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Original Article

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체질량지수, 허리둘레 및 체지방률 측정이 지니는 대사증후군 예측 지표로서의 효용성 비교

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Comparison of BMI, WC and Body Fat percentage in predicting metabolic syndrome

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Background: The objective of this study was to compare the relative usefulness of measuring body fat percentage by bioimpedance, BMI, and waist circumference, respectively, for the purpose of predicting metabolic syndrome.

Methods: In this cross-sectional study, we studied 14,400 subjects between the ages of 20-80 years. Spearman correlation analysis was performed to confirm correlation coefficients between BMI, waist circumference, body fat percentage and metabolic syndrome. Logistic regression analysis was performed to examine the odds ratio between three obesity indicators and metabolic syndrome.

Results: In the Spearman correlation analysis, the correlation between body fat percentage and waist circumference and the correlation between body fat percentage and BMI were less than the correlation between BMI and waist circumference. (Body fat percentage and waist circumference =0.61, body fat percentage and BMI=0.69, BMI and waist circumference=0.81 in males; and body fat percentage and waist circumference=0.61, body fat percentage and BMI=0.74, 0.77 in females). Body fat percentage, BMI and waist circumference all showed statistically significant correlation to metabolic syndrome in the logistic regression analysis (waist circumference: odds ratio(OR)=1.11, BMI:OR=1.09, body fat percentage: OR=1.05 in males, waist circumference: OR 1.15, BMI:OR=1.08, body fat percentage: OR=1.03 in females, P≤0.05). In the univariate analysis the odds ratio of body fat percentage was the highest among the three indicators in males (OR=1.17, 95%CI 1.15-1.18, P≤0.05)

Conclusion: Assessment of total body fat percentage by bioimpedence, waist circumference or body mass index are similar in predicting metabolic syndrome.

Key Words: *Body fat percentage, BIA, Metabolic syndrome*

Introduction

Obesity has nearly doubled worldwide since 1980. In 2008, more than 200 million men and nearly 300 million women were obese. Body mass index(BMI) is a simple index of weight-for-height that is commonly used to classify overweight and obesity in adults.[1] As obesity have been issued over past 30 years, many studies found that central obesity is most strongly associated with the metabolic syndrome. Consequently, another obesity indicator, waist circumference, became a representing indicator of central obesity.[2] However, since subgroups of obesity were found[3], evaluating obesity by other various modalities has been suggested.

One study, for example, focused on the prevalence of metabolic syndrome in individuals with normal BMI and slightly elevated BMI. They suggested screening body fat distribution in individuals with normal or slightly elevated BMI would be an important contribution to prevent diabetes and cardiovascular diseases. For screening body fat distribution, bioimpedance is a widely-used technique due to its safety, accuracy, reliability, and low cost as compare to other body composition methods.[4]

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Most studies compared bioimpedance to BMI or waist circumference, but it is hard to find studies comparing these three obesity indicator at the same time. This study aims to investigate the usefulness of bioimpedance it is compared to BMI and waist circumference to predict metabolic syndromes.

Methods

1. Subject

In this cross-sectional study, we studied clinical data of the health examination center of a university hospital in Seoul, South Korea from January 2nd 2004 to December 31st 2013. The initial number of the subjects was 68287. We excluded 4262 foreigners and 58 subjects under 20 years old. We further excluded 49567 subjects who do not have any one of anthropometric measurements(BMI, waist circumference, systolic blood pressure, diastolic blood pressure, body fat percentage), or laboratory data for the assessment of metabolic syndrome(fasting glucose, high density lipoprotein(HDL) and triglyceride). The final number of the subjects was 14400.

2. Anthropometric Measurements

BMI was calculated as weight in kilograms divided by squared height in meters(kg/m^2). Waist circumference was measured in centimeter using a tailor's tape. Waist circumference was measured with light clothing at a level midway between the lower rib margin and the iliac crest standing and breathing normally.[5]

3. Bioimpedance

Body fat percentage was assessed by bioelectrical impendence analysis, with a commercially available body analyzer(InBody720Ⓡ, Biospace, Korea). As the manufacturer's manual, the subjects were asked to take off their socks and then stand over the electrodes of the machine. This instrument works by eight tactile electrodes to detect the amount of segmental body water: two are in contact with the palm and thumb of each hand and two with the anterior and posterior aspects of the sole of each foot. It is a segmental impedance device measuring the voltage drop in the upper and lower body. The technique uses multiple frequencies to measure intracellular and extracellular water separately. The frequency at 50kHz measures the extracellular water while the frequency above 200kHz measures the intracellular water.[3, 6]

4. Clinical and Laboratory Measurements

Systolic blood pressure and diastolic blood pressure were measured on the right arm after at least 10 minute rest in the seated position using an automated oscillometric sphygmomanometer(Jawon, South Korea). Blood samples for measuring triglyceride, HDL, and fasting glucose were obtained from fresh venous blood in the morning after overnight fasting. Blood samples were immediately put into ethylenediaminetetraacetic acid(EDTA)-treated tubes.

5. Definition of metabolic syndrome

In this study, we basically followed the National Cholesterol Education program Adult Treatment Panel(NCEP ATPIII) criteria for the assessment of metabolic syndrome. This decision is based on the conclusion that ATP III criteria are simple to use in a clinical setting. In addition, a large number of studies have been carried out to evaluate the ATP III criteria for the metabolic syndrome.[7] According to ATP III criteria published in 2004, subjects with metabolic syndrome are identified if they have more than 3 of the following: (1) waist circumference greater than 102cm in men and 88 in women; (2) serum triglyceride level of 150mg/dL or greater, (3) HDL cholesterol level less than 40mg/dL in men, and in 50mg/dL in women; (4) blood pressure of 130/85mmHg or greater; and (5) serum glucose level of 110mg/dL or more. In addition, individuals who reported currently using antihypertensive or antidiabetic medication were counted as meeting the high blood pressure or glucose criterion, respectively. However, we used the adjusted level of impaired fasting glucose level according to the American Diabetes Association's updated definition of impaired fasting glucose, [fasting glucose ≥100 mg/dL(mmol/L)] [8]. Furthermore, we used the adjusted cut-off for waist circumference also, because in the year of 2000, World Health Organization(WHO) recommended different ranges of obesity measurements for the Asia-Pacific region based on risk factors and morbidities. Considering waist circumference, the 1998 WHO report suggested that the European cut-offs are not suitable for Asian populations[9]. Consequently, we selected the cut-off point of normal waist circumference from Korea Centers Control and Prevention(KCDC): WC less than 90cm in men and less than 85cm in women[10]

6. Statistical Analysis

Descriptive values were expressed as mean standard deviation (SD) using T-test for age, BMI, waist circumference, body fat percentage, systolic and diastolic blood pressure, HDL, triglyceride, and fasting glucose. We did the *Chi*-square test for metabolic syndrome, which was the categorical variable(Table 1). Spearman's correlation was performed using the SPSS statistical package(SPSS21 IBM® Chicago, IL) (Table 2). A value of $p < 0.05$ was considered statistically significant. Logistic regression and correlation were used to evaluate the relationships between variables(Table 3). This study has been completed after IRB's approval.

Results

In the descriptive analysis, the mean ages of the enrolled subjects were 46.78 (Standard deviation(SD) = 10.716, $p < 0.01$) in male, 45.91 (SD = 11.435, $p < 0.01$) in female (95% confidence interval(CI) 0.51~1.23, $p \leq 0.05$). Mean BMI was 24.813 (SD = 2.95, $p < 0.01$) for male, 22.59(SD = 3.13, $p < 0.01$) in female(95% CI 2.12~2.32) and mean waist circumference was 86.56 (SD = 8.074) in male, 77.49(SD = 6.22) in female (95% CI 7.26~6.88). The mean body fat percentage measured by bioimpedance was 22.61(SD = 5.44) in male, and 29.68 (SD = 6.22) in female (95%CI 7.26~6.88, $p \leq 0.05$). (Table 1). The percentage of subjects with metabolic syndrome was 26.2% (40.00% in male, 10.9% in female). (Table 2).

In the Spearman correlation analysis, the correlation of body fat percentage between waist circumference and the correlation of body fat percentage and BMI were less than the correlation of BMI and waist circumference. (body fat percentage and waist circumference = 0.61, body fat percentage and BMI = 0.69, BMI and waist circumference = 0.81 in male, body fat percentage and waist circumference = 0.61, body fat percentage and BMI = 0.74, BMI and waist circumference in female) (Table 2-1, Table 2-2).

In the univariate analysis the odds ratio of body fat percentage was the highest among the three indicators in male(OR = 1.17,

Table 1. Anthropometric and Laboratory characteristics

	Male(n = 7554)		Female(n = 6846)	
	Mean	SD	Mean	SD
Age	46.78	10.72	45.91	11.44
BMI(kg/m^2)	24.81	2.948	22.59	3.13
Body fat percentage (%)	22.61	5.44	29.68	6.22
Waist circumference(cm)	86.56	8.074	77.49	8.90
Systolic blood pressure (mmHg)	124.21	14.923	114.94	15.624
Diastolic blood pressure (mmHg)	76.62	10.79	70.94	10.20
HDL	47.55	10.79	56.75	12.71
Triglyceride	139.79	89.62	92.5	56.40
Glucose	96.64	24.15	90.68	16.97
Metabolic syndrome *	3022	(40)	745	(0.9)

BMI, body mass index; HDL, high density lipoprotein
* Metabolic syndrome is presented as the number and percentage (%). P-value was less than 0.01 when calculated by the chi-square test.

Table 2-1. Coefficients of Spearman's Correlation Analysis (Male)

	Age	BMI	Waist circumference	Body fat percentage	Metabolic syndrome
Age	1				
BMI	0.02	1			
Waist circumference	0.06*	0.81*	1		
Body fat percentage	0.06*	0.69*	0.61*	1	
Metabolic syndrome	0.07*	0.43*	0.47*	0.36*	1*

BMI, body mass index * $p < 0.01$

Table 2-2. Coefficients of Spearman's Correlation Analysis (Female)

	Age	BMI	Waist circumference	Body fat percentage	Metabolic syndrome
Age	1				
BMI	0.39*	1			
Waist circumference	0.35*	0.77*	1		
Body fat percentage	0.29*	0.74*	0.61*	1	
Metabolic syndrome	0.26*	0.39*	0.36*	0.30*	1

BMI, body mass index *$p < 0.01$

Table 3-1. Associations between metabolic syndrome and BMI, waist circumference, and body fat percentage by Logistic Regression (Univariate Analysis)

	Male		Female	
	OR	P-value	OR	P-value
BMI	1.43	<0.01	1.49	<0.01
waist circumference	1.16	<0.01	1.19	<0.01
body fat percentage	1.17	<0.01	1.2	<0.01

BMI, body mass index; OR, Odds ratio

Table 3-2. Associations between metabolic syndrome and BMI, waist circumference, and body fat percentage by Logistic Regression (Multivariate Analysis).

	Male		Female	
	OR	P-value	OR	P-value
BMI	1.09	<0.01	1.08	<0.01
waist circumference	1.11	<0.01	1.15	<0.01
body fat percentage	1.05	0.01	1.03	<0.01

BMI, body mass index; OR, Odds ratio

95%CI 1.15~1.18, P ≤ 0.05)(Table 3−1).

body fat percentage, BMI and waist circumference all showed statistically significant correlations to metabolic syndromes in the logistic regression analysis(waist circumference: odds ratio(OR)=1.11, BMI: OR=1.09, body fat percentage: OR=1.05 in male, waist circumference: OR 1.15, BMI: OR=1.08, body fat percentage: OR=1.03 in female, P ≤ 0.05). (Table 3−2)

Discussion

In the present study we compared correlation between BMI, waist circumference, body fat percentage measured by bioimpedance and metabolic syndrome. Through this investigation, we figured out if bioimpedance could predict metabolic syndrome as well as BMI or waist circumference could. When comparing each coefficient value to another in the Spearman analysis, the three indicators showed similar value. Similarly, both the univariate and multivariate analyses, showed almost same correlation to metabolic syndrome.

Many prior studies have figured out the correlation between body fat and metabolic syndrome. However, the strength of this study is that unlike previous studies,[12−20, 26] the study compared the three representative types of obesity indicators at the same time. Furthermore, many of the prior studies measured body fat portion by dual energy X−ray absorptiometry(DXA) or computed tomography(CT),[11, 23, 25] but we measured body fat percentage by bioimpedance. Bioimpedance is a widely used technique for body−composition measurement due to its safety, accuracy, reliability, and low cost as compared to other body composition methods.[4] A couple of studies, for examples, showed that conventional measurement such as manual tape method for waist circumference can be varied dependant on examiner especially when they measure many subjects. Also, the result showed more variability interobserver than intraobserver.[21, 22] On the other hand, studies have concluded, bioimpedance has very limited between observer variations and can be performed in almost any subject because it is portable.[23, 24] Furthermore, it was found to be more sensitive and specific for grading average adiposity in groups than some other anthropometric indexes such as the BMI[25]

Nevertheless, our study still has limitation. In screening subjects who have metabolic syndrome, we did not consider those who are on treatment for hypertension and diabetes.

Conclusion

In conclusion, assessment of total body fat percentage by bioimpedence, waist circumference and body mass index are similar in predicting metabolic syndromes.

요 약

연구배경: 체질량지수(BMI), 허리둘레는 대표적인 비만의 지표로 잘 알려져 있다. 한편 최근에는, 의학적 건강검진과 더불어 사설 운동기관에서 바이오임피던스를 이용한 체내 총 체지방률 측정에 대한 관심이 높아지고 있는데 이것은 측정과 해석의 편의성에 기인한다. 이 연구에서는 BMI, 허리둘레, 체지방률이 대사증후군을 예측하는데 효용성을 비교하고자 한다.

방법: 이 연구의 대상자는 총 14400명으로 20세 이상 80세 미만의 연령을 중심으로 실시하였다. 기술통계를 위하여 연령, BMI, 허리둘레, 체지방량, 수축기 및 이완기혈압, 고밀도지단백질(HDL), 중성지방(TG), 혈당에 대해 t−검정을 시행하였으며 대사증후군에 대해서 카이제곱검정을 시행하였다. 대사증후군과 BMI, 허리둘레, 체지방률 각각의 상관관계를 알아보기 위해 Spearman 검정을 시행하였으며, 각각의 표지자와 대사증후군간의 교차비를 알아보기 위하여 해서 로지스틱 회귀분석을 시행하였다.

결과: 각각의 비만지표들과 대사증후군의 관계가 통계적으로 유효아였으며, 남성의 경우, 단변량 분석에 있어서 체지방률의 교차비가 다른 두 지표에 비교했을 때 더 높은 상관 관계를 보였다.

결론: 대사증후군을 예측하는데 있어 바이오임피던스를 이용한 체지방률이 대안으로 활용될수 있을 것이다. 향후 체지방률과 다른 주요 비만관련 질병들의 상관관계에 대한 추가 연구가 필요할 것으로 예상된다.

중심단어: 비만, 체지방률, 대사증후군, 바이오임피던스

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