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Exploring the Relationship Between Different Obesity Measurements, Blood Pressure, and Blood Lipid Levels in Middle-Aged Korean Women

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Abstract: This study aimed to examine how blood pressure and blood lipid levels are associated with body mass index(BMI), body fat percentage (BF%), waist circumference (WC), waist-stature ratio (WSR), and waist-hip ratio (WHR) in middle-aged Korean women. A cross-sectional survey of 174 middle-aged Korean women was conducted in 2019. As measurement items, obesity index was BMI, BF%, WC, WSR, and WHR, blood pressure was SBP, DBP, and blood lipids were total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) was measured. Statistical analysis methods such as Pearson correlation and multiple regression were used to analyze the relationship between obesity index, blood pressure, and blood lipids. Results of the study revealed causal relationship between systolic blood pressure (SBP) and BMI and diastolic blood pressure (DBP) and WSR. TC showed a causal relationship with BF%, TG with BMI, HDL-C with WHR, and LDL-C with BF% and BMI. To sum up, the examination of five obesity measures in middle-aged Korean women revealed that BMI had the greatest ability to predict blood pressure, whereas BF% exhibited the strongest correlation with blood lipids.

Keywords: Blood Lipids Levels, Blood Pressure, Middle-aged Korean Women, Obesity Measurement

1. Introduction

The elevated prevalence of heaviness and its adversative effect on multiple health outcomes have made it a significant public health issue in primary care during the 21st century. Various epidemiological investigations have provided evidence of a progressive rise in hypertension prevalence with increasing levels of obesity[1]. Additionally, dyslipidemia, a disorder marked by elevated whole cholesterol content, triglycerides, and low-density lipoprotein cholesterol, in conjunction with diminished high-density lipoprotein cholesterol, is strongly linked to fatness [2]. Based on the 2021 National Health and Nutrition Examination Survey, the occurrence of obesity among females aged 19-29 was 15.9%, while for those aged 30-39, it increased to 25.7%, 27.2% for those aged 40-49, 31.6% for those aged 50-59, and 40.3% for those aged 60-69. In addition, the prevalence of obesity was found to be 36.6% for women aged 70 years or older[3]. Women's weight tends to increase significantly after middle age, and menopause-related hormonal changes lead to higher obesity-related morbidity rates among women compared to men[4].

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There are several criteria for determining obesity, among which body mass index (BMI) is commonly used. BMI can be easily measured using height and weight, and has a high correlation with body fat, which makes it a good predictor of obesity-related morbidity and mortality[5]. BMI, however, does not differentiate from body fat and muscle or bone in terms of body composition, so it may incorrectly assess athletes with a lot of muscle as obese and those with a lot of body fat but a low BMI as normal[6]. Multiple investigations have revealed that BMI has a robust association with general obesity, but it exhibits a relatively weak correlation with visceral obesity, comprising central obesity and abdominal fat[7]. To overcome the limitations of BMI in evaluating visceral obesity, several obesity indices have been developed, such as waist circumference (WC), waist-stature ratio (WSR), and waist-hip ratio (WHR). These indices have been reported to show a higher correlation with coronary artery disease-related disorders than BMI[8]. Even if their BMI is within the normal range, individuals with a high WHR is with a greater threat of emerging cardiovascular illness, metabolic syndrome, and diabetes[9]. Abdominal obesity, which is strongly linked with visceral obesity, has been recognized as a potent forecaster of metabolic syndrome[10].

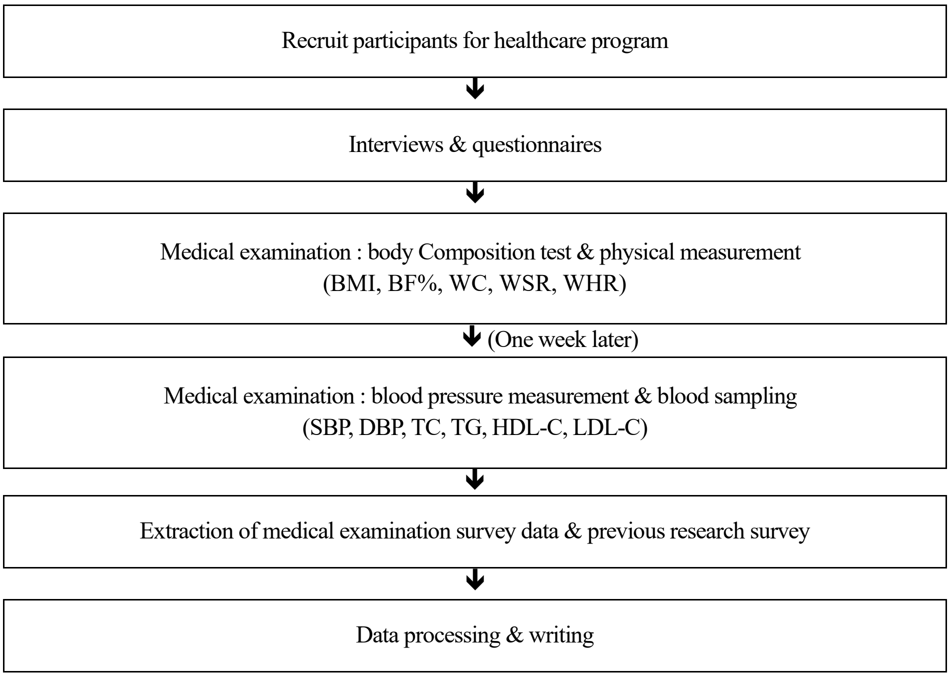
Jang & Park[11] conducted a study on 231 female college students to explore the connection between body fat percentage (BF%), BMI, and different obesity-related parameters such as body composition, blood pressure, blood lipids, and blood sugar. The study showed that, in female college students, BF% was a more accurate predictor of obesity-related variables compared to BMI. A study conducted by Kim & Lim[12] examined the comparative predictive abilities of BMI and body fat percentage in diagnosing hyperlipidemia among 224 middle-aged women, as reported in the literature. The results revealed that it is desirable to evaluate BMI and body fat percentage in combination. Kim, Yoo, Jeon, Kim, Choi, Park, & Lee[13] investigated the relationship concerning WC and WSR with metabolic syndrome in females and found that WSR exhibited a stronger correlation with metabolic syndrome than WC. In a study by Rubira, Rubira, Rubira, Lima, Franco, and Consolim-Colombo[14], BMI and BF% were positively linked with blood pressure, BF% was greatly important in the overweight group. While some research have studied the relationship with various obesity indices and metabolic risk factors, including BF%, BMI, WC, and WHR, there is still no clear consensus on which index is the most strongly associated with blood pressure and blood lipids. Moreover, many of these studies have focused on one or two obesity indices, highlighting the need for further research to determine the most reliable indicators of metabolic health.

In line with this, it aimed to investigate the link with blood pressure, blood lipid content, and five commonly used obesity indices (BMI, BF%, WC, WSR, and WHR) in middle-aged Korean women. The selected indices were chosen based on their accessibility, ease of measurement, and previous research utilization.

2. Research Methodology

2.1 Research Design

The research was a cross-sectional study with a secondary analysis of data from participants in a healthcare program at Gyeongsangnam-do Health Center from May to November 2019. During the program, the interview survey investigated the actual status of illnesses, hospital use, activity limitations, and health-related risk factors, and the health checkup survey was a physical examination, blood sampling, and blood pressure measurement in the local survey area. The specific experimental procedure is shown in [Fig. 1]. Using this design, this study examined the relationship between five obesity indices (BMI, BF%, WC, WSR, and WHR), blood pressure, and blood lipids.



[Fig. 1] Experimental Procedures

2.2 Research Instrument

In this study, height was measured using an automatic stadiometer GL-150R (G-tech Co., Korea), and weight, BF%, WHR, and BMI were calculated by a body composition analyzer InBody 720 (BioSpace Co., Korea). Blood pressure were calculated by an automated sphygmomanometer BP 500 (SELVAS Healthcare Co., Korea), and blood lipids were calculated by an Afinion Analyzer (Abbott Co., USA).

2.3 Respondents of the Study

The study included 174 Korean women aged 30-65 who participated in a healthcare program at a health center in Gyeongsangnam-do in 2019. To ensure that the sample size was appropriate, the G*power (3.1.9.4) program was used to calculate the effect size (0.15), significance level (0.05), power (0.9), and five independent variables for the multiple regression analysis. The least possible sample size necessary was determined to be 116 subjects, which means that the study's sample size of 174 participants was sufficient for conducting the multiple regression analysis. [Table 1] details each respondent's bodily features.

[Table 1] Subject Characteristics (n=174)

Variables	Mean±SD
Age (yrs)	46.64±7.74
Height (cm)	160.25±5.50
Weight (kg)	63.89±9.92
BMI (body mass index, kg/m2)	24.98±3.77

BF% (body fat percentage, %)	35.40±6.06
WC (waist circumference, cm)	85.98±9.41
WSR (waist-stature ratio)	0.54±0.06
WHR(waist hip ratio)	0.90±0.05
SBP (systolic blood pressure, mmHg)	120.41±10.13
DBP (diastolic blood pressure, mmHg)	78.43±7.92
TC (total cholesterol, mg/dL)	197.87±31.31
TG (triglycerides, mg/dL)	121.67±32.85
HDL-C (high density lipoprotein cholesterol, mg/dL)	53.15±13.20
LDL-C (low density lipoprotein cholesterol, mg/dL)	169.06±36.25

2.4 Data Gathering Procedures

2.4.1 Physical Measurements

Body composition was analyzed using Inbody 720 to calculate BMI, BF%, and WHR. Since body condition and posture can be affected when measuring obesity, researchers and research assistants who are sufficiently familiar with the use of the machine conducted the measurement directly. For body composition measurements, all subjects were asked to do fasting for at least 12 hours, wearing short sleeves and shorts, barefoot and standing on a metal scaffold with arms extended and holding the electrode handles with both hands in an upright position. WC was measured in centimeters while standing, using a tape measure, at the finest part of the waist, between the iliac crest and the lowest part of the ribcage. WSR was computed by dividing the WC by the participant's height in centimeters (cm).

2.4.2 Blood Pressure

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) was measured after a rest period of at least 10 minutes using an automated sphygmomanometer. Blood pressure was measured two times, 5 minutes separately, and the average value was documented.

2.4.3 Blood Lipids

Blood lipids were measured using a cholesterol diagnostic test. After the researcher was fully familiar with the use of the machine, the subject was instructed to fast for at least 12 hours, and then blood was directly collected from the fingertip capillaries and dropped into a blood component analysis kit. Blood lipids were analyzed for total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) levels, and it took about 5 minutes to confirm the analysis results.

2.5 Data Analysis

Data analysis were made by SPSS version 25.0 (SPSS Inc, Chicago, IL, USA). Pearson correlation coefficients were used to determine the relationship of BMI, BF%, WC, WSR, and WHR with SBP, DBP, TC, TG, HDL-C, and LDL-C. Multiple regression analysis was made to determine which of the five obesity indices had the highest impact on blood pressure and blood lipids. The significance level (α) of .05 was applied to all statistical analyses.

3. Results and Discussion

[Table 2] shows the correlation results between BMI, BF%, WC, WSR, WHR, blood pressure, and blood lipids in Korean middle-aged females. The study's results indicated statistically significant positive correlations between BMI and SBP, DBP, TC, TG, and LDL-C, while BMI was negatively correlated with HDL-C levels. Additionally, significant positive links were found by BF% and TC, TG, and LDL-C, while a negative association was observed between BF% and HDL-C. WC was significantly positively linked with SBP, DBP, TC, TG, and LDL-C, and negatively associated with HDL-C. Furthermore, the study revealed a significant positive connection between WSR and SBP, DBP, TC, TG, and LDL-C, whereas finding a negative association amid WSR and HDL-C. The results showed a significant positive connection amid WHR and TG and LDL-C, while there was a negative connection with HDL-C.

[Table 2] Results of Correlating BMI, BF%, WC, WSR, WHR, Blood Pressure, and Blood Lipids

Variables	SBP	DBP	TC	TG	HDL-C	LDL-C
BMI	.273**	.172*	.226**	.343**	-.195*	.328**
BF%	.098	.084	.249**	.277**	-.199**	.338**
WC	.243**	.167*	.166*	.296**	-.197**	.269**
WSR	.254**	.185*	.212**	.304**	-.235**	.324**
WHR	.041	.079	.095	.240**	-.248**	.216**

BMI: body mass index, BF%: body fat percentage, WC: waist circumference, WSR: waist-stature ratio, WHR: waist hip ratio, SBP: systolic blood pressure, DBP: diastolic blood pressure, TC: total cholesterol, TG: triglycerides, HDL-C: high density lipoprotein cholesterol, LDL-C: low density lipoprotein cholesterol.**p<.01, *p<.05.

The researchers conducted an importance analysis to determine the most influential obesity factor among BMI, BF%, WC, WSR, and WHR on blood pressure and blood lipids. To determine the significance of the impact of these factors on blood pressure and blood lipid content, multiple regression analysis with the stepwise technique was utilized. To check for autocorrelation and multicollinearity, the Durbin-Watson test was used, as well as tolerance limits and variance inflation factor (VIF).

In exploring the effects of BMI, BF%, WC, WSR, and WHR on blood pressure, the study conducted multiple regression analysis, the findings of which are seen in [Table 3]. Prior to the investigation, autocorrelation in the dependent variable and multicollinearity among the independent variables was assessed. The Durbin-Watson index were used to assess autocorrelation, and the values obtained were 2.071 and 1.798 for SBP and DBP, respectively. These values were adjacent to 2, indicating the lack of autocorrelation. The analysis of multicollinearity among the independent variables revealed that each factor had a tolerance greater than 0.1 and a VIF less than 10, suggesting the absence of multicollinearity issues. The analysis identified BMI as an important factor for SBP (β=.273, $p<.001$), explaining 7.5% of the variance. In addition, WSR (β=.185, $p<.05$) was selected as an important factor for DBP, explaining 3.4% of the variance. In a look at the research on obesity indices and blood pressure, Mark, Correia, Morgan, Shaffer, & Haynes[15] reported a positive correlation between hypertension prevalence and an increase in adipose tissue. Fuchs, Gus, Moreira, Moraes, Wiehe, Pereira, & Fuchs[16] suggested that WHR and WSR were better predictors of hypertension incidence than BMI. However, Ghosh & Bandyopadhyay [17] reported that BMI had a tougher causal link with hypertension than WSR and WC. The BMI was the obesity index most closely related with SBP, while WSR was most closely associated with DBP, suggesting that predicting blood pressure in middle-aged Korean women may benefit from using both indices. In general, WSR has been recognized as a reliable marker of cardiovascular risk factors and abdominal visceral fat[18][19], while BMI is commonly utilized as a computation of the total fat mass[20].

[Table 3] Results of Multiple Regression Analysis of BMI, BF%, WC, WSR, WHR and Blood Pressure

Category	Step	Item	Standardized coefficients	*t*	*p*	Collinearity statistics		Durbin -Watson
			Beta			tolerance limit	VIF	
SBP	1	(constant) BMI	.273	20.498 3.728	.000*** .000***	1.000	1.000	2.071
		R^2=.075, F=13.895, p=.000						
DBP	1	(constant) WSR	.185	11.345 2.476	.000*** .014*	1.000	1.000	1.798
		R^2=.034, F=6.129, p=.014						

SBP: systolic blood pressure, DBP: diastolic blood pressure, BMI: body mass index, WSR: waist-stature ratio, $^{***}p$<.001, $^{*}p$<.05.

The analysis results on the importance of BMI, BF%, WC, WSR, and WHR on blood lipids are presented in [Table 4]. The tolerance level for each factor was determined to be greater than 0.1, and the VIF is found to be a smaller amount than 10, representing that there was no multicollinearity present. This study evaluated the Durbin-Watson indices to assess the presence of autocorrelation issues. According to the results, the Durbin-Watson indices of TC, TG, HDL-C, and LDL-C were 1.881, 1.960, 1.683, and 1.927, respectively, which were near 2, indicating no significant autocorrelation problems. The multiple regression analysis identified BF% (β=.249, p<.01) as an important factor for TC, with an explanatory power of 6.2%. For TG, BMI (β=.343, p<.001) was selected as an important factor, with an explanatory power of 11.7%. For HDL-C, WHR (β=-.248, p<.01) was selected, with an explanatory power of 6.2%. On the other hand, LDL-C was ranked in two stages of importance, and BF% and BMI were selected. These two items explained 13.7% of LDL-C, followed by BF% (β=.217, p<.05) and BMI (β=.192, p<.05).

According to Jang & Park[21], there was a positive connection concerning BF% and TC and LDL-C, and a negative connection with HDL-C among female college students. Their study concluded that BF% exhibited a stronger association with blood lipids than other obesity indices. Nagaya, Yoshida, Takahashi, Matsuda, & Kawai[22] also reported a stronger correlation between BF% and TG, TC, LDL-C, and HDL-C than BMI. Conversely, Kim[23] reported that BMI had a stronger correlation with blood lipids, particularly LDL-C, and suggested that diagnosis by BMI may be more significant than by BF%. Plachta-Danielzik, Landsberg, Johannsen, Lange, & Müller[24] found a significant connection among blood lipids and both BMI and WC in youngsters and teenagers. The correlation findings of this study was also alike to prior studies and most studies recommended using these obesity indices in combination.

Bosy-Westphal, Geisler, Onur, Korth, Selberg, Schrezenmeir, & Müller [25] found that in adult men, BF% was more weakly associated with blood lipids than BMI and WC. In adult females, BMI was highly connected with HDL-C. In multiple regression analyses, WSR were the key predictor of adverse outcomes in both gender. Consequently, BF% was a poorer predictor of metabolic risk than BMI and WC. WC and WSR was closely related with metabolic risk factors than BF%, but the changes were minor and varied by type of risk issue and gender. Bovet, Arlabosse, Viswanathan, & Myers[26] examined the association of BMI, WHR, WSR, and BF% with cardiovascular risk factors (blood pressure, LDL-C, HDL-C, TG, etc.) in adolescents. The results showed that all obesity markers, except WHR, were strongly associated with cardiovascular risk factors. BMI, like other markers, consistently predicted cardiovascular risk and may be particularly useful in low-resource settings. Ge, Lu, & Lei[27] reported that BMI and WC are important mediators of blood lipids (TG and LDL-C) in Chinese elderly. As a result of multiple regression analysis of this study, BF% was related to TC, BMI was related to TG, WHR was related to HDL-C, and BF% and BMI were related to LDL-C. appeared to have a slightly higher effect than BMI and WHR. The findings of this study, unlike previous studies, showed that BF% was an important mediator of blood lipid. Studies investigating the association between various obesity indices and blood lipids have shown inconsistent results, which may be due to differences in gender, age, race, and lifestyle.

[Table 4] Results of Multiple Regression Analysis of BMI, BF%, WC, WSR, WHR and Blood Lipids

Category	Step	Item	Standardized coefficients	t	p	Collinearity statistics		Durbin -Watson
			Beta			tolerance limit	VIF	
TC	1	(constant) BF%	.249	11.125 3.371	.000*** .001**	1.000	1.000	1.881
		R^2=.062, F=11.365, p=.001						
TG	1	(constant) BMI	.343	2.983 4.782	.003** .000***	1.000	1.000	1.960
		R^2=.117, F=22.872, p=.000						
HDL-C	1	(constant) WHR	-.248	6.557 -3.359	.000*** .001**	1.000	1.000	1.683
		R^2=.062, F=11.282, p=.001						
LDL-C	1	(constant) BF%	.338	6.330 4.706	.000*** .000***	1.000	1.000	
		R^2=.114, F=22.150, p=.000						
	2	(constant) BF% BMI	.217 .192	4.231 2.388 2.114	.000*** .018* .036*	.609 .609	1.642 1.642	1.927
		R^2=.137, F=13.533, p=.000						

TC: total cholesterol, TG: triglycerides, HDL-C: high density lipoprotein cholesterol, LDL-C: low density lipoprotein cholesterol, BF%: body fat percentage, BMI: body mass index, WHR: waist hip ratio. ***p<.001, **p<.01, *p<.05.

4. Conclusions

This reseach aimed to define the connection between five obesity indices (BMI, BF%, WC, WSR, and WHR), blood pressure, and blood lipids in middle-aged Korean women. The findings of the connection concerning the five obesity indices, blood pressure, and blood lipids are as follows. First, BMI was significantly positively linked with SBP, DBP, TC, TG, and LDL-C, while BMI was negatively linked with HDL-C. Second, BF% was considerably and positively linked with TC, TG, and LDL-C, while BF% was also correlated with HDL-C. Third, WC and WSR were significantly positively correlated with SBP, DBP, TC, TG, and LDL-C, while HDL-C was significantly negatively correlated. Fourth, WHR was significantly positively linked with TG, LDL-C, and negatively linked with HDL-C. Multiple regression analysis were performed to determine the effect of the five obesity indices on blood pressure and blood lipids. The analysis of blood pressure shows that BMI is the most influential obesity index on SBP, and DBP is most influenced by WSR. As a result of blood lipid analysis, BF% was the most important factor for TC, and BMI was selected as an important factor for TG. For HDL-C, WHR was the most influential factor, and for LDL-C, BF% and BMI were the most influential factors. Taken together, these results suggest that BMI is most strongly associated with blood pressure, while BF% is most strongly associated with blood lipids in middle-aged Korean women. Therefore, we recommend combining BMI and BF% to predict metabolic risk factors for blood pressure and blood lipids.

The study's limitation lies in its random sampling of middle-aged women from a single region, thus limiting the generalizability of the findings. Nevertheless, it is important to highlight specifically observed the connection concerning blood pressure and blood lipids using five different obesity indices in middle-aged Korean women, offering valuable insights for effective obesity management within this population. To enhance obesity management in middle-aged Korean women, future research should explore potential variations in health perceptions based on BF% and BMI and investigate the impact of exercise and nutrition interventions on different obesity indicators.

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