

Percentage Body Fat Assessed by Bioelectrical Impedance Analysis as a New Health Index for Rural Areas in the Asia-Pacific Region

Kazuo MINEMATSU,¹ Yoshinori KANEKO,² Mio NAKAZATO,³ Takahiro MAEDA,³ Nmor Jephtha CHRISTOPHER,¹ Takeshi YODA,⁴ Kensuke GOTO,⁴ Noboru TAKAMURA,⁵ and Tsutomu MIZOTA¹

¹ Department of Global Health Development Policy Sciences, Institute of Tropical Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan

² Laboratory of Gymnastics Methodology, Kagawa Nutrition University, Saitama, Japan

³ Department of Island Community Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan

⁴ Department of Global Health Development Policy Sciences, Institute of Tropical Medicine, Nagasaki University, Nagasaki, Japan

⁵ Department of Radiation Epidemiology, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki, Japan

Objective: The incidence of obesity has been increasing in the Asia-Pacific region, but many areas do not have access to expensive medical devices for evaluating body composition. Bioelectrical impedance analysis (BIA) can precisely and easily estimate percentage body fat (%BF), regardless of social environment. The purpose of this study was to evaluate differences in body composition among ethnic groups living in rural areas in the Asia-Pacific region, and to analyze associations between body mass index (BMI) and %BF as measured by BIA. **Methods:** A total of 869 middle-elderly adults (Japanese: 131 men, 435 women; Palauan: 42 men, 49 women; Thai: 106 men, 106 women; mean age, 58 years; range, 40-69 years) were recruited from rural areas in Thailand, Koror Island in Palau, and Goto Island in Japan. Weight and %BF were estimated using BIA. Height was measured and BMI was calculated. **Results:** Weight, BMI, and %BF clearly differed among ethnic groups and by gender ($p < 0.0001$). In each ethnic group, %BF was significantly correlated with BMI for each sex (men: Japanese, $r = 0.691$, $p < 0.0001$; Palauan, $r = 0.892$, $p < 0.0001$; Thai, $r = 0.842$, $p < 0.0001$; women: Japanese, $r = 0.892$, $p < 0.0001$; Palauan, $r = 0.892$, $p < 0.0001$; Thai, $r = 0.779$, $p < 0.0001$). **Conclusions:** BIA offers a reliable option for measuring %BF and a strong association exists between %BF and BMI for individuals in rural areas of the Asia-Pacific region, regardless of ethnicity.

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Introduction

The incidence of obesity has been increasing in both developed and developing countries, particularly in the Asia-Pacific region.¹⁻⁴ Obesity is a well-known risk factor for future cardiovascular disease (CVD) and certain kinds of malignant disorders for all populations.⁵⁻⁷ In particular, obesity in middle- to old-aged individuals has quantitatively different effects on morbidity and mortality and decreases in quality of life (QOL) compared with young individuals.⁸ Obesity in elderly individuals is also an important risk factor for both the development and progression of osteoarthritis.^{9,10}

Body mass index (BMI) is widely recognized as the standard index for defining obesity not only by the World Health Organization

(WHO),^{11,12} but also by organizations such as the International Society for the Study of Obesity (ISSO),¹² the International Obesity Task Force (IOTF),¹² the National Institutes of Health,¹³ the Expert Panel on the Identification, Evaluation, and Treatment of Overweight in Adults,¹⁴ and the Japan Society of the Study for Obesity.¹⁵ In Japan, BMI has been officially recognized as the index for defining obesity by the Ministry of Health, Labour and Welfare and has been used in calculations at health examinations since 2008.¹⁶

However, setting a unifying cut-off value for obesity for all ethnic groups is difficult using BMI, as body compositions differ among ethnic groups.¹⁷⁻¹⁸ The WHO has admitted this and recommended different cut-off values for obesity in each ethnic group. The WHO, ISSO, and IOTF have issued a joint publication¹² rec-

Address correspondence: Kazuo Minematsu, M.D., Department of Global Health Development Policy Sciences, Institute of Tropical Medicine, Nagasaki University Graduate School of Biomedical Sciences, 1-12-4 Sakamoto, Nagasaki 852-8523, JAPAN

TEL: +81-(0)95-819-7866, FAX: +81-(0)95-819-7867, E-mail: dm06087d@cc.nagasaki-u.ac.jp

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ommending different cut-off BMIs for defining overweight status and obesity in the Asia-Pacific region: "24 and 29 in Chinese"; "24 and 26 in Indonesians"; "22 and 27 in Singaporeans"; and "27 and 31 in Thais", respectively. They also suggested that these cut-off values do not apply to ethnic groups living in the Pacific region.

BMI is a simple index calculated by height and weight, but does not reflect the actual body composition of fat mass (FM) and fat-free mass (FFM).¹⁹ Obesity is defined as an excess accumulation of FM.¹¹ Excess FM is represented by percentage body fat (%BF), which is defined as the "gold standard".²⁰ The importance of body composition measurements for the assessment of obesity is well recognized and various methods have been developed.²¹⁻²⁵ Expensive medical equipment such as nuclear magnetic resonance (NMR), computed tomography (CT), and dual-energy X-ray absorptiometry (DEXA) can evaluate body composition in detail. However, since many developing countries, particularly in rural areas, and island communities in developed countries do not have access to such equipment, bioelectrical impedance analysis (BIA) has become the most convenient method for large-scale surveys, regardless of the medical environmental conditions.²⁶

We therefore selected rural study areas in developed and developing countries in the Asia-Pacific region in which utilization of expensive medical devices is difficult. The hypothesis of our study was that the measurement of BMI in combination with %BF measured by BIA would offer the most effective means of evaluating overweight status and obesity, offering a new health index for each region.

The first objective of this study was to investigate differences in body composition among middle-aged to elderly individuals in ethnic groups living in rural areas of Thailand, Koror Island in Palau, and Goto Island in Japan using BIA. We then analyzed associations between BMI and %BF to clarify a new health index in each region.

Materials and Methods

Subjects

Prior to this study, approvals for the study protocol were obtained from the Special Committee of Nagasaki University (Nagasaki, Japan), the ethics committee of Kagawa Nutrition University (Saitama, Japan), the Official Research Permission of the Ministry of Health of Palau (Koror, Palau), and the Committee on Rights Related Human Experimentation of Mahidol University (Bangkok, Thailand). Data were obtained from three countries in the Asia-Pacific region: Japan, Palau, and Thailand. After obtaining informed consent, we enrolled a total of 869 subjects: 566 Japanese participants (131 men, 435 women; mean age, 58 years; range, 40-69 years), 91 Palauan participants (42 men, 49 women; mean age, 57 years; range, 40-69 years), and 212 Thai participants (106 men, 106 women; mean age, 58 years; range, 40-69 years) through the medical screening program in Goto City (Nagasaki, Japan), the National Bureau of Clinical Services of the Ministry of

Health in Palau at the National Hospital (Koror, Palau), and health centers in the Pracha Nviet Area of Jatujuk District and the Sainoi Area of Nontaburi Province (Thailand), respectively. Participants from Japan, Palau, and Thailand were of Japanese, Palauan, and Thai ethnicity, respectively. No participants were excluded from this study, since none had any apparent past or present history of atherosclerotic diseases, including cerebral infarction, hemorrhage or ischemic heart disease.

Data Collection

Weight and %BF were estimated using a BIA machine (DC-320, traditional 4-electrode, foot-to-foot system, 50 kHz; Tanita, Tokyo, Japan). Weight was measured to the nearest 0.1 kg and %BF to the nearest 0.1%. Measurements of BIA were carried out according to the instructions from the manufacturer and data on age, sex, and height of subjects were recorded before measurement. After cleaning all skin contact areas with diluted alcohol, participants stood on a device with the soles of the feet to detect bioelectrical impedance. BIA measurements were conducted once in each subject. Height was measured to the nearest 0.1 cm and BMI was calculated as weight in kilograms divided by the height in meters squared.

Statistical Analyses

Height, weight, BMI and %BF are expressed as mean standard deviation (SD). Differences in body composition between sexes and ethnicities were evaluated using the Kruskal-Wallis test. The Pearson correlation coefficient (r) was also used to assess associations among each measurement variable, including BMI and %BF in each ethnic group and in each sex. Values of $p < 0.05$ were considered indicative of statistical significance. All statistical analyses were performed using SPSS v15.0 software (SPSS Japan, Tokyo, Japan).

Results

A total of 869 subjects were evaluated for body composition, consisting of 279 men (32.1%) and 590 women (67.9%). The study not only showed a strong association between %BF and BMI with regard to ethnicity, but also confirmed the viability of using BIA to assess %BF in the study areas. Data in Table 1 and Figure 1 show pooled characteristics of body composition among subjects. Body weight, BMI, and %BF in both sexes and among the three ethnic groups showed significant differences as revealed by the Kruskal-Wallis test ($p < 0.0001$). Table 2 indicates correlation coefficients and p -values among ethnic groups with respect to gender. A significant correlation was seen between %BF and BMI among the three ethnic groups in each sex (men: Japanese, $r = 0.691$, $p < 0.0001$; Palauan, $r = 0.892$, $p < 0.0001$; Thai, $r = 0.842$, $p < 0.0001$; women: Japanese, $r = 0.892$, $p < 0.0001$; Palauan, $r = 0.892$, $p < 0.0001$; Thai, $r = 0.779$, $p < 0.0001$) (Figure 2a, b).

Table 1a. Physical characteristics of men in three ethnic groups

	Ethnic group			Kruskal-Wallis test
	Japanese	Palauan	Thai	
n	131	42	106	
Height(cm)	163.9 ± 5.7	166.4 ± 4.1	163.7 ± 5.4	p=0.0046
Weight(kg)	63.6 ± 8.4	87.7 ± 19.6	63.6 ± 9.8	p<0.0001
BMI(kg/m ²)	23.6 ± 2.7	31.7 ± 6.6	23.8 ± 3.4	p<0.0001
%BF (%)	21.4 ± 5.4	29.0 ± 8.1	23.8 ± 6.6	p<0.0001

Data are expressed as mean ± standard deviation

Table 1b. Physical characteristics of women in three ethnic groups

	Ethnic group			Kruskal-Wallis test
	Japanese	Palauan	Thai	
n	435	49	106	
Height(cm)	153.2 ± 5.1	155.5 ± 5.0	151.6 ± 5.4	p=0.0001
Weight(kg)	52.8 ± 7.8	76.9 ± 16.1	57.8 ± 10.5	p<0.0001
BMI(kg/m ²)	22.5 ± 3.1	31.7 ± 5.7	25.2 ± 4.3	p<0.0001
%BF (%)	27.2 ± 5.6	39.2 ± 6.0	36.3 ± 8.3	p<0.0001

Data are expressed as mean ± standard deviation

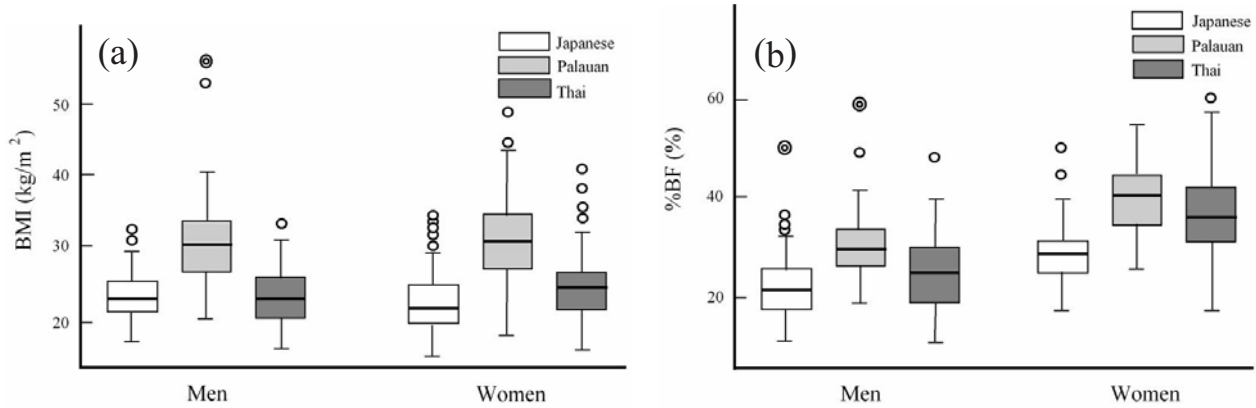


Figure 1. Characteristics of BMI(a) and %BF(b) among Japanese, Palauan, and Thai for each sex using box-and-whisker plots. The end of whiskers indicates the position of the minimum and maximum of the data, and the edges and line in the center of box indicate the upper and lower quartiles and the median, respectively. Extreme values and outliers are represented by double circles and circles, respectively.

Table 2a. Pearson correlation coefficients (p-values) for men in three ethnic groups

	Height	Weight	BMI	%BF
Height	-	0.487(p<0.0001)	-0.049	-0.099
	-	0.308(p<0.05)	0.094	0.192
	-	0.325(p<0.0001)	-0.095	-0.030
Weight	0.487(p<0.0001)	-	0.847(p<0.0001)	0.553(p<0.0001)
	0.308(p<0.05)	-	0.975(p<0.0001)	0.892(p<0.0001)
	0.325(p<0.0001)	-	0.908(p<0.0001)	0.786(p<0.0001)
BMI	-0.049	0.847(p<0.0001)	-	0.691(p<0.0001)
	0.094	0.975(p<0.0001)	-	0.892(p<0.0001)
	-0.095	0.908(p<0.0001)	-	0.842(p<0.0001)
%BF	-0.099	0.553(p<0.0001)	0.691(p<0.0001)	-
	0.192	0.892(p<0.0001)	0.892(p<0.0001)	-
	-0.030	0.786(p<0.0001)	0.842(p<0.0001)	-

Top row, Japanese; second row, Palauan; third row, Thai

Table 2b. Pearson correlation coefficients (p-values) for women in three ethnic groups

	Height	Weight	BMI	%BF
Height	-	0.378(p<0.0001)	-0.077	-0.107(p<0.05)
	-	0.540(p<0.0001)	0.286(p<0.05)	0.389(p<0.0001)
	-	0.402(p<0.0001)	0.005	-0.104
Weight	0.378(p<0.0001)	-	0.892(p<0.0001)	0.777(p<0.0001)
	0.540(p<0.0001)	-	0.960(p<0.0001)	0.893(p<0.0001)
	0.402(p<0.0001)	-	0.915(p<0.0001)	0.669(p<0.0001)
BMI	-0.077	0.892(p<0.0001)	-	0.892(p<0.0001)
	0.286(p<0.05)	0.960(p<0.0001)	-	0.892(p<0.0001)
	0.005	0.915(p<0.0001)	-	0.779(p<0.0001)
%BF	-0.107(p<0.05)	0.553(p<0.0001)	0.892(p<0.0001)	-
	0.389(p<0.0001)	0.892(p<0.0001)	0.892(p<0.0001)	-
	-0.104	0.669(p<0.0001)	0.779(p<0.0001)	-

Top row, Japanese; second row, Palauan; third row, Thai

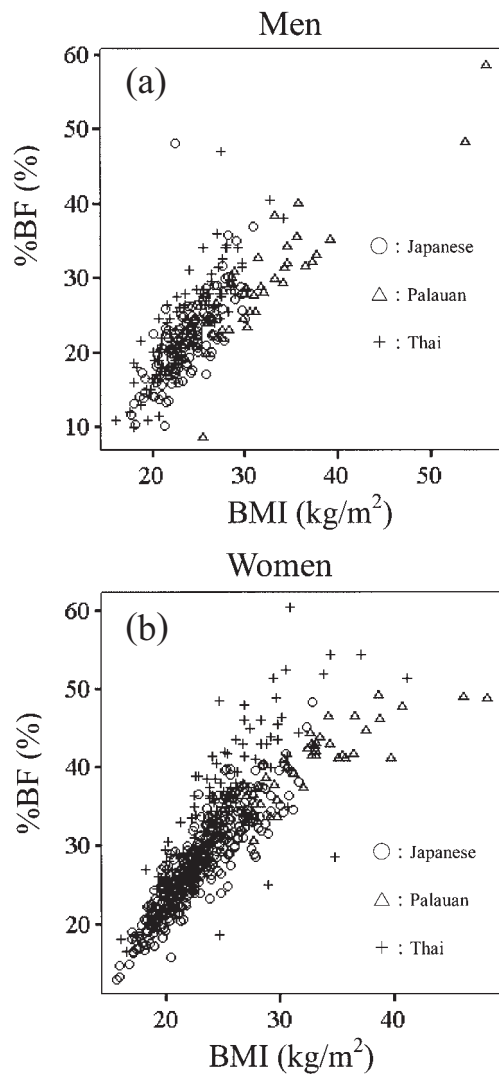


Figure 2. Correlation between %BF and BMI of Japanese (○), Palauan (△), and Thai (+) for men (a) and women (b).

Discussion

Recent developments in the field of body composition analysis have increased the accuracy of estimating differences in body composition.²⁷ However, research techniques such as whole body counting, isotope electrical conductivity, in vivo neutron-activation analysis, and others have limited availability, are expensive to develop and maintain, and are technologically difficult to perform in rural areas, thus hindering applicability in field studies.

BIA has shown great potential for use in estimating body composition. The method is based on the assumption that the body is basically a cylindrical ionic conductor in which the extra- and intracellular non-adipose tissue compartments act as resistors and capacitors, respectively.²⁸ From this perspective, BIA offers numerous advantages over conventional methods such as skinfold thickness measurement or updated evaluation methods using expensive medical devices, since BIA is inexpensive, easy to use, free of observer

bias, and precise.²⁹

This study evaluated body compositions of three ethnic groups living in rural areas of the Asia-Pacific region using BIA, revealing significant differences in body composition (height, weight, BMI, and %BF) between men and women and among each ethnicity. However, the current results show that relationships between BMI and %BF were strong in each ethnic group and in both sexes. We therefore strongly suggest that a combined method using BMI and %BF as measured by BIA offers an appropriate biological marker to evaluate overweight and obese status, and as such remains a viable option for assessing body composition in settings where sophisticated and expensive equipment is lacking. BIA demonstrates a good relationship with DEXA (FM, squared correlation coefficient (r^2)=0.81; FFM, r^2 =0.81; %BF, r^2 =0.69) and BIA is a good predictor of DEXA-derived FFM (r =0.85-0.88).^{30,31}

Results and the findings of this study strongly suggest that we need to evaluate body composition not only using expensive medical equipment in developed countries, but also using BIA in developing countries and less-developed areas in developed countries. Although BIA is one of the most practical approaches to assess %BF for large population surveys, we need to consider that water content of FFM based on BIA varies between ethnic groups, and diurnal changes in fluid balance are likely to occur in tropical countries.³²

The present study shows several limitations. We could not estimate the cut-off value as a criterion for obesity in each ethnic group, since sample size was relatively small, and we could not perform laboratory evaluations for each ethnic group. In addition, we did not investigate daily lifestyles of each participant, such as food intake and physical activity, even though these factors are associated with being overweight. Further studies are needed to clarify relationships in each ethnic group between body composition in obese status and risk of related diseases, such as cardiovascular diseases and osteoarthritis.

In conclusion, we evaluated body composition using BIA in different ethnicities of the Asia-Pacific region where utilization of new medical devices is difficult, and identified differences in body composition among ethnic groups. We also confirmed a strong association between BMI and %BF, regardless of ethnicity. These results suggest that %BF as measured by BIA offers a new and useful health index as along with BMI for individuals living in rural areas of the Asia-Pacific region without access to expensive medical equipment.

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Conflicts of interest

We do not have any conflict of interest. Also, this research

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Word counts

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Number of figures and tables

4 figures (Figure 1a,b and 2a,b) and 4 tables (Table 1a,b and 2a,b)

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