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Ethnic Differences in the Relationship between Bioelectrical Impedance and Body Size

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Abstract The present study compared the regression equations of bioelectrical impedance on body size among various groups to investigate potential differences due to ethnicity. Data consisted of 30 Japanese and 28 Caucasoid subjects, and other groups of Aborigines, Danes, Melanesians and Polynesians from literature. The relationship between impedance and body weight fot the groups showed the ethnic difference. In the regression equations for Japanese and Caucasoid, a statistically significant difference was observed between both groups. The regression equation for Japanese was lower in the elevation. This seemed to be attributable to differences in the volume of fat-free mass for the same body build, configuration of the body, and fat-free mass density.
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Introduction

The use of bioelectrical impedance analysis (BIA) for the determination of body composition has been documented since the 1970s (Baumgartner, 1996). The theory underlying BIA is that impedance (I) is a function of the length (L) and the cross sectional area (A) of the conductor, that is, $I=\rho L/A$, where ρ is a proportionality constant. Multiplying the right hand side by L/L, the equation can be expressed as $I=\rho L^2/AL$. Since L and AL represent height (H) and weight (W) respectively, the equation can be rewritten as $I=\rho H^2/W$. Strictly, since W is the volume of a conductor and fat-free mass (FFM) is typical of the conductive portion of weight, the equation is expressed as $FFM=\rho H^2/I$. Therefore, many prediction equations in BIA have been developed on the basis of the relationship between I and H^2/W, or FFM and H^2/I.

However, there is a possibility that the prediction equation developed for a specific population inaccurately estimates percent body fat of other ethnic groups. Heyward (1996) reviewed previously published prediction equations in BIA and described that equations using White samples underestimate percent body fat in African American men and women. In addition, he suggested that further research is needed to cross-validate the prediction equations for American Indian, Asian, African American, and Hispanic populations. Later, Heitmann et al. (1997) investigated ethnic differences in the regression equations of impedance on body weight and concluded that, except for Australian Aborigines, the regression equations were generally constant in the different ethnic groups. This implies the possibility of a constant relationship between impedance and body weight among many ethnic groups. In order to extend the above-mentioned findings, the present study compared the regression equations of bioelectrical impedance on body size between Japanese (Mongoloid) and Caucasoid samples to investigate potential differences due to ethnicity.

Methods

Japanese subjects consisted of 30 male volunteer physical education students who were residents in Akita prefecture of Japan. The measurement of Caucasoid subjects was firstly made with 12 male students majoring in kinesiology in California State University, Northridge, in the United States of America. A second measurement of Caucasoid subjects was made with 16 male students of the Anthropological Institute at the University of Kiel in Germany. All measurements were carried out in the morning. Standing height, body weight, skinfold thickness and bioelectrical impedance were measured. A skilled investigator measured skinfold thickness at the triceps and the subscapular sites to the nearest half-millimeter using either a skinfold caliper developed by the National Institute of Nutrition in Japan or a Harpenden skinfold caliper. The same bioelectrical impedance analysis equipment (SIF-

Table 1 Physical characteristics of Japanese and Caucasoid students.

	Japanese n=30		Caucasoids n=28		Difference#
	mean	SD	mean	SD	
Age, year	19.6	1.7	24.4	2.0	**
Height, cm	173.3	6.6	180.0	7.1	**
Weight, kg	66.5	8.1	75.7	9.2	**
Body Mass Index, kg/m^2	22.1	1.8	23.3	2.0	*
Triceps skinfold, mm	8.2	2.3	9.3	3.4	n.s.
Subscapular skinfold, mm	10.3	2.0	11.7	2.4	*
Bioelectrical impedance, ohm	450.3	31.8	463.0	40.6	n.s.

shows results of the t-test for the difference in mean values between both groups.
* and ** show the significance levels at 5% and 1%, respectively.

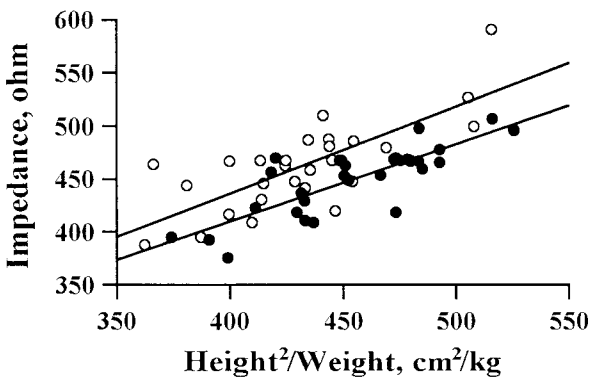

Fig. 1 Relationships between height^2/weight and impedance. Regression equations are y=119+0.727x (r=0.817, p<0.01) for Japanese (solid circle) and y=108+0.821x (r=0.755, p<0.01) for Caucasoid (open circle), respectively.

891, Selco Inc., Japan) was used for both Japanese and Caucasoid groups. Subjects were measured in the supine position with no contact between arms and the trunk and with legs not touching each other. Electrodes were attached to the dorsal surfaces of the right hand and the right foot and electrodes for the conduction of electricity between distal prominences of the radius and the ulna at the wrist, and the medial and lateral malleoli at the ankle. The electric current was 800 microamperes and the frequency 50 kilohertz. Impedance readings of the equipment were assessed at a mean error of 0.6% using resistors in 300 to 500 ohms level range.

Results and Discussion

The mean value and standard deviation of the physical characteristics for Japanese and Caucasoid are shown in Table 1. Results of the t-test for the difference in mean values are also indicated on the right hand side. Height and body weight were significantly different between the groups with Caucasoid being larger than Japanese. In addition, Caucasoid had larger body mass index (BMI) and subscapular skinfold thickness. The mean bioelectrical impedance was approximately 450 ohms for both groups.

Regression equations of impedance on H^2/W for Japanese and Caucasoid were calculated and are shown in Figure 1. The impedance values were highly correlated with the H^2/W values for each group. Comparing the regression coefficients (F=0.31, n.s.) and the elevations (F=22.31, P<0.01) with each group, the regression equations of impedance on H^2/W for both groups were significantly different with respect to the elevations. Caucasoid showed higher impedance values compared to Japanese for the same H^2/W value. Consequently, it was speculated that Caucasoid has less FFM compared with Japanese of the same body build. This result implies that prediction equations developed previously need ethnically specific cross-validation to determine their applicability to individuals from various ethnic groups.

Figure 2 shows the relationship between impedance and body weight for various ethnic groups including the present data for Japanese and Caucasoid. Data for Aborigines, Danes, Melanesians and Polynesians are quoted from the investigation by Heitmann et al. (1997) who supposed a constant relationship between impedance and body weight among many ethnic groups except for Australian Aborigines. In the regression equations for Japanese and Caucasoid, however, a statistically significant difference was observed between both groups. That is, F-values were 0.42 (n.s.) for the regression coefficient and 10.29 (P<0.01) for the elevation, respectively. This result is somewhat different from the results reported by Heitmann et al. (1997). Their investigation was only based on Caucasoid, Melanesian and Polynesian groups, with Japanese (Mongoloid) group not included.

As Heitmann et al. (1997) described, Australian Aborigines who had slender limbs gave different impedance readings compared to other ethnic groups, and it seems that the difference in body shape between Japanese and Caucasoid subjects may be partly responsible for different regression equations of impedance on body weight or on H^2/W. In contrast to Australian Aborigines, Mongoloid ancestors had evolved over time in cold environments and been shaped to have shorter limbs than the Caucasoid, according to Allen's ecological rule. Since resistance against extremities considerably determines total body resistance, the impedance

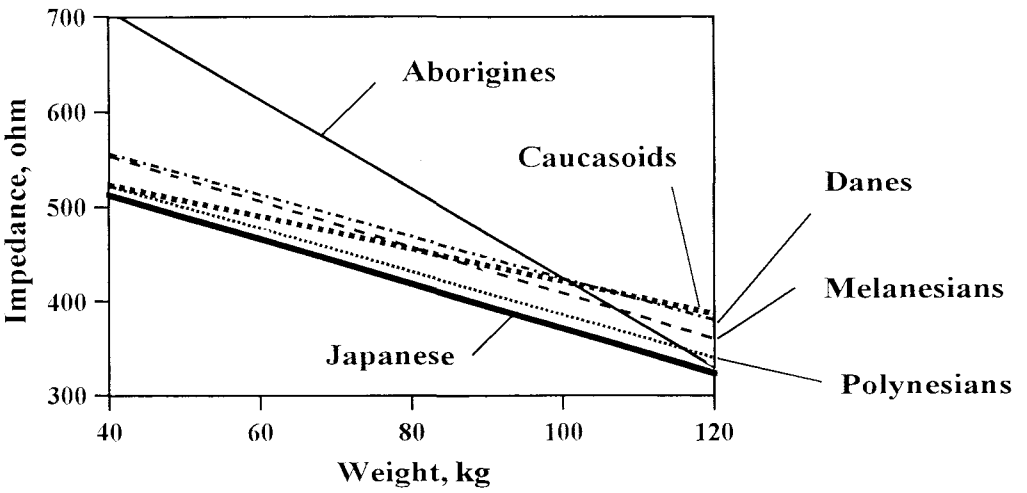

Fig. 2 Relationships between body weight and impedance for various ethnic groups. Regression equations are $y=608-2.37x$ ($r=-0.604$, $p<0.01$) for Japanese and $y=593-1.72x$ ($r=-0.388$, $p<0.05$) for Caucasoid respectively. Data for other ethnic groups are from literature (Heitmann et al., 1997).

may be disproportionately lower in Japanese compared with Caucasoid. Furthermore, the difference in regression equations observed between Japanese and Caucasoid may be partly attributed to differences in FFM density, although there is no study to suggest the difference between Asians and Whites on the molecular level (Wang et al., 1995).

In conclusion, findings in this study suggest that the relationship between bioelectrical impedance and body size in Japanese and Caucasoid is ethnically specific, and possible explanations are as follows. Firstly, Caucasoid may fundamentally have less fat-free mass compared with Japanese of the same body build. Secondly, the difference in configuration of the body between Japanese and Caucasoid may affect the conductivity. And thirdly, it is possible to suppose that there is the difference in fat-free mass density between both groups, which may also lead to the difference in the conductivity.

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