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THE RELATIONSHIP BETWEEN NECK CIRCUMFERENCE, ENERGY NUTRIENT INTAKE AND METABOLIC SYNDROME BY MENOPAUSE IN KOREAN MIDDLE-AGED WOMEN

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ABSTRACT

Recently, neck circumference has been considered a screening index for metabolic syndrome, which is rising in Korea. This study aimed to investigate the relationship between neck circumference, energy nutrient intake, and metabolic syndrome caused by menopause in middle-aged women using data from the 8th KNHANES. Menopausal status showed a significant difference in energy nutrient intake ($P<0.05$), however no correlation with neck circumference was observed. Regarding the correlation between the metabolic syndrome diagnostic components and neck circumference, only HDL cholesterol showed a negative correlation, whereas all other diagnostic components showed a positive correlation in both groups. Among the diagnostic components for metabolic syndrome, the HDL cholesterol level ($P<0.01$) was lower in the post-menopausal group; however, the levels of the other components were higher than those in the pre-menopausal group ($P<0.05$, ($P<0.001$). The prevalence of metabolic syndrome was significantly higher in the post-menopausal group (34.4%) than in the pre-menopausal group (19.2%). The neck circumference reference point calculated using ROC curve analysis for the diagnosis of metabolic syndrome was higher in the pre-menopausal group (33.5 cm) than in the post-menopausal group (33.0 cm). The odds ratio for the effect of the neck circumference reference point on the prevalence of metabolic syndrome were 14.571 and 7.287 in the in the pre-menopausal and post-menopausal groups, respectively. This study showed that neck circumference has potential as a diagnostic index for metabolic syndrome in middle-aged women; however, it is necessary to reflect the standard neck circumference by menopause status.

Keywords: Neck Circumference, Energy Nutrient, Metabolic syndrome, Menopause, Middle-aged Women

1. INTRODUCTION

The life expectancy of Koreans is 83.6 years as of 2021, which is an increase of 21.3 years compared to 30 years ago (62.3 years in 1970) (Statistics Korea, 2022b). The proportion of the older population aged 65 or older in Korea increased from 10.7 % in 2009 to 17.5 % (aged society) in 2022, and is expected to increase to 20.8 % in (super-aged society) by 2026 (Statistics Korea, 2022a). Middle age ranges from 40 to 64 years old, and the change to an aging society also increases the middle-aged population, accounting for 40.6 % of the total population in 2022 (Ministry of the Interior and Safety, 2022). However, the healthy life expectancy is 73.1 years as of 2019, which is about 10 years lower than the life expectancy, and people suffer from diseases, pain, physical discomfort, and emotional instability during the last period of their lives (World Health Statistics, 2022).

Middle-aged women are under increased stress due to household chores, economic activities, and caring for children and parents. It is also the period in which psychological changes such as decreased metabolism and increased prevalence of chronic diseases due to hormonal changes, and depression and lethargy are most common (Brown et al., 2014). In these changed among middle-aged women, menopause is a major variable. Menopause occurs spontaneously in most women between 45 and 52 years old. It is associated with hot flashes, sleep disturbances, mood disorders, sexual dysfunction, weight gain, cognitive decline, and cardiovascular disease (Johnson et al., 2019). The incidence of post-menopausal diseases is closely related to a balanced intake of energy and micronutrients; several previous studies have reported that the nutritional status of post-menopausal women in Korea is very poor (Lee & Jung, 2018; Kim et al., 2019).

Neck circumference is easy and cost-effective body index to measure easily in clinical practice (Kim et al., 2022). In studies on the correlation between various diseases using neck circumference, neck circumference has an independent correlation with body fat, and has been used as an index to evaluate the distribution of subcutaneous fat in the upper body (An & Park, 2022). Studies have also suggested that an increase in neck circumference is independently associated with an increased risk of metabolic syndrome, cardiovascular disease, and sleep apnea (Yan et al., 2020; Kim et al., 2021). Accordingly, the Korea Disease Control and Prevention Agency (KDCA) has been investigating neck circumference as a body measurement parameter for people aged ≥40 years since the 2019 Korea National Health and Nutrition Examination Survey (KNHANES) (Korea Disease Control and Prevention Agency, 2022).

This study aimed to investigate the relationship between neck circumference, energy nutrient intake, and metabolic syndrome according to menopause in middle-aged women. Therefore, this study aimed to provide basic data for the health management of menopausal women using the following research questions (RQ):

RQ1: Does menopause affect the relationship between energy nutrient intake and neck circumference?

RQ2: Does menopause affect the relationship between metabolic syndrome and neck circumference?

1. LITERATURE REVIEW

In middle age, physical decline and health problems emerge due to the onset of physical aging (Baek et al., 2014). In middle-aged women, menopause causes several health problems. For example, cardiovascular disease incidence in women before menopause is lower than

that in men; however, after menopause, the incidence increases more rapidly than that in men owing to the effects of estrogen deficiency (So et al., 2010; Laroche et al., 2017). So et al. (2010) reported that the levels of low-density lipoprotein cholesterol and triglycerides, among the diagnostic factors for metabolic syndrome, increased by 10-20 %, while the high-density lipoprotein cholesterol level decreased by 10 % after menopause. In addition, estrogen deficiency increases waist circumference by accumulating fat in the central body (Han, 2011). The prevalence of metabolic syndrome among middle-aged Korean women is rapidly increasing (Statistics Korea, 2021), and menopause is known to increase the risk of metabolic syndrome by 60 % independent of age, body mass index, and physical activity (Polotsky & Polotsky, 2010)

The definition of metabolic syndrome in Korea is based on the modified National Cholesterol Education Program III (Grundy, 2005), but the Korean Obesity Society defined waist circumference (Lee et al., 2007). A woman can be diagnosed with metabolic syndrome if they meet three or more of the following criteria: 1) triglycerides ≥150 mg/dL or medication use. 2) waist circumference >85 cm. 3) blood pressure ≥130/85 mmHg or antihypertensive medication use. 4) HDL cholesterol level <50 mg/dL or medication use. 5) fasting glucose ≥100 mg/dL or medication use (insulin or oral agents). Recently, studies have used neck circumference as a physical indicator of metabolic syndrome risk. Increased neck circumference is associated with increased waist circumference, blood pressure, insulin resistance, and lipid abnormalities (Ben-Noun & Laor, 2003; Alfadhli et al, 2017). Therefore, research is being conducted on the reference point of the neck circumference that increases the risk of metabolic syndrome; the criterion for neck circumference for screening metabolic syndrome in Korean adults over the age of 40 has been limited to 38.0 cm for men and 33.0 cm for women (An & Park, 2022). However, a clinically acceptable reference point has yet to be established.

Endocrine changes and psychological symptoms due to menopause change food preference, increase food intake, and decrease the basal metabolic rate (Kim & Jung, 2016). In a study by Lee et al. (2012a), no significant differences in energy and protein intake by menopause status were observed. Energy was consumed at 89.71 % of the estimated energy requirement; protein intake was above the recommended intake. A comparison of the composition ratio of the three major energy nutrients before and after menopause showed that, the carbohydrate intake ratio of post-menopausal women was significantly higher (P<0.001), whereas the fat intake ratio was significantly higher in pre-menopausal women (P<0.001). Yang & Moon (2021) reported that the prevalence of metabolic syndrome increase when carbohydrate intake exceeds the appropriate standard in middle-aged women; however, there was no relationship between fat and protein intake. However, no study has investigated whether the nutritional characteristics of menopausal middle-aged women affect neck circumference.

2. RESEARCH METHODOLOGY

3.1. Subjects

This study used data from the 2019-2021 KNHANES conducted by the Korea Disease Control Prevention Agency of the Ministry of Health and Welfare. The participants were selected using a stratified multi-stage clustered complex sampling method based on the area of residence, sex, and age. Among the 4769 middle-aged women between the ages of 40 and 64, those with implausible dietary intake (<500 kcal or >5,000 kcal/day; n=59), those who did not fast for 8 hours before the blood test (n = 105), those who did not have

measurements for neck circumference (n = 21), and those with missing demographic data (n=332) were excluded. Finally, 3551 participants were included in the analysis.

3.2. Study contents

Demographic variables included age, residence, house type, marital status, education level, economic activity, and household income. The types and amounts of food consumed 2 days before the survey were investigated using the 24-hour recall method, and the results were used to determine the intake of energy nutrients such as carbohydrates, sugars, proteins, and fats. Health factors included neck circumference, monthly drinking rate, lifetime smoking rate, mental stress perception rate, walking (days/week), and strength exercises (days/week). Metabolic syndrome was defined according to the criteria of the modified National Cholesterol Education Program III (Grundy, 2005) and modified abdominal obesity cutoff for Korean adults (Lee et al., 2007).

3.3. Data Analysis

The collected data were analyzed by the SPSS 23.0 package (IBM Inc., Chicago, IL, USA), and complex sampling analyses with cluster sampling variables, strata, and weighted values were performed. Nominal and rank variables were presented as frequency and percentage using the chi-squared test, and continuous variables were presented as mean and standard error using a general linear model. Pearson's correlation analysis was used to investigate the correlation between neck circumference, energy nutrients, and diagnostic factors for metabolic syndrome by menopause status. Receiver operating characteristic (ROC) curve analysis was performed to present a neck circumference reference point for diagnosis of metabolic syndrome follwing menopause. The odds ratio and 95% confidence interval of metabolic syndrome according to neck circumference were obtained by multi-sample logistic regression analysis by dividing to menopausal status. The statistical significance level was set at $P < 0.05$.

3. RESULT AND DISCUSSION

4.1. Demographic characteristics

The demographic characteristics of participants are presented in Table 1. There were significant differences between the two groups in all demographic characteristics ($P<0.001$). Age analysis revealed that, the menopausal group (57.16) was approximately 10.1 years older than the pre-menopausal group (47.07). The pre-menopausal group had a higher percentage of living in urban than rural areas and in apartments rather than general housing than the post-menopausal group. The percentage of people married was highest in the post-menopausal group (95.3 vs. 98.1). Educational level, percentage of economic activity (64.5 vs. 55.0), and household income were higher in the pre-menopausal group than in the post-menopausal group. The differences in demographic characteristics observed in this study can be similarly seen in the study by Lee et al. (2012a), who found that the age difference between the two groups was about 10 years, and variables such as retirement caused this result (Trading Economics, 2021).

Table 1. Demographic characteristics of subjects by menopause status

Variables	Items	Pre-menopausal group (n=1745)	Post-menopausal group (n=1806)	*P*-value
Age (years)		47.07±0.14	57.16±0.12	<0.001***

Residence	Urban	1481(84.9)	1428(79.1)	<0.001***
	Rural	264(15.1)	378(20.9)	
House type	General housing	575(33.0)	792(43.9)	<0.001***
	Apartment	1170(67.0)	1014(56.1)	
Marital status	Married	1663(95.3)	1771(98.1)	<0.001***
	Unmarried	82(4.7)	35(1.9)	
Education level	≤Primary school	41(2.4)	274(15.2)	<0.001***
	Middle school	89(5.1)	286(15.8)	
	High school	671(38.4)	784(43.4)	
	≥College	944(54.1)	462(25.6)	
Economic activity	Yes	1126(64.5)	993(55.0)	<0.001***
	No	619(35.5)	813(45.0)	
Household income	Low	120(6.9)	212(11.7)	<0.001***
	Middle low	409(23.4)	444(24.6)	
	Middle high	559(32.0)	517(28.6)	
	High	657(37.7)	633(35.1)	

Values are presented as number (%) of mean ± S.E.

$^{***}P<0.001$

4.2. Energy nutrient intake and health factors

Table 2 shows no significant difference in energy intake by menopause status. However, based on the estimated energy requirements of Korean women, 1,900 kcal for those aged 30-49 and 1,700 kcal for those aged 50-64 (Ministry of Health and Welfare and Korean Nutrition Society, 2020), the intake rate was higher in the post-menopausal group (94.5) than in the pre-menopausal group (86.1). The recommended carbohydrate intake for middle-aged Korean women is 130 g (Ministry of Health and Welfare and Korean Nutrition Society, 2020). Both groups in this study consumed more than this amount, but the intake was significantly higher in the menopausal group than in the pre-menopausal group. The total sugar intake standard for Koreans is 10-20% of the total energy intake (Ministry of Health and Welfare and Korean Nutrition Society, 2020), and it has been reported that the incidence of metabolic syndrome increases when this ratio is exceeded (Kang & Lee, 2022). Sugar intake in this study was within the appropriate range for both groups, but was higher in the post-menopausal group ($P<0.05$). Protein and fat intake (g) showed opposite results to carbohydrate intake ($P<0.05$). Protein (62.1 vs. 59.9) and fat intake (42.9 vs. 39.2) were higher in the pre-menopausal group than in the menopausal group. Furthermore, the protein intake in both groups exceeded the recommended intake of 50 g for middle-aged Korean women (Ministry of Health and Welfare and Korean Nutrition Society, 2020). A study by Lee et al. (2012a) also showed similar results to this study. The carbohydrate: protein: fat energy composition ratios of the two groups were all within the appropriate ratio (55-65 % : 7-20 % : 15-30 %) (Ministry of Health and Welfare and Korean Nutrition Society, 2020). In the comparison between the two groups, the carbohydrate intake rate in the post-menopausal group was significantly higher ($P<0.001$), and the protein and fat intake rates were significantly higher in the pre-menopausal group ($P<0.001$). It is known that excessive intake of carbohydrates above the appropriate level

in middle-aged women increases the prevalence of metabolic syndrome (Yang & Moon, 2021).

Among health factors, there was no significant difference in neck circumference by menopause status. A study by Kim et al. (2022) showed no significant difference in neck circumference among older women of all age groups. The monthly drinking rate (47.3 vs. 33.1), lifetime smoking rate (12.7 vs. 8.4), and mental stress perception rate (28.1 vs. 26.2) were higher in the pre-menopausal group (P<0.01~P<0.001). A study by Kim (2022) of pre- and post-menopausal women, obesity, current smoking status, and alcohol consumption influenced health factors related to metabolic syndrome. Furthermore, this study showed that, post-menopausal strength exercises affected metabolic syndrome; however, this study was a difference in walking (day/week) in the post-menopausal group (P<0.05).

Table 2. Comparison of energy nutrient intake and health factors by menopause status

Variables	**Pre-menopausal group (n=1745)**	**Post-menopausal group (n=1806)**	***P*-value**
Energy intake (kcal)	1635.4±17.7	1606.6±15.9	0.245
Energy nutrient intake			
Carbohydrate (g)	242.2±2.7	251.0±2.7	<0.05*
Sugar (g)	57.7±1.1	61.2±1.3	<0.05*
Protein (g)	62.1±0.8	59.9±0.7	<0.05*
Fat (g)	42.9±0.7	39.2±0.7	<0.05*
CPF Ratio[1)]			
Carbohydrate (%)	61.0±10.9	63.8±10.7	<0.001***
Protein (%)	15.6±4.4	15.0±4.2	<0.001***
Fat (%)	23.4±9.0	21.1±8.7	<0.001***
Neck circumference (cm)	32.6±0.1	32.7±0.06	0.135
Monthly drinking	826(47.3)	598(33.1)	<0.001***
Lifetime smoking	222(12.7)	152(8.4)	<0.001***
Mental stress perception	490(28.1)	420(26.2)	<0.01**
Exercise(day/week)			
Walking	4.88±0.08	5.11±0.07	<0.05*
Strength exercise	1.56±0.03	1.60±0.04	0.436

Values are presented as mean ± S.E. or number (%)

[1)]Intaked energy distribution ratio of carbohydrate:protein:fat

*P<0.05, **P<0.01, ***P<0.001

4.3. Diagnosis components and prevalence for metabolic syndrome

Among the five metabolic syndrome diagnosis, the HDL cholesterol level (P<0.01) decreased in the post-menopausal group compared to the pre-menopausal group, while the values of the other components (P<0.05, P<0.001) were higher (Table 3). The main causes in this study were is estrogen deficiency and age (M.S. Han, 2011; Lee et al., 2012a; Lee et al., 2012b; An & Park, 2022). Reflecting this result, the rate of satisfying each criterion for diagnosing metabolic syndrome was high in the post-menopausal group (P<0.01-P<0.001), and the prevalence of metabolic syndrome also increased significantly in the post-menopausal group (34.4%) compared to the pre-menopausal group (19.2%) (P<0.001).

Table 3. Comparison of diagnosis components and prevalence for metabolic syndrome by menopause status

Variable	Items	Pre-menopausal group (n=1745)	Post-menopausal group (n=1806)	*P*-value
Diagnosis components	Waist circumference (cm)	79.4±0.3	81.7±0.3	<0.001***
	SBP (mm/Hg)	113.7±0.4	119.2±0.5	<0.001***
	DBP (mm/Hg)	74.9±0.3	75.7±0.3	<0.05*
	FBS (mg/dL)	97.1±0.5	101.8±0.6	<0.001***
	HDL cholesterol (mg/dL)	57.4±0.4	55.7±0.3	<0.01**
	Triglyceride (mg/dL)	107.3±1.9	118.9±1.9	<0.001***
diagnostic criteria	≥85 cm waist circumference	429(24.6)	633(35.0)	<0.001***
	≥130 mmHg SBP or ≥85 mmHg DBP or medicine Treatment	393(22.5)	755(41.8)	<0.001***
	≥100mg/dL fasting blood glucose or medicine Treatment	481(27.6)	753(41.7)	<0.001***
	≥100mg/dL Triglyceride or medicine Treatment	410(23.5)	769(42.6)	<0.001***
	〈40mg/dL HDL-cholesterol	501(28.7)	647(35.8)	<0.01**
Metabolic syndrome prevalence		336(19.2)	622(34.4)	<0.001***

Values are presented as mean ± S.E. or number (%)

$^{*}P<0.05$, $^{**}P<0.01$, $^{***}P<0.001$

4.4. Correlation between neck circumference, energy nutrients, and diagnostic components for metabolic syndrome

In previous studies, opinions on the effect of each macronutrient on metabolic syndrome have, been divided; however, it has been reported that energy and macronutrient intake are closely related to metabolic syndrome (Kim & Back, 2020; Yang & Moon, 2021; Kang & LEE, 2022). However, in this study, neck circumference did not show any correlation with energy and energy nutrient intake s regardless of post-menopausal status (Table 4). Among the diagnostic components of metabolic syndrome in both groups, only HDL cholesterol showed negative correlations with neck circumference, whereas, all other diagnostic factors showed positive correlation (especially a strong correlation with waist circumference). A study by An & Park (2022) showed similar results to this study. The correlation between neck circumference and metabolic syndrome diagnostic components was weaker in the post-menopausal group than in the pre-menopausal group. These results are probably influenced more by age than menopause (Lee et al., 2012b; An & Park, 2022).

Table 4. Correlation analysis between neck circumference, energy nutrient intake, and diagnostic components for metabolic syndrome by menopause status

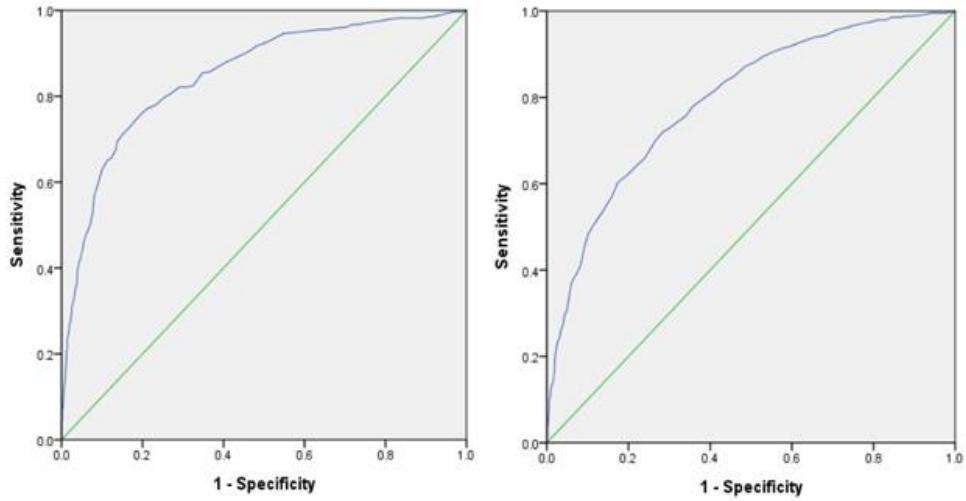
Variables	Pre-menopausal group (n=1745)		Post-menopausal group (n=1806)	
	r	*P*-value	r	*P*-value
Energy intake (kcal)	0.012	0.629	-0.016	0.509
Energy nutrient				
Carbohydrate (g)	0.035	0.148	0.013	0.587
Sugar (g)	-0.023	0.341	-0.030	0.205
Protein (g)	0.009	0.720	-0.0(4	0.147
Fat (g)	-0.028	0.235	-0.068	0.004
Waist circumference (cm)	0.815	<0.001***	0.758	<0.001***
SBP (mm/Hg)	0.260	<0.001***	0.187	<0.001***
DBP (mm/Hg)	0.248	<0.001***	0.150	<0.001***
FBS (mg/dL)	0.346	<0.001***	0.276	<0.001***
HDL cholesterol (mg/dL)	-0.315	<0.001***	-0.282	<0.001***
Triglyceride (mg/dL)	0.319	<0.001***	0.244	<0.001***

$^{***}P<0.001$

4.5. Neck circumference reference point for diagnosis of metabolic syndrome

ROC curve analysis was performed to obtain the reference point of the neck circumference for the diagnosis of metabolic syndrome by menopause status, and the ROC curve is shown in Figure 1. The area under the curve was 0.849 in the pre-menopausal group and 0.793 in the post-menopausal group. The maximum Youden's index value, considered as an ideal reference point, was 33.5 cm (sensitivity 74.4%, specificity 81.8%) in the pre-menopausal group and 33.0 cm (sensitivity 72.0%, specificity 71.5%) in the post-

menopausal group (Table 5). An & Park (2022) stated that the neck circumference reference point for diagnosing metabolic syndrome in women aged ≥ 40 years was 33.0 cm, the same as the post-menopausal group in this study.



Pre-menopausal group Post-menopausal group

Fig.1: The ROC curve of neck circumference for the diagnosis of metabolic syndrome by menopause status

Table 5. AUC, Standard Error, 95% Confidence Interval, and P-value of neck circumference by menopause status in the diagnosis of metabolic syndrome

Variables		**Pre-menopausal group (n=1745)**	**Post-menopausal group (n=1806)**
Area Under the Curve (AUC)		0.849	0.793
SE		0.012	0.011
95% Confidence Interval	Lower	0.825	0.771
	Upper	0.873	0.814
Significance		0.000	0.000
Cut-point		0.562	0.436
Sensitivity		0.744	0.720
Specificity		0.818	0.715
Ideal neck circumference reference point (cm)		33.5	33.0

4.6. Odds ratio for metabolic syndrome by neck circumference

Table 6 shows the results of the logistic regression analysis to investigate the effect of neck circumference on the prevalence of metabolic syndrome. In the premenopausal group, the odds ratio for metabolic syndrome increased to 2.176 when the neck circumference increased by 1 cm, and the odds ratio increased significantly to 14.571 in the longer group based on a neck circumference of 33.5 cm. A similar trend was observed in the menopause

group. When the neck circumference was increased by 1 cm, the odds ratio for metabolic syndrome increased to 2.022, and when the neck circumference was 33.0 cm as a standard, the odds ratio of the longer group increased to 7.287. In the study by An & Park (2022), the odds ratio between metabolic syndrome and neck circumference was 2.919 (95% CI, 2.269–3.757) in women with neck circumference longer than 33.0 cm, which was lower than that in this study. This difference is affected by the control variable.

Table 6. Odd's ratio for metabolic syndrome by neck circumference by menopause status

Menopausal stages	Variable	Adjusted OR(95% CI) [1)]	P-value
Pre-menopausal group (n=1745)	NC (cm)[2)]	2.176(1.972-2.401)	<0.001***
	≥33.5 cm NC	14.571(10.392-20.431)	<0.001***
Post-menopausal group(n=1806)	NC (cm)	2.022(1.843-2.219)	<0.001***
	≥33.0 cm NC	7.287(5.635-9.422)	<0.001***

[1)]Adjusted for significance in demographic characteristics and health-related factors.

[2)]The odds ratio at increase of 1 cm neck circumference

***P<0.001

4. CONCLUSION AND FUTURE WORK

Menopause is an important variables that contributes to changes in health and nutritional intake in a woman's life. The incidence of metabolic syndrome is rapidly increasing in Korea; therefore, many studies are being conducted. A limitation of this study is that the data from the National Health and Nutrition Examination Survey used in this study are cross-sectional studies, making it difficult to explain causal relationships. In addition, because the nutrition survey is a 1 day 24-hour recall method, it is difficult to view it as a daily intake. In addition, this study did not consider pathological conditions that could change the neck circumference. However, because this is large-scale data that can be representative, the following significant results were confirmed: First, there was no relationship between neck circumference and energy and energy nutrient intake, which are known to be related to metabolic syndrome in middle-aged women. Second, there was no difference in neck circumference due to menopause; however, the prevalence of metabolic syndrome increased, and there was a clear correlation between neck circumference and metabolic syndrome diagnostic components. Third, neck circumference has the potential as an index for the risk assessment of metabolic syndrome in middle-aged women. However, since there is a difference in standard neck circumference depending on menopause status, this should be reflected in future standards.

Follow-up studies, complement the limitations of this study, and research on neck circumference as a diagnostic criterion for metabolic syndrome by life cycle should be conducted in multiple aspects. In addition, internationally and domestically recognized guidelines should be prepared for the clinical use of neck circumference.

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