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Evaluation of BMI as an Obesity Index for Korean

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ABSTRACT

The purpose of the present study is to evaluate the validity of the BMI as an indicator of obesity for Koreans. The usefulness of the BMI to represent overweight and obesity was evaluated by measuring the relative validity of sensitivity and specificity, and was compared with the validity of triceps skinfold thickness(mm). To measure the relative validity of the BMI and triceps skinfold thickness, body fat(%) was used as a reference measure of obesity. The study population included 844 participants aged 20 – 69 years who resided in Kuri City in Kyunggi province. Participants were measured regarding weight, height, triceps skinfold thickness and body fat. The prevalence of obesity for male subjects was 32.0%, 66.2%, and 0.9%, and for female subjects, 17.6%, 56.1%, 12.4% based on the BMI, triceps skinfold thickness, and body fat(%) respectively. The prevalence of obesity was higher based on the BMI or triceps skinfold thickness than body fat measurement. The sensitivity and specificity of the BMI were 33.3% and 67.9% in male subjects and 77.7% and 90.8% in female subjects. Sensitivity of the BMI was lower, and specificity was higher than those of triceps skinfold thickness. In summary, BMI as an indicator of obesity for Koreans showed a tendency of overestimation of obesity prevalence. Therefore, there is a need to develop a more reliable obesity index other than the BMI for Koreans. (*J Community Nutrition* 2(2) : 129~134, 2000)

KEY WORDS : obese · body mass index · triceps skinfold thickness · body fat.

Introduction

Obesity is defined as excessive fat accumulation, but not a state of being overweight. Usually a normal body consists of 82% lean body mass, which is essential for maintaining healthy life and physical activity, and 18% body fat, which acts as energy storage for urgent situations. Thus, obesity is the overstorage of body fat(Inoue 1992).

Obesity is regarded as a risk factor of many degenerative diseases which lead to serious health problems among the general population(Lee 1990). The prevalence of obesity depends on measurement as well as the cutoff points chosen for those measurements. There are two ways to assess obesity. One is the direct assessment of body fat based on a body composition measurement. Various techniques used for body fat measurement include underwater weighing, densitometry, potassium counting, bioimpedence analysis, and infared intractance etc. Another way to assess obesity is the indirect assessment based on anthropometric measurements of weight and height. Using weight and height measurements, many obesity indexes have been developed such as the Broca index, Body Mass Index (BMI), Rohler index, Ponderal index(Lee 1992). Criteria for obesity vary by indicators, therefore, there is a need for an indicator that has applicability across a broad range of populations.

Currently, the BMI is used widely as an indicator of obesity because of the relative easiness and accuracy of the basic measurements(Himes & Dietz 1994). However, the BMI has limitations : it tends to have high specificity, but variable sensitivity among different ethnic groups(Gurrici et al. 1998 ; Deurenberg et al. 1998 ; Deurenberg-Yap et al. 2000).

The purpose of the present study is to evaluate the validity of the BMI as an indicator of obesity for Kore-

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ans. The usefulness of the BMI to represent obesity was evaluated by measuring the relative validity of sensitivity and specificity, and was compared with the validity of triceps skinfold thickness(mm). To measure the relative validity of BMI and triceps skinfold thickness, body fat(%) was used as a reference measure of obesity.

Subjects and Methods

1. Study subjects

The study subjects included 844 participants aged 20 – 69 years residing in Kuri City in Kyunggi province. The participants were drawn randomly from a population-based list of men and women in the area within the selected age group. Participants were interviewed and measured between July and August 1999.

2. Data collection and obesity assessment

1) Weight measurement

Weight was measured using a beam balance scale measuring up to a maximum of 200kgs with increments of 100gs. The subjects were allowed only to wear underwear with a weight of less than 100g. Readings were taken to the nearest 100grams.

2) Height measurement

The height of the subjects was measured while the subjects stood on a flat surface by the scale with feet parallel to each other and with heels, buttocks, and shoulders touching the backboard. The subjects' heads were to be held comfortably erect, with the lower border of the orbit of the eyes in the same horizontal plane as the opening of the canal into the ear(Jeejeebhoy 1998 ; Kirby & Dudrick 1994 ; William 1993). The subjects' arm was to be hanging loosely at their sides. Readings were taken to the nearest 0.1cm.

3) Triceps skinfold thickness measurement

The triceps skinfold site is on the posterior aspect of the right arm, over the triceps muscle, midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna with the elbow flexed 90 degrees(Lee & Nieman 1998). The caliper tips were about 1cm or 1/2 in from the thumb and finger, the caliper was perpendicular to the long axis of the skinfold.

4) Body fat measurement

Body fat was measured using a bioelectrical impedance. When an electrical current was passed through the body, it was opposed by the nonconducting tissues and transmitted by electrolytes dissolved in water (Brodie 1988). This opposition to an alternating current is called impedance, which is composed of two elements : resistance and reactance. In bioelectrical impedance analysis, an electronic instrument generates an alternating current, which is passed through the body by means of four electrodes placed on the hand and foot(Lee & Nieman 1998).

5) Obesity assessment

Obesity has been defined based on three measurements such as the BMI, triceps skinfold thickness, and body fat. Appendix showed the cut off points of each measurement for obesity assessment. The cut-off points were selected based on the distribution of each measurement considering American standards(Kuczmarshi 1992 ; Parker & Bar-Or 1991 : Gerard et al. 1991). An officially published Korean standard was not available at the moment of analysis.

3. Estimation of relative validity

Validity refers to the extent to which a situation as observer reflects the 'true' situation, or the situation as evaluated by other criteria that are thought to reflect the true situation more accurately. In the present context the term was used to refer to the extent to which subjects in an alternative indicator(BMI and triceps skinfold thickness) are correctly identifying as to the presence or absence of obesity comparing the body fat as an reference indicator.

Sensitivity and specificity were the two components measuring the validity. Sensitivity is the extent to which subjects who are truly obese are so classified. Specificity is the extent to which subjects who are not obese are correctly classified.

Mathematical description of :

Sensitivity

= [subjects who are classified as obese by the alternative test(BMI, triceps skinfold thickness)/subjects who are classified as obese by body fat]×100

Specificity

=[subjects who are classified as not obese by the alternative test(BMI, triceps skinfold thickness)/subjects who are classified as not obese by body fat]×100

4. **Statistical analysis**

The chi-square test was used to test the association between the obesity estimated by BMI and by body fat and between the obesity estimated by triceps skinfold thickness and by body fat.

A SAS computer program was used for data processing and all the statistical analysis.

Results and Discussion

1. **General characteristics of subjects**

Table 1 shows the age and sex distribution of the study subjects. The sex distribution of study subjects shows that the majority of subjects were female(male 39.6%, female 60.4%). The age distribution of twenties, thirties, forties, fifties, and sixties of the subjects were 12.3%, 33.4%, 26.7%, 17.3%, and 10.3% respectively.

Table 1. Age and sex distribution of study subjects

Unit : number(%)

Age	Male	Female	Total
20 29	37	67	104(12.3)
30 – 39	110	172	282(33.4)
40 – 49	98	127	225(26.7)
50 – 59	59	87	146(17.3)
60 69	30	57	87(10.3)
Total	334(39.6)	510(60.4)	844(100.0)

2. **Anthropometric measurements of subjects**

The mean weight, height, BMI, triceps skinfold thickness, and body fat of all subjects were 60.6kg, 159.2cm, 23.6, 21.7mm, and 21.7% respectively (Table 2). The mean weight and height of male subjects was higher than those of the females. However, the mean BMI, triceps skinfold thickness, and body fat of males was lower than those of the female subjects. Specially, the differences of mean triceps skinfold thickness and body fat between the sex groups was great.

Table 2. Mean value of anthropometric measurements of study subjects

Anthropometric measurements	Male (n=334)	Female (n=510)	Total (n=844)
Weight(kg)	65.9±8.9[1)]	57.1±8.6	60.6±9.7
Height(cm)	166.4±6.2	154.4±5.6	159.2±8.2
BMI(kg/m²)	23.5±2.8	23.6±3.5	23.6±3.2
Tricep skinfold thickness(mm)	15.6±9.3	25.7±6.3	21.7±9.1
Body fat(%)	15.7±7.4	25.7±4.8	21.7±7.7

1) mean±S.D.

Table 3-1. Mean value at different percentiles for BMI by age and sex

Age	Male(n=334)								Female(n=510)							
	n	5	10	25	50	75	90	95	n	5	10	25	50	75	90	95
20 – 29	37[1)]	18.2	19.2	20.3	22.1	24.3	26.0*	26.4*	67	17.9	18.2	19.5	20.3	22.2	24.4	23.6
30 39	110	19.2	19.9	21.8	23.6	25.1*	27.3*	28.1*	172	18.6	19.3	20.7	22.6	24.6	27.7*	29.9*
40 – 49	98	20.3	20.4	22.2	24.0	25.7*	28.4*	28.8*	127	19.8	20.4	21.7	23.9	25.9	28.5*	30.4*
50 – 59	59	18.6	19.0	21.5	23.7	26.0*	27.1*	27.4*	87	19.8	21.0	22.6	23.7	25.1	25.6	25.8
60 – 69	30	18.6	19.2	20.7	23.2	24.3	26.8*	28.2*	57	20.3	21.2	23.3	25.4	27.4*	28.6*	30.3*

1) mean * : Indication of obesity evaluation

Table 3-2. Mean value at different percentiles for triceps skinfold thickness by age and sex

Unit : mm

Age	Male(n=334)								Female(n=510)							
	n	5	10	25	50	75	90	95	n	5	10	25	50	75	90	95
20 – 29	37	8.0[1)]	8.5	10.5	15.5	20.5*	24.5*	26.5*	67	12.0	14.0	20.5	23.0	27.0*	30.5*	32.0*
30 – 39	110	7.0	9.0	10.5	13.0	19.0*	22.0*	24.7*	172	13.5	17.5	21.5	25.5*	29.4*	34.0*	37.0*
40 – 49	98	9.0	9.5	12.0	17.5	20.0*	22.0*	23.5*	127	17.0	19.2	23.0	26.5*	30.5*	34.0*	36.5*
50 - 59	59	7.0	9.0	11.0	12.0	18.0*	22.2*	24.0*	87	19.5	20.2	24.0	26.5*	30.0*	35.5*	39.0*
60 – 69	30	9.0	9.0	11.5	14.0	19.5*	22.0*	22.5*	57	13.5	17.5	22.0	25.5*	29.0*	31.0*	32.5*

1) mean * : Indication of obesity evaluation

Table 3-3. Mean value at the different percentiles for body fat by age and sex Unit : %

Age	Male(n=334)								Female(n=510)							
	n	5	10	25	50	75	90	95	n	5	10	25	50	75	90	95
20-29	37	6.0[1)]	6.7	8.8	13.1	15.4	20.3	20.9	67	17.3	19.3	21.3	23.9	25.0	27.0	28.8
30-39	110	7.3	8.3	12.5	15.6	18.9	20.2	21.6	172	17.6	19.7	23.0	25.6	28.1	29.9	30.7*
40-49	98	7.8	9.0	11.7	16.9	19.6	21.3	22.4	127	19.8	21.6	24.1	26.6	28.4	29.8	31.1*
50-59	59	6.1	10.2	12.1	16.2	18.7	21.0	22.0	87	19.9	22.8	25.8	27.9	29.6	30.9	31.2*
60-69	30	10.4	10.7	12.0	16.2	19.0	21.3	21.6	57	19.2	24.0	26.4	27.5	29.6	30.6	31.9*

1) mean *: Indication of obesity evaluation

3. Distribution of BMI, triceps skinfold thickness, and body fat by age and sex

In this study, table 3-1 shows the distribution of BMI by age and sex. Obesity of male subjects was defined as a BMI at or above the 90th percentile in subjects in their twenties and sixties, and the 75th percentile in subjects in their thirties, forties, and fifties. Obesity of female subjects was defined as a BMI at or above the 90th percentile in subjects in their thirties, forties, and the 75th percentile for those in their sixties. The 75 percentiles from 30 to 59-year-old male subjects and from 60 to 69-year-old female subjects were higher than other groups.

Table 3-2 shows the distribution of triceps skinfold thickness(mm) value by age and sex. Obesity of male subjects was defined as a triceps skinfold thickness at or above the 75th percentile in all groups. And obesity of female subjects was defined as a triceps skinfold thickness at or above the 75th percentile in subjects in their twenties and the 50th percentile from those in their thirties to sixties.

Table 3-3 shows the distribution of body fat(%) value by age and sex. Obesity of female subjects was defined as a body fat(%) at or above the 95th percentile in subjects in their thirties to sixties.

Generally speaking, the 85th and 95th percentiles of BMI and triceps skinfold thickness are often used operationally to define obesity and superobesity(Muat et al. 1991). In this study, the distribution of obesity based on BMI and triceps skinfold thickness in particular was very broad. On the other hand, the distribution of obesity based on body fat(%) was narrow.

4. Prevalence of obesity based on BMI, triceps skinfold thickness, and body fat

The prevalence of obesity were 32.0%, 66.2%, and 0.9% in male subjects, and 17.6%, 56.1%, and 12.4% in female subjects based on the BMI, triceps skinfold thickness, and body fat(%) respectively(Table 4). Prevalence of the risk of obesity in this study was higher based on BMI or triceps skinfold thickness than body fat measurement. There are two possible causes of these phenomena. One is relatively shorter height than weight for Koreans comparing with westerners. The other is the characteristics of study subjects which comprized of elderly population who tend to be obese as a nature of geriatric population. Comparing the prevalence of obesity in this study with the other study(Kim YS & Lee CH 1995) which used the same cut-off points of obesity indicators, the prevalence of obesity based on the BMI, and body fat(%) were much lower than expected of 50.0% and 71.1% in male subjects, and 34.2% and 34.2% in female subjects respectively. On the other hand, the prevalence of obesity based on triceps skinfold thickness was much higher than expected of 15.8% in male subjects and 26.3% in female subjects. Lopez and Masse(1992) showed a similar tendency which indicators that it is possible to overestimate the proportion of overweight when the BMI is used as an obesity indicator.

Table 4. Estimated relative validity between obesity indicators

Indicators	Sex	Prevalence (%)	Sensitivity (%)	Specificity (%)
BMI	Male	32.0	33.3	67.9
	Female	17.6	77.7	90.8
Triceps skinfold thickness	Male	66.2	33.3	33.5
	Female	56.1	95.2	49.4
Body fat	Male	0.9	100.0	100.0
	Female	12.4	100.0	100.0

5. Association between obesity indicators

The association between BMI and body fat was not

Table 5. Association between BMI and body fat

Unit : number(%)

BMI \ Body fat(%)	Obese	Not obese	Total	χ^2
Male				
Obese	1(0.3)	106(31.7)	107(32.0)	
Not obese	2(0.6)	225(67.4)	227(68.0)	0.01
Total	3(0.9)	331(99.1)	334(100.0)	
Female				
Obese	49(9.6)	41(8.0)	90(17.6)	
Not obese	14(2.8)	406(79.6)	420(82.4)	179.01***
Total	63(12.4)	447(87.6)	510(100.0)	

*** : $p<0.001$

Cut-off point of obesity based on BMI was 25 for male and 27 for female. And cut-off point of obesity based on body fat(%) was 25 for male and 30 for female.

Table 6. Association between triceps skinfold thickness and body fat

Triceps \ Body fat(%)	Obese	Not obese	Total	χ^2
Male				
Obese	1(0.3)	220(65.9)	221(66.2)	
Not obese	2(0.6)	111(33.2)	113(33.8)	1.43
Total	3(0.9)	331(99.1)	334(100.0)	
Female				
Obese	60(11.8)	226(44.3)	286(56.1)	
Not obese	3(0.6)	221(43.3)	224(43.9)	44.71***
Total	63(12.4)	447(87.6)	510(100.0)	

*** : $p<0.001$

Cut-off point of obesity based on triceps skinfold thickness was 18 for male and 25 for female. And cut-off point of obesity based on body fat(%) was 25 for male and 30 for female.

significant in male subjects, but statistically significant in female subjects(Table 5). The association between triceps skinfold thickness and body fat was also not significant in male subjects, but statistically significant in female subjects(Table 6).

6. Relative validity between obesity indicators

Validity of BMI and triceps skinfold thickness as an indicator of the risk of obesity are shown in Table 4. The sensitivity and specificity of BMI were 33.3% and 67.9% in male subjects and 77.7% and 90.8% in female subjects. The sensitivity and specificity of triceps skinfold thickness were 33.3% and 33.5% in male subjects and 95.2% and 49.4% in female subjects. Sensitivity, meaning the proportions of subjects truly at obesity, of the BMI was lower than that of triceps skinfold thickness. In contrast, specificity of the BMI was higher than that of triceps skinfold thickness, indicating that most of the subjects not obese were classified correctly.

Study results of Malina and Katzmarzyk(1999) showed a similar tendency that BMI as an indicator of each condition had high specificity from 96.3% to 100.0% and lower but wide range of sensitivity from 14.3% to 60.0%. There may have been ethnic variations in sensitivities. For the same level of body fat, age and gender, American blacks have a 1.3kg/m^2 and Polynesians a 4.5kg/m^2 and their BMI were lower compared to Caucasians. By contrast, in case of Chinese, Ethiopians, Indonesians and Thais, mean BMI were 1.9, 4.6, 3.2 and 2.9 respectively and higher than that of Caucasians(Deurenberg et al. 1998). These results could be due to the differences in energy balance as well as differences in body build. Ethnic variation in relative subcutaneous fat distribution and lower extremities to height are potentially confounding factors in high BMI(Malina et al. 1987 ; Malina 1996). Individual and population differences in the timing and tempo of the adolescent growth spurt and sexual maturation may be additional concerns in the interpretation of BMI as an obesity index in different ethnic groups at the same ages(Malina & Katzmarzyk 1999).

In this study, BMI has a tendency to overestimate the prevalence of obesity for Koreans. Therefore, there is a need to develop a more reliable obesity indicator to identify obese Koreans.

Summary and Conclusion

Prevalence of the risk of obesity was higher based on BMI or triceps skinfold thickness than body fat measurement. Sensitivity of the BMI was lower, and specificity was higher than those of triceps skinfold thickness. In conclusion, BMI has a tendency to overestimate the prevalence of obesity for Koreans. Therefore, there is a need to develop a more reliable obesity indicator to identify obese Koreans.

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