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Body Mass Index and Body Fat Percent of Koreans in Seoul and Pusan Compared to those of Caucasians

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This study was conducted to determine the relationship between the body fat percent (BF%) and body mass index (BMI) of Koreans and the differences with Caucasians. Complete data were collected from 3297 subjects (2441 females and 856 males) between the ages of 18 and 79. Data were collected between September 2001 and November 2001 in Seoul and Pusan. For the statistical analysis, only the data on subjects between the ages of 18 and 65 (3200) were used. Body weight and height were measured. BMI (kg/m^2) was computed. From BMI, BF (%) was calculated using age- and sex-specific prediction formulas. BF% was assessed using an INBODY 2.0 body fat analyser. Data analysis showed that the females were significantly younger than the males, were smaller, lighter and had a lower body mass index. Body fat percent of the females was higher than that of the males. The differences between actual measured BF% and BF% as predicted from prediction equations from the literature, based on BMI, age and sex, were correlated with level of body fat and age. There is a significant age-related decrease in body fat in Koreans for any given BMI and sex, which is remarkably different compared to age-related increases in body fat in the European reference group. For the same age and BF%, Korean females have a slightly lower BMI than their European counterparts. Korean males have, for the same age and BF%, a higher BMI than their European counterparts. The differences between females and males were not significant. It was concluded that, assuming that the data on body fat percent was correct, that the relationship between BF% and BMI is quite different in Koreans than in European Caucasians. Thus, for younger Koreans cut-off values for obesity should be slightly lower than those for Caucasians whereas for older Koreans the cut-off points for obesity should be higher than those for Caucasians.

Key Words: Body mass index, Body fat percent, Body fat, Obesity

INTRODUCTION

The World health Organization (WHO) defines obesity as a condition in which excess body fat has accumulated to the extent that health and well-being are adversely affected.[1)] Body fat can be measured *in vivo* using various techniques.[2)] For epidemiological studies, the techniques should be simple and yet accurate.[3)] The method of choice, especially for large epidemiological studies, is normally the Body Mass Index (BMI, weight (kg)/height (m)^2) which is used as a surrogate for body fat percent. Numerous studies have shown that BMI correlates highly with body fat percent (BF%) which is independent of height, enabling "unbiased" comparisons between short and tall population groups.[4-7)] However, it must be borne in mind that BMI is no more than weight adjusted for height, and thus BMI is also related to fat-free mass[8)] and body build.[9,10)]

In the report "Obesity, preventing and managing the global epidemic", the WHO[1)] classifies overweight and obesity at BMI cut-off levels of 25 and 30 kg/m^2, respectively. These WHO cut-off values are independent of age and are the same for both sexes. However, as stated in the report, WHO recognises that BMI may not correspond to the same degree of fat across populations.

Several studies have been published in which the relationship between BMI and BF% was investigated. Many studies suggested that the relationship between BMI and BF% depends on age and sex[4,6,7)] and also differs across ethnic groups.[10-16)] However, not all studies found differences in the BMI/BF% relationship between ethnic groups.[17,18)]

Recent studies of Hong Kong Chinese,[14,19)] Singaporean Chinese, Malays and Indians,[13)] Indonesians[12)] and Japanese[20)] suggested that these Asian populations have a high body fat percent at low BMI. This might partly explain the high relative risks of having risk factors such as hypertension, hyperglycemia, diabetes and elevated serum lipids in these populations at low BMI.[21,22)] The high BF% at low BMI and the high prevalence of risk factors at low BMI have led several authors to suggest

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that BMI cut-off points for overweight and obesity should not be universal but ethnic group-specific.[21-23]

Thus, there is a need to determine the relationship between BMI and BF% in each ethnic group. This report analyses the relationship between body mass index (BMI) and body fat percent (BF%) in adult Koreans and compares the data with available data on Europeans (Italian and Dutch). Body fat percent in this group of Koreans was measured using bioelectrical impedance. Bioelectrical impedance is not a reference method for measuring body fat. Body fat percent is obtained after measuring the bioelectrical impedance of the body (in this case total body impedance using INBODY) and using prediction equations. Predictive methods are known to be susceptible to population specificity, which could result in biased predicted values and hence biased conclusions. One has to realise that, unless the predictive method is validated against a reference method in the population under study, such validation studies are not conclusive about the general validity of the method, as factors that influence the validity of the methodology might be different in the population under study compared to the population in which the prediction formula was developed.[24-26] The use of weight and height in the prediction equation limits comparisons of predicted body fat percent with body mass index and/or predicted body fat percent from body mass index.[27-29] In this report, we set out to determine the relationship between BF% and BMI in Koreans. Also, with some limitations, BF% and BMI were compared to those of Caucasians to determine the differences and relationships.

SUBJECTS AND METHODS

Complete data were collected from 3297 subjects (2441 females and 856 males) between the ages of 18 and 79. Data were collected between September 2001 and November 2001 in two cities (Seoul and Pusan) during public events organised by the Korean Dietetic Association. For the analyses in this report, only the data on subjects between the ages of 18 and 65 (3225) were used. After cleaning the data file for some outliers (extremely low BMI, body fat percent, weight or height) a total of 3200 subjects remained for the statistical analyses.

Body weight and body height were measured without shoes to the nearest 0.1 kg and 1 cm, respectively. Body mass index (BMI, kg/m^2) was computed as weight divided by height squared.

From body mass index, body fat percent was calculated using age- and sex-specific prediction formulas.[6,7,16] The formulas are follows:

Dutch prediction formula:[6]

$$BF\% = 1.2 \times BMI - 10.8 \times sex + 0.23 \times age - 5.4$$

American (Caucasian) prediction formula:[7]

$$BF\% = 1.506 \times BMI - 11.5 \times sex + 0.133 \times age - 11.5$$

Caucasian prediction formula, based on a meta-analyses of Caucasian data:[16]

$$BF\% = 1.294 \times BMI - 11.4 \times sex + 0.20 \times age - 8$$

(BF%; body fat percent; BMI: body mass index (kg/m^2); age: in years; sex: females=0, males=1).

Body fat percent (BF%) was assessed to the nearest 0.1 percent point using a INBODY 2.0 body fat analyser (INBODY, Seoul, Korea). Currently, information is not available on the validity of the predicted body fat percent values with this instrument for the Korean-population specific.

Statistical analyses were performed using SPSS for Windows, version 10.0.0.[27] Comparisons between groups of subjects were done using analysis of variance (ANOVA) or analysis of covariance (ANCOVA). Comparison between variables was done using student t-test. The validity of predicted values was tested using the Bland and Altman[28] procedure. Correlation coefficients were Pearson product moment or partial correlation coefficients.

Stepwise linear regression was performed using BF% as a dependent variable and BMI, age, sex (as dummy variable, female=0, male=1) as independent variables. Data are expressed as mean±standard deviation (SD) unless otherwise indicated. Significance is set at $p<0.05$.

RESULTS

Table 1 shows characteristics of the female and male subjects. The females were significantly younger than the males, were smaller, lighter and had a lower body mass index. The body fat percent of the females was higher than that of the males.

Table 1. Characteristics of the Korean subjects.

	Females (2403)				Males (797)			
	Mean	SD	Range		Mean	SD	Range	
Age (years)	27.0*	11.1	18	65	34.9	13.4	18	65
Height (cm)	160.6*	4.9	142	176	172.2	5.7	152	189
Weight (kg)	55.1*	7.8	35.0	98.0	71.0	10.2	47.0	108.0
BMI[1)] (kg/m^2)	21.4*	2.9	14.4	36.3	23.9	3.0	16.8	34.0
Body fat percent	27.7*	5.0	13.9	49.1	18.8	5.1	7.0	42.0

1) BMI, body mass index kg/m^2
*: $p<0.001$ between females and males

Table 2 shows the differences between actual measured BF% and BF% as predicted from prediction equations from the literature, based on BMI, age and sex.

Table 2. Bias in predicted body fat percent from BMI, age and sex using various Caucasians prediction equations from the literature.

BF% minus	Females		Males	
	Mean	SD	Mean	SD
BF% 6[1)]	1.2*	4.5	-1.8*	3.9
BF% 7[2)]	3.4*	3.9	1.1*	3.4
BF% 16[3)]	2.6*	4.3	0.2	3.7

Values differ from zero (p<0.001). All values differ between females and males

1) body fat predicted using a Dutch prediction equation (reference 6)
2) body fat predicted using an 'American' prediction equation (reference 7)
3) Caucasians: body fat predicted using a 'Caucasian' prediction equation (reference 16)

The uncorrected bias of the different predicted values is correlated with level of body fat and with age (Table 3). As body fat percent normally increases with age, the partial correlations of the biases with BF% (corrected for age) and with age (corrected for BF%) were also calculated. All (partial) correlation coefficients are tabulated in Table 3 for females and males, separately. The given values of correlation coefficients are only for bias from predicted BF% using a Dutch formula.[6)] The correlation coefficients of the biases of the other equations did not differ substantially.

Table 3. Pearson correlation coefficients and partial correlation coefficients of bias of predicted body fat percent using a Dutch prediction equation (6) with BF% and age*

	Females		Males	
	BF%	Age	BF%	Age
	0.45	-0.72	0.34	-0.61
Controlling for: BF%	-	-0.87	-	-0.79
Controlling for: Age	0.76	-	0.69	-

*: all correlations significant at p<0.001

Fig. 1 shows the bias in 4 different age groups for males and females separately. Notable is that the bias strongly decreases with age, indicating that the regression coefficient for age in the Dutch prediction equation was too high for the Korean population group.

Stepwise multiple regression analysis was used to test the age-related increase in body fat in the Korean population. Males and females were analysed together, using sex as a dummy variable (females=0, males=1). To check whether the regression lines for males and females had similar slopes, an interaction term (BMI*sex) was included in the stepwise forward regression (p<0.05). Table 4 shows the coefficients of the regression equation for each step, including the explained variance (R2) and the standard error of estimate (SEE). The interaction term did not enter in the stepwise regression (p=0.887), indicating that there is no difference between females and males in the slope of regression line between BF% and BMI.

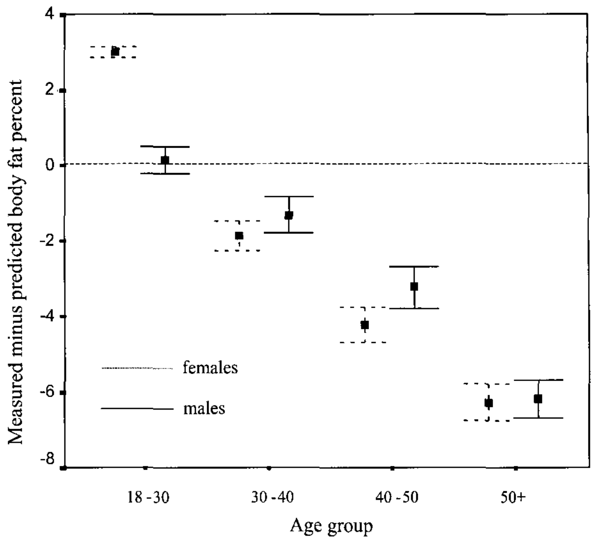

Fig. 1 Bias (mean±2 SE) of predicted body fat percent* from BMI, age and sex in various age groups.

*BF%: from Ducth equation (6)

Table 4. Stepwise multiple regression with BF% as dependent variable.

Step	BMI[1)]		Sex		Age		Intercept		R2[2)]	SEE
	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
1	-	-	-8.9	0.2	-	-	27.7	0.1	0.37	5.0
2	1.327	0.019	-12.3	0.1	-	-	-0.7	0.4	0.75	3.2
3	1.377	0.020	-12.1	0.1	-0.040	0.005	-0.7	0.4	0.76	3.1

1) BMI: body mass index; sex: female=0, male=1; age: in years;
2) R2: explained variance; SEE: standard error of estimate

Table 4 shows that there is a significant age-related decrease in body fat in the Korean population (-0.040±0.005) for any given BMI and sex, which is remarkably different compared to the age-related increase in body fat in the Dutch group (0.23±0.01) from which the prediction equation used in the current study was developed[6)] and in the European reference group.[16)] This explains, at least in part, the age-related bias as shown in Fig. 1. The (physiological) rather uncommon age-related decrease in body fat is likely to be an artefact and could be due to an erroneous (too-low) age factor in the prediction equation used by the INBODY impedance analyser. The prediction equation incorporated in the INBODY is not known.

The data on the Korean subjects were combined with the data on the European subjects.[6)] Analysis of covariance was performed using "country" as grouping variable, BF% as dependent variable and age and BMI as covariates. Table 5 shows for females and males separately the parameter estimates. Mean (SE) body fat percent in Korean females is 2.4 (0.2) lower (p=0.001) than that of their European counterparts of the same age and BMI. In males, the mean (SE) difference in body fat percent is 1.6 (0.2), which is significant at p<0.001. The differences between males and females are statistically significant.

Table 5. Analysis of covariance with body fat percent as dependent variable and country of origin as grouping variable.

		Beta	SE	t-value	p-value	95% CI	
Females							
	Intercept	-0.410	0.381	-1.075	0.282	-1.158	0.338
	Age	-0.013	0.006	-2.316	0.021	-0.024	-0.002
	BMI	1.331	0.018	72.050	0.000	1.295	1.368
	Europe	2.400	0.177	13.536	0.000	2.053	2.748
	Korea[1)]	0					
Males							
	Intercept	-19.458	0.782	-24.891	0.000	-20.992	-17.925
	Age	0.122	0.009	13.864	0.000	0.105	0.139
	BMI[2)]	1.419	0.034	42.262	0.000	1.353	1.485
	Europe	1.550	0.234	6.615	0.000	1.090	2.010
	Korea[1)]	0					

1) This parameter is set to zero because it is redundant; Age in years,
2) BMI: body mass index

For the same age and BF%, the Korean females have a slightly lower BMI (0.2 (0.1) kg/m^2, p=0.06) than their European counterparts. Korean males have for the same age and BF% a 0.2 (0.1) kg/m^2 higher BMI than their European counterparts (p=0.08). The differences between females and males are not significant (Table 6).

Table 6. Analysis of covariance with body mass index as dependent variable and country of origin as grouping variable.

		Beta	SE	t-value	p-value	95% CI	
Female							
	Intercept	7.284	0.185	39.357	0.000	6.922	7.647
	Age	0.043	0.003	13.356	0.000	0.037	0.050
	BF%	0.466	0.006	72.050	0.000	0.454	0.479
	Europe	0.200	0.108	1.858	0.063	-0.011	0.412
	Korea[1)]	0					
Male							
	Intercept	16.802	0.204	82.548	0.000	16.403	17.202
	Age	-0.017	0.005	-3.443	0.001	-0.027	-0.008
	BF%[2)]	0.413	0.010	42.262	0.000	0.393	0.432
	Europe	-0.221	0.128	-1.722	0.085	-0.473	0.031
	Korea[1)]	0					

1) This parameter is set to zero because it is redundant; Age in years;
2) BF%: body fat percent

If males and females are combined in the ANCOVA (controlling for sex), Koreans have 1.6±0.1 (p=0.001) lower body fat percent than Europeans of the same age, BMI and gender. Their BMI, for the same age, BF% and gender is 0.3±0.1 kg/m^2 (p<0.001) lower than Europeans with the same age and body fat percent.

Detailed ANCOVA for the various age groups, females and males combined, revealed that the differences in BF% (corrected for age and BMI) and the differences in BMI (corrected for age and BF%) are based on the age groups. Table 7 gives the corrected values. This finding is in accordance with the data in Fig. 1.

Table 7. Differences in body fat percent (corrected for age, body mass index and sex) and differences in body mass index (corrected for age, body fat percent and sex) between Koreans and European Caucasians in various age groups*.

Age group	Body fat percent		Body mass index	
	Mean	SE	Mean	SE
18-29 years	+0.9	0.2	-0.8	0.1
30-39 years	-2.9	0.4	-0.2	0.2
40-49 years	-4.7	0.3	+1.3	0.2
50-65 years	-5.8	0.3	+1.6	0.2

*p<0.01 different from zero, negative value means lower value in Koreans

DISCUSSION AND CONCLUSIONS

The main limitation of this set of Korean data is the use of a prediction method rather than a reference method to assess body fat percent and a lack of proof of the validity of the prediction method used. The data show significant differences in the BF%/BMI relationship between Koreans and Europeans. At younger ages, BF% of Koreans is slightly higher than that of Caucasians, and consequently their BMI for the same amount of BF% is lower. This is especially the case in females. The described relationship may be affected by several factors. Impedance prediction formulas use, in addition to impedance, weight, height, age and sex. The use of weight and height in the predicted value probably explains the rather high correlation between body fat and BMI and the low SEE of the regression equation (Table 4). It may also (partly) explain the observed age-related decrease in body fat percent, as age is already used to predict body fat and the age factor in the prediction equation used might be too low for the population under study. However, as in other Asian populations, a low age-related increase in body fat percent might also be due to differences in physical activity and eating patterns between young and old.

As the relationship between BF% and BMI, age and sex is different in this Korean population compared to the European population, some additional analyses were performed.

Body fat percent was predicted using the sex- and age-specific prediction equations as developed in this population (Table 4) for various levels of BMI and age. In comparison, the European prediction equation was also used. Table 8 shows that the differences in BF% in Koreans and Europeans of the same BMI and age are more extreme in males than in females, and are prominent mainly at older ages and at lower BMI values.

In addition, body fat percent was calculated for all subjects assuming they were Caucasians and had a body mass index of 30 kg/m^2 (the current WHO[1]) cut-off point for obesity). This body fat percent value was then substituted in the equation as given in Table 4 and the corresponding BMI values were calculated. The corresponding BMI (±SE) values, which can be seen as the cut-off value for obesity comparable with Caucasians, were 29.4±0.03 kg/m^2 and 30.8±0.07 kg/m^2 for females and males, respectively. Both values differ (statistically) from 30 kg/m^2 ($p<0.001$). In the various age groups the cut-off values calculated in this way are given in Table 9 for males and females separately. Both additional ways of analysis confirm the other analyses in this report (Table 5, 6, 7).

It is concluded that, assuming that the data on body fat percent are correct, the relationship between BF% and BMI is quite different for Koreans compared to that for European Caucasians.

For younger Koreans, cut-off values for obesity should be slightly lower than those for Caucasians whereas for elder Koreans the cut-off points for obesity should be higher than those for Caucasians. Unless the validity of the data on body fat percent is validated in the Korean population, these results should be interpreted with caution.

Table 8. Predicted body fat percent at given body mass index and age in Koreans and in Europeans.

BMI[1]) (kg/m^2)	Age (Years)	Males			Females		
		Koreans[2])	Europeans[3])	difference	Koreans[2])	Europeans[3])	difference
20	25	13.7	13.7	0.0	26.7	25.6	1.1
25	25	20.6	20.1	0.5	33.6	32.0	1.6
30	25	27.5	26.5	1.0	40.5	38.4	2.1
35	25	34.4	32.9	1.5	47.4	44.8	2.6
20	35	13.3	15.5	-2.2	26.7	27.4	-0.7
25	35	20.2	21.8	-1.6	33.6	33.7	-0.1
30	35	27.1	28.2	-1.1	40.5	40.1	0.4
35	35	34.0	34.6	-0.6	47.4	46.5	0.9
20	45	12.9	17.2	-4.3	26.7	29.1	-2.4
25	45	19.8	23.6	-3.8	33.5	35.5	-2.0
30	45	26.7	30.0	-3.3	40.4	41.9	-1.5
35	45	33.6	36.4	-2.8	47.3	48.3	-1.0
20	55	12.5	19.0	-6.5	26.6	30.9	-4.3
25	55	19.4	25.4	-6.0	33.5	37.3	-3.8
30	55	26.3	31.8	-5.5	40.4	43.7	-3.3
35	55	33.2	38.2	-5.0	47.3	50.1	-2.8

1) BMI: body mass index: sex: females=0, males=1
2) formula: 1.377×BMI-12.1×sex-0.04×age-0.7
3) formula: BF%=1.278×BMI-11.9×sex+0.177×age-4.4

Table 9. Calculated BMI cut-off points in various age groups*

Age group (years)	BMI kg/m^2 cut-off(SE)					
	Females			Males		
	n	Cut-off		n	Cut-off	
18-30	1782	28.5	(0.01)	357	28.9	(0.03)
30-40	252	30.5	(0.03)	183	30.7	(0.03)
40-50	198	32.1	(0.03)	122	32.3	(0.04)
50+	171	34.0	(0.06)	135	34.5	(0.06)

The cut-off values are calculated assuming Koreans have the same body fat (for age and sex) as Europeans with a BMI of 30 kg/m^2.

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