보건학 석사학위논문

Contribution of body-mass-to-waist ratio to metabolic syndrome by gender in Korean population

Body mass-to-waist 지수를 통한 한국인 대사증후군의 성별 분석

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ABSTRACT

Contribution of body-mass-to-waist ratio to metabolic syndrome by gender in Korean population

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Introduction : Incidence of metabolic syndrome (MS) had been increased in Korea. One of the main reasons of MS is obesity. For this reason, intervention for MS is focused on obesity control based on weight loss and lower BMI. However, there is disconnection between diagnosis and intervention of MS because of different usage of indices (waist circumference and BMI). Moreover, previous studies have shown that higher muscle mass has preventive role on MS, but muscularity have not been considered in the population basis by using index. Comprehensive approach on obesity considering muscularity as well as adiposity would help make better treatment for MS. This study aimed to see the

association of body composition indices and MS to consider muscularity regarding MS in Korean adult population.

Methods : Information of health screening results from the National Health Insurance Service in 2010, 2013, and 2016 was used as dataset. Total number of dataset is 2,993,760. From the dataset, body mass index (BMI), waist-to-body height ratio (W/BH), and body mass-to-waist ratio (BM/W) were calculated. MS was identified according to the modified definition of MS from ATP III and IDF. Body composition indices were compared by sex, year, and age groups. Correlation of each indices, and association between indices and MS were statistically analyzed. In addition, ROC curve and AUC measurements were compared with different models.

Results : The results of the logistic regression analysis showed higher association of BMI and MS when model included both BMI(OR:1.23) and BM/W(OR:0.17) as independent variables compared to when model included only BMI(OR:1.20), and AUC increased as well. Especially younger female group under 60 had the highest AUC(85.7%), and female had higher AUC compared to male. Different pattern of BMI, W/BH, and BM/W were shown by sex, year, and age groups. Especially male showed higher BMI, W/BH, and BM/W in recent years. Difference between male and female was also shown in the association between BM/W and MS components by odds ratio. In female group, BM/W showed consistent inverse association between BM/W and MS including its components.

Conclusion : Applying BM/W ratio which represents muscularity in addition to BMI is more effective for better explanation of MS. For the

preventive role of muscularity in MS, muscle strengthening exercise is required for the prevention and intervention of MS especially for female. Considering muscularity by BM/W ratio can improve accessibility of health information and contribute to the paradigm shift in obesity.

Keywords : Body mass-to-waist ratio, Body Composition Index, Metabolic Syndrome, Muscle, Adiposity, Obesity, Korean population

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CHAPTER 1 INTRODUCTION

1.1 Background

Incidence of metabolic syndrome (MS) has increased in Korea and the main reason of it is obesity. Metabolic syndrome (MS) is an accumulation of cardiovascular disease risk factors and it doubles the risk of early mortality [1]. Increasing MS is threatening quality of prolonged life of people both as risk factor of non-communicable diseases (NCDs) and as a disease itself worldwide. In Korean population, prevalence of MS has increased steadily and cost for prevention and intervention has also increased because of it. MS is associated with cardiovascular diseases (CVDs) and type II diabetes mellitus sharing common risk factors such as central obesity, increased fasting glucose levels, dyslipidemia, and high blood pressure [2-4].

According to previous studies, obesity has been identified as a main reason of MS providing criteria to diagnose MS with waist circumference. There are two types of criteria to diagnose MS which has been widely used worldwide; one is ATP III by the National Cholesterol Education Program in the United States, and the other is by the International Diabetes Federation (IDF). Modified definition of MS is mainly based on ATP III criteria and IDF criteria was applied on waist circumference especially for Asian standard. These criteria had been widely used for the analysis of MS in Korean population [2].

Disconnection between diagnosis and intervention of MS occurs when different body composition indices (waist circumference and BMI) are used for each step. BMI has been widely used for obesity control

since the concept of body mass index (BMI), body mass divided by squared height, was introduced. For this reason, obesity control by BMI focused on weight loss is a common way for prevention and intervention of MS even though MS diagnosis criteria include waist circumference for abdominal adiposity [5].

However, weight loss and lower BMI don't always lead to lower abdominal adiposity because body mass is composed of fat mass and fat-free mass. Furthermore, the pattern of obesity has been diversified including TOFI phenotype (thin outside, fat inside) which is known as having higher risk on the occurrence of NCDs including diabetes [5]. In addition, recent previous studies have shown that higher muscle mass has a preventive or treatment role on MS. However, muscle mass has not been considered in the population basis by using indices so far. For these reasons, when obesity control is applied for MS, fat mass and fat-free mass need to be considered respectively. Comprehensive approach on obesity considering muscularity as well as adiposity would help make better treatment for MS.

1.2 Objectives

This study aimed to see the association of body composition indices and MS to consider muscularity as well as adiposity regarding MS in Korean adult population. To consider obesity and body composition in a comprehensive way including abdominal adiposity and muscularity, index needs to be supplemented. Body composition indices such as waist circumference, waist-to-height ratio, and waist-to-hip ratio has been suggested as supplementary indices to BMI so far. Body mass-to-waist

ratio showed significant positive correlation with skeletal muscle mass or volume in previous studies [6-8]. In this study, both muscularity and abdominal adiposity were considered regarding MS by introducing existing indices for abdominal adiposity and muscle mass. Waist-to-body height ratio(W/BH) was used for the measurement of abdominal adiposity. For the measurement of muscle mass, body mass-to-waist ratio (BM/W) was used. By newly applying body composition index which reflects muscularity, diversified obesity pattern by different sex, year, age group would be also identified for better prevention and treatment of MS.

CHAPTER 2 LITERATURE REVIEW

2.1 Concept of muscularity

Muscularity includes wide range of concepts relating to muscle. Previous studies have used the concept of muscularity as alternative or embracing term for muscle mass or muscle volume or muscle thickness [9-11]. To our knowledge, there has been no previous studies giving a definition for muscularity in the perspective of public health so far. However, previous studies used the term of muscularity when it needed to embrace broader concept than sole concept relating to muscle, For example, one of recent studies suggests that muscle quality and muscle strength were more reliable measures than muscle mass in term of functional capacity and lower risk for the development of the MS [12]. In this case, muscle mass, muscle strength, and muscle quality needs to be distinguished but these concepts also can be embraced in broader term of muscularity considering that loss of muscle mass, strength, or quality make interaction and leads to health effect related to muscle.

In other words, muscularity embraces and breaks into different subordinate concepts relating to muscle, including muscle mass, strength, and quality. Above all, muscle mass and muscle strength have been widely used for previous studies to examine its health effects especially related to chronic diseases such as MS. For muscle mass, mass of muscle is mechanically measured by kg unit. For muscle strength, using parameters such as grip strength, leg strength are common way for measurement [13-14]. Most common example for the use of those measurements is

diagnose of sarcopecia as sarcopenia being defined as low muscle mass in addtion to low muscle strength [15].

2.2 Measurement of muscularity

For the measurement of muscle mass or volume, body composition is evaluated by dual-energy X-ray absorptiomery (DXA) and this was the most common way in the previous studies [15-20]. In addition to DXA, evaluation of body composition(muscle composition) can be supplemented by carnosine measurement with proton magnetic resonance spectroscopy (1H-mrs) [21]. The measurements of muscle mass can be normalized to height squared, weight, or BMI for analysis [22].

Another way to assess muscle mass or volume(thickness) is computed tomography (CT) images [23]. By CT, visceral fat area and partial muscle area such as thigh muscle can be measured and compared [24]. Also, body composition and muscle mass can be measured by bioelectrical impedance analysis (BIA) [25-26]. This measurement was presented as a body weight-adjusted skeletal muscle mass index(SMI) in a previous study [27].

Most common way to define muscle strength is using isometric grip strength and leg extension power. Also, handgrip strength can be measured for assessing general muscle strength and function. in previous studies [13]. For the measurement of leg extension power, knee extension test, for example 10 maximal repetitions or peak torque of the knee extensors in newton meter, is one of the common way which is widely used [16,28]. Handgrip strength can be meausred using adjustable hand dynamometer in

Newton or kg [13,15,28,29]. In addition, muscle strength can be assessed by one-repetition maximum (1RM) test in excercises such as leg press, bench press, and biceps curl [18,30]. Measurement of muscularity is often accompanied by physical activity tests such as six-minute walk test, Timed Up and Go (TUG), 30-second sitting-rising, sit-and-reach (flexibility), and vertical jump tests [18].

After muscle strength is tested in such ways, muscle strength can be normalized to body mass or evaluated by muscular strength score. Muscular strength score is computed with the body weight adjusted by one repetition maximum(RM) measures in newton per kilogram [28-30]. In addition, Z score for total muscle mass, superior and inferior segments can be calculated to measure muscle development[31].

2.3 Health effects of muscularity

Skeletal muscle is a great energy consumer and store in body, and this enables skeletal muscle to play a central role in metabolic and vascular adaptation by insulin-mediated glucose disposal. For this reason, impaired insulin action in skeletal muscle cause decreased level of nonoxidative glucose disposal which is observed in patients with MS, obesity, and type 2 diabetes [32]. In addition, skeletal muscle is an endocrine organ which modulates insulin sensitivity and cardiovascular adaptation by releasing myokines in the process of chronic activity or deconditioning [23,33,34].

Inverse association of muscularity and MS has been suggested consistently in recent previous studies [35]. According to previous

cross-sectional studies, lower muscle mass or strength per body weight was one of the characteristic features in MS patients compared to participants without MS [14,16,19]. Results of a previous study showed Odds for MS increased for lower muscle mass and strength, and PAR% due to lowest muscle mass and strength being 27% and 17% repectively. With these results, previous studies have suggested that muscle mass and strength have a positive effect on MS prevention [19,20,27].

Moreover, recent studies have focused on specific population or difference among groups such as specific gender, age groups, and ethnicity. There was study about gender difference in the association of muscle mass with MS in Taiwan. From that study, the risk of MS with lower muscle mass was higher in female than male [35]. On the other hand, another study insisted only men showed a significant interaction between MS and muscle strength [28]. There was another study suggesting that both cardiorespiratory fitness and muscle fitness showed independent and joint inverse associations with metabolic syndrome prevalence in Korean adult male [36].

Similar study about young adults suggested that young adults with low muscle mass have a high risk of MS, especially when they are nonobese. The conclusion of this study was that interventions aimed at increased muscle mass at younger ages may have the potential to reduce MS [37].

There was a study comparing Australian and Korean population about the effect of low muscle mass on MS. Low muscle mass was associated with increased likelihood of MS in Australian, but not Koreans when muscle mass was adjusted by body mass, suggesting potential differences in effects of low muscle mass on cardiometabolic health in Caucasian and Asian [22].

Based on the previous study results that support preventive effect of muscularity on MS, following studies have suggested muscularity index as a predictor of MS.

One of those previous studies suggested a muscle fitness to visceral fat level (MVF) ratio as a complementary screening tool that could help clinicians identify young adults with metabolic risk and unfavorable levels of cardiovascular health (CVH). A lower MVF ratio is associated with worse CVH metrics and a higher prevalence of MS in early adulthood [38].

Similarly, fat-to-muscle ratio was proposed for detecting MS in a study about young Colombian adults. The results of receiver operating characteristic (ROC) and logistic regression analysis supported the significant ability of the fat-to-muscle ratio to predict MS. Based on the IDF standard, the best cut-off point of fat-to-muscle ratio for detecting MS in male was 0.225 kg, with an area under the curve (AUC) of 0.83, sensitivity of 80%, and specificity of 70%. For female, the best cut-off point of fat-to-muscle ratio was 0.495 kg, with AUC of 0.88, and the sensitivity and specificity of 82% and 80%, respectively. This results showed that the fat-to-muscle ratio cut-off points indicate significant discriminatory power for detecting MS in young Colombian adults [26].

Based on another study results, relative skeletal muscle mass (SMM) ratio to body composition, rather than absolute mass, could be used as a strong predictor for MS since it may play a critical role in development of MS [34].

Low muscle mass (LMM) was suggested to be considered as a standard which require intervention in adolescents. Appendicular skeletal muscle mass was divided by body weight to decide LMM, and below the lower quintile of the study population was considered to represent LMM

according to each age and sex category. LMM significantly increased the risk of MS and its components. This results suggest that adolescents with LMM may have a higher risk of MS [37].

However, there were controversial results on muscularity index. Diverse patterns of the relationship between low muscle mass and MS were shown according to the various muscle mass indices. When the influence of fat mass was controlled, lower muscle mass was not an independent risk factor for MS [39].

In addition to the use of muscularity index as a predictor of MS, muscle strengthening activities had been suggested for invention and prevention of MS.

Untrained skeletal muscle limits the role of muscle for energy metabolism. It is unfavorable for muscle to utilize both free fatty acids in blood and intramuscular triglycerides as substrates for energy metabolism when muscle is reliant on glycolysis to generate ATP. However, when muscle is accustomed to habitual aerobic exercise, it is able to utilize both substrates to generate ATP more efficiently than in the untrained state. This is particularly associated with the prediabetic MS with damaged insulin senstivity, glucose tolerance, and lipid abnormalities. This study results highlights the importance of exercise for limiting or reversing its progression from prediabetic MS to Type 2 diabetes [40].

One of previous study results showed that the intense exercise strengthens muscle by directly inducing fibrinolytic genes and protein cascades within muscle in the systemic circulation. Given that the MS is an independent risk factor for vascular disease and thrombotic events within the heard and brain, this finding is particularly significant. Based on this result, this study insisted that aerobic exercise training has protective effect on cardiovascular disease by inducing both local and systemic

changes in fibrinolysis and vascular homeostasis [9].

Moreover, complementary interaction of aerobic physical activity and muscle strengthening activities and their association with MS was examined from a study. The results showed that individuals meeting guidelines for aerobic physical activity or muscle strengthening activity had lower odds of having MS with 61% and 25% respectively. Furthermore, individuals meeting both guidelines had the lowest odds of having MS with 70%, partly due to the complementary interaction of aerobic and muscle strengthening types of exercise [41].

In addition, different types of exercise were compared about its effectiveness and efficiency related to MS. Continuous aerobic exercise (CAE) and high intensity interval(HIIT)-low volume training represented aerobic and muscle strengthening types of exercise respectively. HIIT-low volume was suggested to be better at improving physical capacity and decreasing cardiovascular risk factors in terms of both effectiveness and efficiency in patients with metabolic disorders [21].

Sarcopenia is also closely related to muscularity considering sarcopenia is defined in terms of muscle mass and strength. According to the definition of II sarcopenia, sarcopenia was diagnosed when study participants had a weight-adjusted skeletal muscle mass more than two standard deviations below the sex-specific mean for young adults [25,42]. In addition, sarcopenia can be defined as low muscle mass (according to FNIH cut-offs) and low muscle strength (lowest sex-specific tertile for 30-s chair-stand test) [15].

According to additional previous studies about sarcopenia, sarcopenia and sarcopenic obesity with MS is associated with each other so those must be considered as part of the community-based management of non-communicable diseases [25]. For this reason, studies about physical

activities as intervention for sarcopenia also serve as a good reference for the intervention of MS as well as other chronic non-communicable diseases. Based on a previous study about scarcopenia and the effect of physical activity intervention, light physical activity was not significantly associated with any outcome. However, moderate-vigorous physical activity was inversely associated with BMI, waist circmference, fat mass, and muscle strength [15].

CHAPTER 3 METHODS

3.1 Data source and subjects

Health screening results data was obtained from the open source of the National Health Insurance Service in Korea. Total dataset includes 2,993,760 random samples of Korean adult population (age over 20) from 2010 to 2016. Each year had 1,000,000 random samples respectively and 3 years in 3 years interval (2010, 2013, 2016) were selected to combine into the total dataset. Missing and outlier data was removed from the original dataset of 3,000,000. The population is composed of insurance subscribers and their dependents, the coverage rate is 97 percent of total population in Korea as of 201611. Since Korean health insurance service is a national system by government, this sample represents national population. The 1,000,000 samples in each year were randomly selected from the medical examination results of insurance subscribers and their dependents mentioned below:

1) Workplace subscriber of the national health insurance.

2) Dependent subscriber over 40

3) Local subscriber who is the householder

4) Local subscriber who is over 40

5) Among above, subscribes who took the ‘life transition period health exam’ in the age of 40 or 66

Age groups are divided by 5 years interval into 14 groups starting from 20-24 to the eldest group of 85 and over. Obesity and body shape indices including BMI, W/BH, and BM/W were calculated using the information of weight(kg), height(cm), and waist(cm) obtained from the dataset.

3.2 Definition of obesity and body composition indices

From the dataset, body mass (BM, kg), body height (BH, cm), and waist circumference (W, cm) were used to calculated obesity and body shape indices. Body mass index (BMI, kg/m2) was calculated based upon BM and BH, and waist circumference-to-body height ratio (W/BH) was calculated from W divided by BH. Body mass-to-waist ratio (BM/W, kg/cm) was calculated based upon BM and W. In this study, BMI, W/BH, and BM/W were interpreted as representing obesity, adiposity, and muscularity respectively based on the results of previous studies.

3.3 Definition of metabolic syndrome

For the diagnosis of MS, modified ATP III definition for MS were used. This definition is mainly based on the guidelines of Unites States National Cholesterol Education Program (NCEP) on metabolic syndrome (ATPIII) [43], and Asian-specific criteria for central obesity from the International Diabetes Foundation (IDF) [44] were partially adopted based on the AHA/NHLBI scientific statement [45]. Those who have three or more factors applied to the criteria below were diagnosed as having MS.

Metabolic risk factors defined based on the modified MS criteria are as follows:

1) Waist circumference > 90 cm in men, > 80 cm in women

2) Triglyceride level ≥ 150 mg/dL (1.7mM/L)

3) HDL cholesterol level < 40 mg/dL (1.03mM/L) in men, < 50 mg/Dl (1.3mM/L) in women

4) Blood pressure SBP ≥ 130 mmHg or DBP ≥ 85mmHg

5) Fasting glucose level ≥ 100 mg/dL (6.1 mM/L)

3.4 Statistical analysis

Mean values for BMI, W/BH, and BM/W were calculated by sex and age groups in each year. Baseline characteristics of population including MS components and body shape indices was tested by ANOVA and Tukey HSD(Honesty Significant Difference) about its difference by sex and year. Correlation of each indices, and association between indices and MS were statistically analyzed by logistic regression. Generalized linear model (GLM) was applied to logistic regression analysis for the association between BMI, W/BH, BM/W ratio and MS. Logistic regression analysis with GLM was conducted under three different models. In addition, ROC curve and AUC measurements were compared with different models. Statistical analysis was performed using SQLite and R software version 3.4.4.

CHAPTER 4 RESULTS

4.1 General characteristics of study population

Baseline characteristics of study population by sex in each year is shown in Table 1. From the total dataset of 2,993,760, distribution of number of population and mean values for measurements were calculated by sex, year, and age groups. Recent years had higher height, weight, and waist measurements both in male and female. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) stayed stable when fasting glucose level steadily increased and triglyceride decreased in recent years. HDL cholesterol level increased as year comes closer to recent years in both gender except for male in 2013. Proportion of population that were diagnosed as having MS increased in recent years in both gender and female had two times higher proportion(20.13%) compared to male(10.13%) as of 2016. Regarding body composition index measurements, BMI, W/BH and BM/W increased each year from 2010 to 2016 in both male and female. Male had higher levels of BMI, W/BH, and BM/W compared to female. Difference in groups were tested for significance by ANOVA and Tukey HSD(Honestly Significant Differenct).

Table 1. General characteristics of study population (n = 2,993,760)

Sex	Male			Female		
Year	2010	2013	2016	2010	2013	2016
Number	546,442	541,682	530,963	451,863	457,313	465,497
Age group (years, N)						
1 (20-24)	9,023	10,912	10,290	13,693	13,736	13,575
2 (25-29)	45,806	39,383	34,548	38,170	31,648	31,403
3 (30-34)	66,625	67,576	52,272	31,736	30,346	29,403
4 (35-39)	68,167	59,106	57,827	28,760	23,151	25,127
5 (40-44)	76,798	80,514	72,449	66,825	68,180	61,518
6 (45-49)	66,252	61,248	63,670	53,644	52,044	55,511
7 (50-54)	70,009	68,244	67,141	68,186	68,977	64,141
8 (55-59)	46,450	51,224	55,684	41,778	49,257	54,420
9 (60-64)	39,081	39,992	49,131	40,023	44,228	52,289
10 (65-69)	25,881	25,562	26,706	27,652	26,291	26,660
11 (70-74)	21,261	23,790	23,181	24,900	28,446	27,143
12 (75-79)	7,584	9,226	10,429	10,263	12,425	13,115
13 (80-84)	2,906	4,185	6,404	5,019	6,761	8,641
14 (85+)	599	720	1,231	1,214	1,823	2,551
Height(cm)	168.11	168.43	168.67	154.75	154.89	155.21
Weight(kg)	68.03	68.66	69.90	54.71	54.99	55.59
Waist(cm)	83.55	83.80	84.77	76.00	76.32	76.76
SBP(mmHg)	124.53	123.94	124.60	119.38	119.02	119.48
DBP(mmHg)	77.94	77.56	77.80	73.99	73.81	73.85
FGL(mg/dL)	99.26	100.14	102.36	94.99	95.92	97.11
Triglyceride (mg/dL)	151.41	150.20	149.34	110.10	109.71	107.92
HDL(mg/dL)	51.91	51.83	52.37	58.47	59.05	60.75
Metabolic Syndrome(%)	9.15	9.16	10.13	19.54	20.06	20.31
BMI(kg/m^2)	24.03	24.16	24.52	22.87	22.94	23.10
W/BH	0.50	0.50	0.50	0.49	0.49	0.50
BM/W (kg/cm)	0.81	0.82	0.82	0.72	0.72	0.72

SBP: systolic blood pressure, DBP: diastolic blood pressure, FGL: fasting glucose level, HDL: high-density lipoprotein, BMI: body mass index, W/BH: waist-to-body height ratio, BM/W: body mass-to-waist ratio.

4.2 Body composition index by sex, year, and age groups

In the year of 2010, 2013, and 2016, BMI decreased from 35-39 (age group 4) for male, and that of female increased from 25-29 (age group 2) until the age of 65-69 (age group 10). In male, recent year had higher BMI level than past years. In female, recent year had higher BMI level until 35-39 (age group 4), and over 70-74 (age group 11). W/BH increased with age in both genders overall except a few older or younger age groups. Differences across age groups were larger for female. BM/W decreased in both gender with age except age groups 1-3 in male. More recent years had higher BM/W ratio in both genders. In male, as year comes closer to recent year, all body composition indices (BMI, W/BH, BM/W) increased. However, in female, only BM/W ratio consistently stayed higher in recent years (Figure 1).

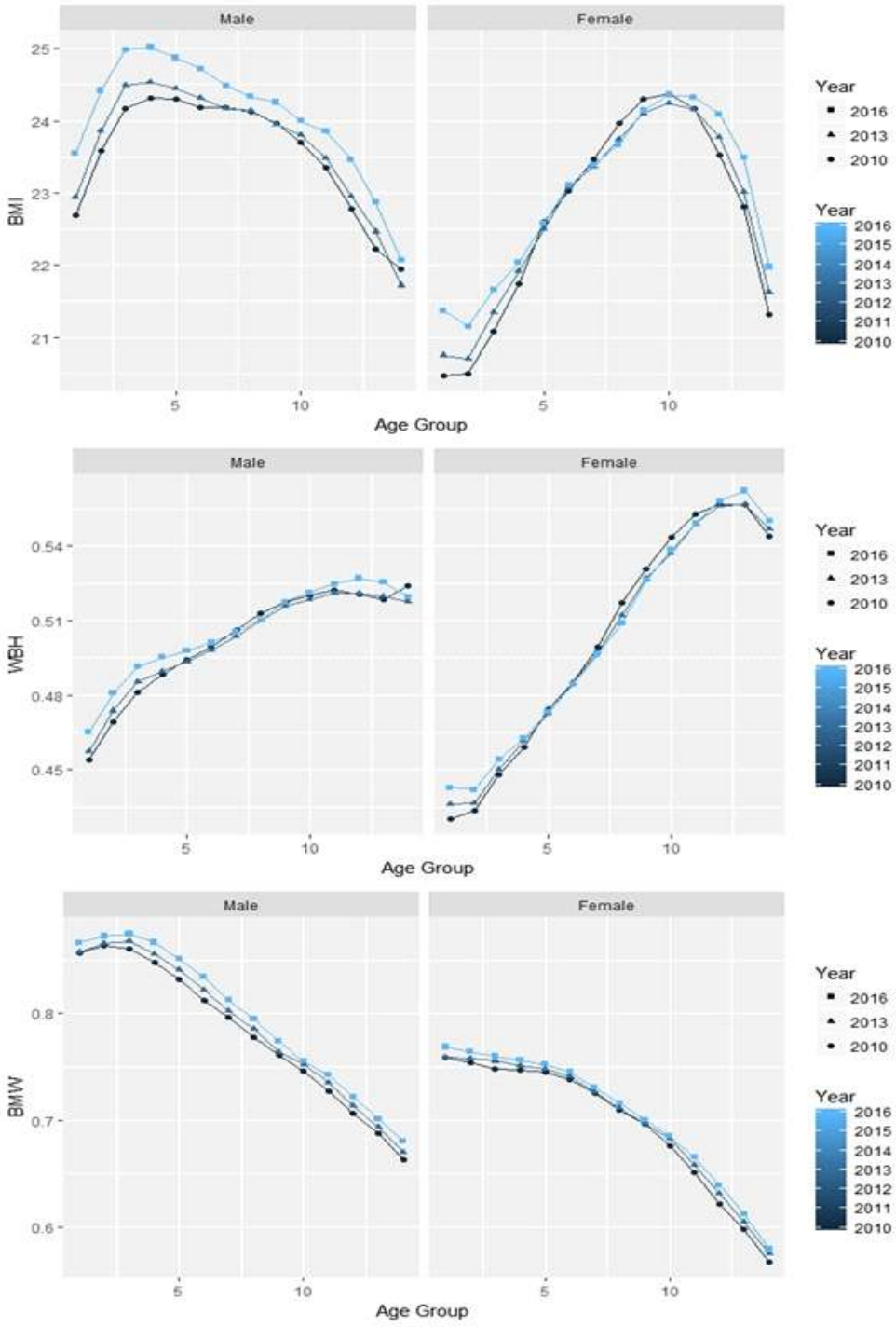

Figure 1. Body composition index by sex, year and age group (n=2,993,760)

4.3 Association between body composition index and MS

BMI had positive correlation with W/BH and BM/W respectively. W/BH and BM/W had negative correlation. Regarding correlation of body composition index(BMI, W/BH) and MS, including its diagnosis criteria(SBP, DBP, FGL), each correlation was higher in female under the consistent direction. However, correlation of BM/W and MS showed difference between male and female. The direction of correlation was the opposite in female compared to male except for fasting glucose level. All risk factors of MS(higher blood pressure, higher fasting glucose level, higher triglyceride, and lower HDL) showed negative correlation with BM/W in female (Table 2).

Table 2. Correlations of body composition index and MS (n=2,993,760)

	Male			Female		
	BMI	W/BH	BM/W	BMI	W/BH	BM/W
BMI	-	0.76	0.57	-	0.78	0.37
W/BH	0.76	-	-0.05	0.78	-	-0.25
BM/W	0.57	-0.05	-	0.37	-0.25	-
MS	0.17	0.19	0.03	0.40	0.49	-0.07
SBP	0.22	0.26	0.02	0.33	0.39	-0.09
DBP	0.22	0.22	0.07	0.28	0.30	-0.02
FGL	0.11	0.19	-0.06	0.21	0.27	-0.07
TRI	0.26	0.25	0.10	0.28	0.34	-0.07
HDL	-0.24	-0.24	-0.09	-0.24	-0.27	0.04

BMI: body mass index, W/BH: waist-to-body height ratio, BM/W: body mass-to-waist ratio, MS: metabolic syndrome, SBP: systolic blood pressure, DBP: diastolic blood pressure, FGL: fasting glucose level, TRI: triglyceride, HDL: high-density lipoprotein.

Regression analysis was conducted with generalized linear model (GLM) under the assumption that including supplementary body composition indices (W/BH and BM/W) with BMI would enable better explanation for MS. Logistic regression analysis was conducted under three different models with whether having MS or not as dependent variable, and body composition indices as independent variables. Age group and year were included as confounding variables and groups were divided by sex. As a result of GLM analysis, the beta of BMI increased(from 0.19 to 0.21) when BM/W(β=-1.75±0.05) was included in model 2. On the other hand, the beta of BMI decreased(from 0.19 to 0.11) when W/BH were included in model 3 and W/BH had much higher association with MS compared to other indices. The result was statistically significant having p-value under 0.05 (Table 3).

GLM analysis produced equations for male and female as follows:

Model 1: $MS = \beta_0 + \beta_1 \times age + \beta_2 \times year + \beta_3 \times BMI + \varepsilon$
Model 2: $MS = \beta_0 + \beta_1 \times age + \beta_2 \times year + \beta_3 \times BMI + \beta_4 \times BM/W + \varepsilon$
Model 3: $MS = \beta_0 + \beta_1 \times age + \beta_2 \times year + \beta_3 \times BMI + \beta_4 \times W/BH + \varepsilon$

To sum up the results of GLM analysis in table 3, the association of BMI and MS increased when BM/W was included in model 2. However, when W/BH was included in model 3, the association of BMI and MS decreased with W/BH having higher association with MS in the same positive direction with BMI. Odds ratio of BMI increased from 1.20 to 1.23 in model 2 compared to model 1, it decreased to 1.12 in model 3. Compared to BMI, W/BH had higher odds ratio especially in male (Table 3).

Table 3. Logistic regression analysis of body composition index and MS

		Male			Female		
		R^2*	OR	95% CI	R^2*	OR	95% CI
Model1	BMI	0.06	1.20	1.20 – 1.21	0.24	1.34	1.33 – 1.34
Model2	BMI	0.06	1.23	1.23 – 1.24	0.26	1.43	1.43
	BM/W		0.17	0.16 – 0.19		0.00	0.00
Model3	BMI	0.06	1.12	1.12	0.28	1.12	1.12 – 1.13
	W/BH		417.30	343.36 – 507.18		2.10	1.82 – 2.42

*R^2 was calculated in the pseudo R squared formula for GLMs.

Variance inflation factor(VIF) analysis was conducted to test the suitability of models in terms of multicollinearity in logistic regression analysis. A cutoff of 5 was applied to make a judgment to exclude model from logistic regression analysis. All variables included in three different models in table 3 satisfied the VIF cutoff under 5. However, when model 3 included W/BH instead of BM/W in addition to BMI, VIF of BMI increased with W/BH having the highest VIF over 3 (Table 4).

Table 4. Variance inflation factor analysis of variables and MS

		VIF						
		age	year	sex	ms	bmi	bmw	wbh
Male	Model1	1.02	1.01	2.00	1.04	1.04	-	-
	Model2	1.49	1.01	2.00	1.04	1.68	2.18	-
	Model3	1.39	1.01	2.00	1.04	3.01	-	3.27
Female	Model1	1.16	1.00	2.00	1.28	1.23	-	-
	Model2	1.68	1.00	2.00	1.31	1.80	1.80	-
	Model3	1.55	1.00	2.00	1.33	2.80	-	3.78

In line with GLM logistic regression analysis, ROC curve and AUC measurements were compared with two different equations for model 1 and 2. In addition to male and female, age group was divided as young(under 60) and old(60 and over). In all groups, AUC increased in model 2 compared to model 1 (from 71.20% to 71.4% in young male group, from 63.0% to 63.7% in old male group, from 84.6% to 85.7% in young female group, from 70.8% to 72.6% in old female group). Moreover, there were fundamental difference on AUC level between male and female, and between young and old groups. The difference of AUC measurements between male and female was 13.4~14.3% in young age group, and 7.8~8.9% in old age group. Female groups showed higher AUC level under same logistic regression model compared to male groups in both young and old age groups(Figure 2).

Odds ratio was calculated with BMI and BM/W to analyze the association with components of MS. Study population was divided into 3 groups based on the BMI or BM/W level. For BMI, BMI classification guideline by WHO was applied(under 25: normal rage, 25.0-29.9: overweight, 30 or over: obese). For BM/W, groups were divided into three equal parts as first group comprising the lowest BM/W level. In both male and female, higher BMI group had higher odds ratio regarding MS and its components. However, BM/W showed different pattern between male and female. Higher BM/W level had odds ratio over 1 regarding waist circumference, HDL, triglyceride in male. On the other hand, blood pressure and fasting glucose level showed odd ratio under 1 when BM/W level was higher. In female, higher BM/W level groups had odds ratio under 1 regarding all MS components (Table 5).

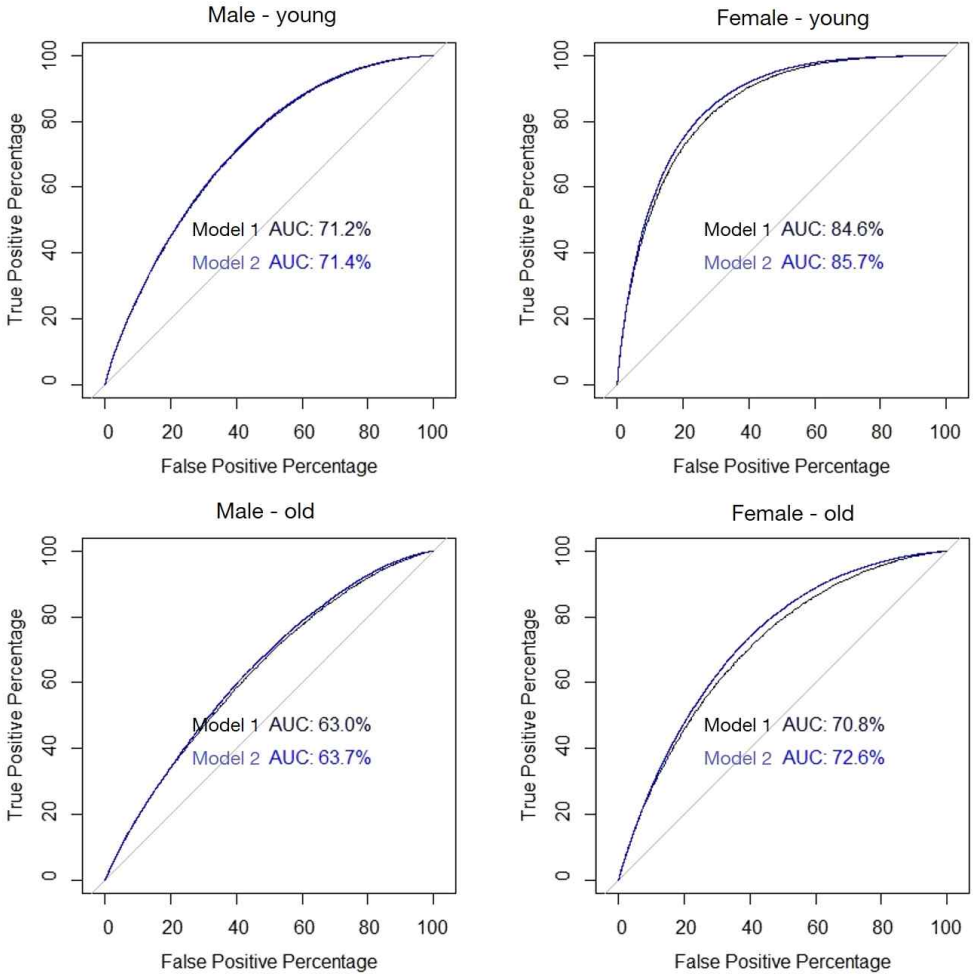

Figure 2. ROC and AUC of logistic regression model

Table 5. Odds ratio analysis of body composition index and MS components

	BMI					BM/W				
	< 25	25 - 29.9		≥ 30		1st	2nd		3rd	
	OR	OR	95% CI	OR	95% CI	OR	OR	95% CI	OR	95% CI
Male										
Waist	1	14.84	(14.70-14.99)	317.98	(306.29-330.22)	1	1.00	(0.99-1.01)	1.85	(1.82-1.87) *
HDL	1	1.83	(1.81-1.84)	2.50	(2.45-2.55)	1	1.05	(1.03-1.06)	1.15	(1.13-1.16)
Tri	1	2.36	(2.34-2.37)	3.76	(3.69-3.82)	1	1.24	(1.23-1.25)	1.56	(1.54-1.57)
BP	1	1.47	(1.46-1.48)	2.26	(2.24-2.28)	1	0.89	(0.88-0.90)	0.96	(0.95-0.96)
FGL	1	1.58	(1.56-1.59)	1.97	(1.93-2.00)	1	0.89	(0.88-0.90)	0.74	(0.74-0.75)
Female										
Waist	1	17.44	(17.25-17.63)	243.96	(227.58-264.41)	1	0.83	(0.82-0.83)	0.93	(0.92-0.94)
HDL	1	1.94	(1.92-1.96)	2.41	(2.36-2.45)	1	0.84	(0.84-0.85)	0.94	(0.92-0.95)
Tri	1	2.48	(2.46-2.50)	3.29	(3.23-3.36)	1	0.77	(0.77-0.78)	0.81	(0.80-0.82)
BP	1	1.82	(1.81-1.84)	3.28	(3.23-3.34)	1	0.73	(0.73-0.74)	0.78	(0.78-0.79)
FGL	1	2.18	(2.16-2.20)	3.35	(3.29-3.42)	1	0.79	(0.79-0.80)	0.81	(0.80-0.82)

* p-value > 0.05, all the other p-values are under 0.001

CHAPTER 5 DISCUSSION AND CONCLUSIONS

5.1 Discussion

In this cross-sectional study of Korean adult population from 2010 to 2016, explanation for MS with logistic regression model improved when model included both BMI and BM/W compared to when model included only BMI as body composition index. Odds ratio of BMI increased and AUC increased by 0.2~0.7% for male and 1.1~1.8% for female. In the comparison of body composition index among different sex, year, age groups, this study found out that increase of BMI can be accompanied by rise of both W/BH(adiposity) and BM/W(muscularity) especially in male. In addition, we found out gender difference on the association of BM/W and MS through correlation and odd ratio analysis. Inverse association of BM/W and MS was consistent and more evidence in female than male. These results support the usefulness of BM/W ratio as body composition index representing muscularity, and the necessity of muscle strengthening exercise for prevention and management of MS especially for women.

The results of this study supports previous studies about the preventive role of muscularity regarding MS. In addition, this study suggests to apply muscularity index for prevention and intervention of MS in public health approach. BMI has been sole dominant means of managing obesity and MS as a body composition index. However, as results of this study showed, increase of BMI doesn't always mean rise of adiposity. Both fat mass and fat-free mass can explain change of BMI, so increased BMI can have positive or negative health effects at the same

time. Even though there has been tremendous amount of previous studies examined a positive important role of muscle on MS, this concept was not applied well in public health area. For example, people's perspective haven't changed much on the obesity control, and activities for intervention and prevention of MS in community basis is still focused on weight loss and some aerobic physical activities. Ease of use in terms of health information is required for the paradigm shift in the perspective of population.

In addition, the results of this study on ROC curve and AUC supports the usefulness of BM/W ratio in terms of power of explanation for MS. According to a recent previous study on visceral fat and its association with metabolic risk factors, visceral fat ratio measured by CT showed the highest AUC (0.70 in male and 0.80 in female) compared to BMI and waist circumference [49]. However, AUC results of model 2 including BMI and BM/W in this study showed higher AUC (0.71 in young male and 0.86 in young female). This results suggest that combination of body composition index with BMI and BM/W would have better explanation for MS than body composition measurements by CT in the age group of 20-59. When body composition index have better explanation for MS, unnecessary cost for CT or MRI doesn't need to be suggested. In other words, using body composition index can be a cost-effective alternatives for managing metabolic syndrome compared to existing tools for measuring adiposity or muscularity.

One of the other advantages of using body composition index is ease of use and accessibility. Since there is no index for measuring muscularity that can be widely and easily used currently, BM/W ratio can be adopted as alternative muscularity measurement when high price measurement tools such as CT, MRI, X-ray are not available for the analysis of general population characteristics. This study introduced body

composition index which represent muscularity based on the results of previous studies, and applied the index to explain MS in 2,993,760 Korean adults population. The results of this study supported previous studies about the inverse association of muscularity and MS, and tested usefulness of BM/W as a body composition index.

In recent years, paradigm shift in obesity has been suggested in previous studies [46-48]. Weight-centered health pradigm(WCHP) refers to discourse about health that focuses predominantly on body weight. WCHP enhances fat oppression (adipophobicogenic environment), hinders well-being and health, and eventually leads to reduced quality of life. For these reasons, critical analysis on the concept of WCHP has risen recently.

In this context, a paradigm shift focusing on health and well-being away from focusing on weight was suggested. Health at Every Size(HAES) is one of the best known models within this paradigm. This model focuses on the improvement of health and well-being, instead of labeling people based on their weight or BMI [46]. HAES is a growing trans-disciplinary movement which insists for a shift in focus to weight-neutral outcomes and it challenges the existing predominant prejudice of encouraging weight loss and dietary behavior. HAES approach was identified as statistically and clinically effective approach in terms of improvements in physiological measures(e.g. blood pressure), health behaviors (e.g. dietary habits), and psychosocial outcomes(e.g. self-esteem) through randomized controlled clinical trials. In addition, such clinical trials suggested that HAES approach is more successful to achieve better health outcomes than weight focused treatment [47].

In Europe, there was another critical opinion about paradigm shift in adult obesity. According to such opinion, rapid weight loss due to drastic energy restriction results in unfavorable changes in the body

composition with the expense of water and the fat-free mass. Therefore, drastic weight loss should not be encouraged. Besides loosing fat mass and preserving lean body mass, improving metabolic control, cardiovascular fitness, and muscle strength even without overall changes in final body weight are also important. This approach is especially advisable for obese elderly patients who need treatment focused on improvement of functional impairments, metabolic complications, rather than on weight loss itself. When exercise training is added to moderate energy restriction, such intervention results in favorable changes to metabolism, body composition, and fitness. These positive effect may take place even without weight loss. Moreover, necessity of new criteria for identifying patients at high risk has been discussed. Fundamental factors that could impact short- and long-term health outcomes rather than weight or BMI should be considered. [48].

The results of this study supports the opinion of previous studies mentioned above by introducing additional body composition index(BM/W) to supplement BMI. In addition, the results of this study supports the necessity of muscle strengthening exercise for the intervention and prevention of MS. This coincides with the opinion of paradigm shift in obesity mentioned above. According to previous studies mentioned above in the literature review part, light physical activity was not significantly associated with any outcome. However, moderate-vigorous physical activity was inversely associated with BMI, waist circumference, fat mass, and muscle strength[15]. For this reason, change in community healthcare strategy is also required with the paradigm shift in obesity especially for younger (under 60) female group population.

In addition, muscularity itself can play an important role to solve the problem of “the obesity paradox” which means the health outcome of overweight patients had less medical symptoms or lower mortality rate than normal weight patients [28]. This also concur in opinion of paradigm shift

in obesity. Because obesity and overweight are determined by BMI, and the concept of BMI include not only fat but also muscle mass at the same time, by applying muscle mass, study group could be divided into subgroups by not only obesity measurement, but also by muscularity measurement. Different intervention and prevention strategy should be considered for population having different body composition considering muscularity and adiposity at the same time.

This study has several potential limitations. The first limitation is the difference between ethnicity in the application of body composition index. As mentioned above in the literature review part, use of index sometimes make different result in different ethnicity or nationality groups. Since previous studies testing BM/W ratio on its representativeness of muscularity was conducted in Japanese population [4-6], the results of clinical test should be supported for the use of body composition index on Korean population. Second, we were unable to explain the difference among gender and age groups about the logistic regression model and AUC. Additional study is required to explain gender and age group difference. Finally, characteristics of cross-sectional study limit the explanation of change of body composition. As it is hard to conduct a large scale cohort study representing general population in Korea, and because of the limitation of data sources, cross-sectional study design was selected. Additional cohort study is required to generalize these study results.

5.2 Conclusions

When body mass-to-waist(BM/W) ratio was included in the logistic

regression model in addition to BMI, AUC increased compared to the model including only BMI, and the younger female group had the highest AUC(85.7%) for the explanation of MS. When body composition indices were compared among different sex, year, and age groups, higher BMI didn't only mean higher adiposity. High BMI can be caused by both high adiposity(W/BH) and high muscularity(BM/W). The results of male group in figure 1 supported this argument. This relationship is also found in the correlation among indices (table 2). Different results by sex on the correlation of BM/W and MS criteria can be interpreted as preventive role of higher muscle mass on MS being explained better in female than male. This is also supported by the results of logistic regression and odds ratio analysis showing higher and consistent association of BM/W and MS in female than male. There is limitation on this study that use of BM/W as body composition index representing muscle mass or volume haven't been tested on Korean population. Further study is required to see the association between measured muscularity with BM/W ratio. This study supports the necessity of considering muscularity and adiposity by using body composition index(BM/W) for better explanation of MS especially in younger female group.

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SUMMARY(국문초록)

Body mass-to-waist 지수를 통한 한국인 대사증후군의 성별 분석

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연구배경 : 한국에서 대사증후군의 발생은 꾸준히 증가하고 있다. 대사증후군의 주요 원인 중 하나는 비만으로, 대사증후군에 대한 중재는 체중 감량과 BMI 감소를 목적으로 한 비만 관리 중심으로 이루어지고 있다. 하지만 대사증후군의 진단과 중재 단계에서 각기 다른 신체지수(허리둘레, BMI)를 사용함으로써 발생하는 괴리가 존재한다. 이와 더불어 선행연구에 의하면 근력이 대사증후군을 예방하는 효과를 가진다고 밝혀져 있으나, 현재 지수를 사용하여 인구집단을 대상으로 근력을 고려하고 있지는 않다. 따라서 지방뿐만 아니라 근력에 대한 종합적인 고려를 포함하는 비만에 대한 접근이 대사증후군 관리를 위해 필요하다. 본 연구의 목적은 한국성인을 대상으로 근력을 고려하여 신체지수와 대사증후군과의 관계를 살펴보고, 더 효과적인 비만과 대사증후군 관리에 기여하고자 하는 것이다.

연구방법 : 본 연구는 국민연금공단의 2010, 2013, 2016년 건강검진자료를 이용하였다. 전국 국민연금 가입자 및 피부양자 성인을 대상으로

한 단면연구로 총 2,993,760명의 자료를 수집하였다. 자료원으로부터 체질량지수(BMI)와 허리둘레-키 비율(W/BH), 체중-허리둘레 비율(BM/W)을 계산하였고, 신체지수와 대사증후군 진단기준 변수를 중심으로 분석하였다. 대사증후군은 ATP III와 IDF의 modified 기준을 사용하여 진단하였다. 신체지수는 성별과 년도, 연령그룹으로 구분하여 비교하였다. 지수와 대사증후군 간의 연관성 분석을 위해 로지스틱 회귀분석을 실시하였다. 이후 ROC 곡선과 AUC 값을 통해 회귀분석 모델을 비교하였다.

연구결과 : 연구결과에 따르면, 로지스틱 회귀분석에서 종속변수로 대사증후군에 대해 독립변수로 BMI(OR:1.23)와 BM/W(OR:0.17)가 함께 포함되었을 때 BMI만 포함한 모델(OR:1.20)에 비해 BMI와 대사증후군의 연관성이 더 높아지고 더 높은 AUC 값을 가졌다. 특히 60세 이하 젊은 여성의 경우 가장 높은 AUC 값(85.7%)을 보였으며, 남성에 비해 여성이 더 높은 AUC를 보였다. 성별, 년도, 연령그룹별로 신체지수를 비교했을 때에도 남녀 간에 큰 차이를 보였으며, 특히 남성의 경우 최근으로 올수록 BMI가 높지만 W/BH와 BM/W도 동시에 높아짐을 확인했다. BM/W와 각 대사증후군 구성요소의 오즈비 분석에서도 남녀간 차이가 컸으며, 특히 여성의 경우 BM/W가 높을수록 모든 대사증후군 구성요소 발생이 낮았다.

결론 : 대사증후군을 관리하고 예방하기 위해서는, 기존의 비만 관리에 근력을 반영하는 신체지수를 함께 도입하는 것이 효과적이다. 특히 여성의 경우 부족한 근력을 보완하는 것이 대사증후군 예방 및 치료 효과가 더 클 것이다.

주요어 : 신체지수, 대사증후군, 근육, 지방, 비만, 한국인
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