Figure 5 shows that the correlation between impedance data with thigh-to-thigh path and BMI index at each frequency under 40 kHz is not so far beneath the data from other traditional current paths and the correlation is bigger than 0.7 when the frequency is lower than 100 kHz. So, as the correlations with BMI index, the thigh-to-thigh current path is as much to monitor one's obesity as the wrist-to-ankle path and foot-to-foot path below 40 kHz, and is available to calculate subject's body fat when the frequency is below 100 kHz.

Figure 6 shows correlations between the waist-hip ratio (W/H ratio) and impedances on every frequency at the three current paths. It shows that the impedance data with the thigh-to-thigh path has higher correlation to the W/H ratio than the data with other paths have.

Both of the BMI and the W/H ratio show the amount of body fatness, but the BMI is related to one's whole body, including his arms and legs, while the W/H ratio is mainly related to his abdominal area because it is calculated with parameters about one's waist and hip. So, it can be said that in concerning about one's abdominal fatness, the thigh-to-thigh path is better than other current paths.

Conclusions

This result shows that measuring body impedance with the thigh-to-thigh path enables to measure the impedance on the trunk, especially on the abdomen without influences from arms and legs. In this paper, we propose a new current path to assess body impedance. Measuring body impedance with this proposed current pathway, we can bypass the higher terms, so concentrate the trunk impedance more than other methods.

References

[1] L. W. Organ, G. B. Bradham, D. W. Gore, and S. L. Lozier, "Segmental bioelectrical impedance analysis: Theory and application of a new technique," J. Appl. Physiol., vol. 77, pp. 98-112, 1994

[2] L Ward, B H Cornish, N I Paton and B J Thomas (1999): "Multiple frequency bioelectrical impedance analysis: a cross-validation study of the inductor circuit and Cole models", Physiological Measurement 1999, pp. 333-347

[3] Hermann Scharfetter, Patricia Brunner, Michael Mayer, Bernhard Brandstätter, and Helmut Hinghofer-Szalkay, "Fat and hydration monitoring by abdominal bioimpedance analysis: Data interpretation by hierarchial electrical modeling," IEEE Trans. Biomed. Eng., vol.52, no.6, pp. 975-982, 2005

[4] R. N. Baumgartner, W. C. Chumela, and A. F. Roche, "Estimation of body composition from

ISSN: 1727-1983 © 2005 IFMBE

bioelectric impedance of body segments," *Amer. J. Clin. Nutrit.*, vol. 50, pp. 221–226, 1989.

[5] K. R. Segal, M. V. Loan, P. I. Fitzgerald, J. A. Hodgon, and T. B. V. Itallie, "Lean body mass estimation by bioelectrical impedance analysis: A four-site cross-validation study," *Amer. J. Clin. Nutrit.*, vol. 47, pp. 7–14, 1988.

[6] H. C. Lukaski, "Methods for the assessment of human body composition: Traditional and new," *Amer. J. Clin. Nutrit.*, vol. 46, pp. 537–556, 1987.

[7] G. McNeill et *al.*, "Body fat in lean and overweight woman estimated by six methods," *Br. J. Nutrit.*, vol. 65, pp. 95–103, 1991.

ISSN: 1727-1983 © 2005 IFMBE