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ANTHROPOMETRICS AND METABOLIC SYNDROME IN HEALTHY KOREAN ADULTS: A 7-YEAR LONGITUDINAL STUDY

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ABSTRACT

Background and Objective

Of anthropometric measurements, body-mass index (BMI) and waist circumference (WC) have been used as determinants of obesity. The waist-to-height (WtHR) is simple, easy to calculate, and easy to apply to various age groups, but its wide use is limited because of a lack of studies. This 7-year longitudinal study was performed to identify the usefulness of WtHR compared with BMI and WC for predicting metabolic syndrome (MetS).

Material and Methods

Of 22,379 people who visited a health screening center over the course of one year, 5,802 men and 3,303 women who consented to the study and had no MetS were followed for 7 years to evaluate the development of MetS. The National Cholesterol Education Program Adult Treatment Panel III criteria were adapted to diagnose MetS. Height, weight, and WC were measured, and traditional reference values for BMI (23 kg/m^2), WC (men 90 cm, women 80 cm), and WtHR (0.5) were calculated; in addition, other cut-off values were calculated by analyzing receiver operating characteristic (ROC) curves. The relative risk (RR) of developing MetS was calculated by Cox proportional-hazards regression using the cut-off values from traditional obesity references and ROC analysis.

Results

Ultimately, 1,724 (29.7%) men and 627(19.0%) women were diagnosed with MetS. Among men with BMI <23 and >23, 15.1% and 37.0% developed MetS, respectively, resulting in an RR of 0.393 (95% confidence interval [CI] 0.349-0.443, p <0.001). Among men with WC <90 cm and >90 cm, 25.5% and 51.4% developed MetS, respectively, resulting in an RR of 0.442 (95% CI 0.389–0.502, p <0.001). WtHR had the lowest RR at 0.388 (95% CI 0.350–0.430, p <0.001). Among women with BMI<23 and >23, 10.2% and 35.5%

developed MetS, respectively, resulting in an RR of 0.290 (95% CI 0.249–0.319, $p < 0.001$). Among women with WC <80 cm and >80 cm, 13.6% and 39.2% developed MetS, respectively, resulting in an RR of 0.346 (95% CI 0.295–0.407, $p < 0.001$). Among women with WtHR <0.5 and > 0.5, 12.7% and 38.2% developed MetS, respectively, resulting in an RR of 0.341 (95% CI 0.290–0.401, $p < 0.001$).

Conclusion

The results of this study on middle-aged men and women show that a WtHR of 0.5, along with BMI and WC, has diagnostic value in predicting MetS. More studies with people of various ethnicities and ages should be conducted, and WtHR should be recognized as a potential health-management tool.

Keywords: *Body mass index, metabolic syndrome, waist circumference, waist-to-height ratio*

Anthropometric, health-related factors have been applied for various purposes. In the representative case of infants, the arm or head can be measured to identify growth status, and skinfold thickness and body circumference can be measured to indirectly calculate body fat mass.[1–4] These methods have been used in clinical setting for many years because they are simple, do not require complicated expensive examination equipment, and are able to be applied inexpensively in any location.[5] Anthropometrics has been used widely to diagnose obesity using body-mass index (BMI), waist circumference (WC), and the waist-to-hip ratio (WtHR).[6] In addition to simply measuring size, anthropometric and health-related studies have been conducted over the decades to predict disease. The seriousness of obesity has been highlighted by studies reporting that obesity is strongly associated with BMI, WC, cardiovascular disease, cancer, and various other diseases.[7,8] In addition, to diagnose metabolic syndrome (MetS), WC is measured along with blood pressure, blood glucose, and dyslipidemia.[9,10]

BMI, the most widely used parameter for obesity diagnosis, is derived from weight and height alone and is calculated by dividing weight by height squared. Therefore, to know their BMI, people need to memorize this equation and not just know their height and weight.[11] A study has shown that the higher the recognition of health, the better the health management.[12] However, it is difficult to memorize the formula for and know one's own BMI.

WC is considered a good index that shows the severity of abdominal obesity.[13] Abdominal obesity is considered a priority control index because it has a more negative impact on metabolic diseases, such as cardiovascular disease and diabetes, than does obesity.[14] Thus, abdominal obesity is a risk factor for MetS; however, WC naturally increases with height during growth.[15] Currently, WC is controversial because it does not consider height and applies a simple absolute value to all people. In this regard, BMI is superior to WC, but it is limited because it cannot reflect abdominal obesity.

Thus, many researchers have suggested the WtHR, which considers height and abdominal obesity, is easy to calculate, and can be applied to various age groups. Previous studies have shown that WtHR is very useful tool and have suggested 0.5 (weight in kg/height in cm) as a reference value.[16] The 0.5 reference value requires no calculations, has no related costs, is easy to apply to various ethnicities and both sexes, and is superior to BMI for predicting cardiovascular risk.[16,17] Also, WtHR is considered superior to WC for diagnosing MetS, in both adults and adolescents.[18,19] However, WtHR has only been studied for 20 years and has not been addressed by as many research papers as have BMI and WC. Furthermore, most studies of WtHR have been cross-sectional, limiting the description of causality.

This study analyzed the differences among BMI, WC, and WtHR, which are representative anthropometric measures. In particular, the usefulness of WtHR for predicting MetS was evaluated by a longitudinal research design. In, Korea, the incidence of MetS is rapidly increasing owing to low physical activity and high calorie intake secondary to rapid economic development and changing industry; furthermore, the incidence of MetS is similar in adult men and women, adolescents, and elderly individuals.[20] Thus, the purpose of this study is to analyze the difference in relative risk (RR) of MetS according to BMI, WC, and WtHR among relatively healthy men and women aged 40-50 years who were followed up for 7 years and to provide optimal values for each parameter by analyzing receiver operating characteristic (ROC) curves. Identifying the scientific character and usefulness of WtHR would be beneficial to health management because people could easily recognize their degree of abdominal obesity.

METHODS

PARTICIPANTS AND PROCEDURE

Participants in this study were visitors to a health examination center at a hospital in Seoul. Of 22,379 visitors from January to December in 2006, those who consented to use their examination result for research purposes were included in this study. Men and women aged 40 to 59 years without MetS who visited the health examination center more than 3 times (once a year) until 2012 were included in this study. Individuals younger than 40 years and older than 59 years and those who missed or refused part of the examination because of poor physical or psychological conditions or health problems were excluded from the study. Finally, 5,802 men and 3,303 women were analyzed. The time to MetS development (over 7 years) was recorded in months, and the MetS-free time was recorded as the time, in months, from the first visit until December, 2012.

During visits to the health examination center, past and current medical history, drinking, smoking, exercise habits, and socioeconomic status including family history were surveyed using a questionnaire. Before the examination, the participant was asked to fast for 8 hours except for adequate water intake. For the examination, a light gown and slippers were provided by the corresponding centre, and the examination began at 8 am. The examinations included blood pressure measurement, blood draw, WC, height, and weight, followed by resting examinations. As all procedures were conducted over the course of one day, the order of examinations was set to minimize the interactions among the examinations.

Metabolic Syndrome

The National Cholesterol Education Program Adult Treatment Panel III was used as the MetS criteria applied in this study, and a WC ≥90 cm for men and ≥80 cm for women, which is the WHO Asia Pacific standard, was used as the criteria for abdominal obesity. The following criteria were also used: triglyceride (TG) ≥150 mg/dl, high-density lipoprotein cholesterol (HDL-C) <40 mg/dl for men and <50 mg/dl for women, blood pressure ≥130 mmHg (systolic) or ≥85 mmHg (diastolic), and fasting glucose for ≥100 mg/dl. Individuals with hypertension and diabetes and those taking drugs for these conditions were regarded as having a risk factor. Individuals with more than 3 (of 5 total) risk factors were classified into the disease group.[9]

Anthropometrics, Weight, Height, Waist Circumference

An electronic scale was used for weight and height. The scale was calibrated every day before the morning examination and was installed using inclinometer. The scale was set on rigid ground. To measure height, the subject was asked to stand naturally. WC was measured by hand using a tape ruler. The tape ruler was placed horizontally on the skin at the level of the navel. Moderate tension was used, but the skin was not pressed. WC was measured twice, and the lower value was used. Remeasurement was conducted for differences greater than 0.5 cm.

Statistical Analysis

SPSS (Version 20.0, SPSS Inc, Chicago, USA) and MedCalc (version 16.4.3, MedCalc, Ostend, Belgium) software were used for data analysis. All continuous variables are expressed as means and standard deviations and are given by sex. The independent t-test was conducted to examine significant differences according to the BMI, WC, and WtHR criteria, and one-way ANOVA with post-hoc Bonferroni was conducted to examine differences among these 3 criteria. ROC curves were generated to identify optimum cut-off values. Pearson's analysis was conducted to identify correlations between MetS risk factors and BMI, WC, and WtHR. Cox proportional-hazards regression was conducted to calculate RRs by adapting traditional WC criteria (90 cm for men and 80 cm for women) in model 1 and by adapting the cut-off values generated by ROC curves in model 2. Based on diagnostic values, the lower value group was set as low and the obesity value group was set as high. Only the high group was expressed in Table 4. For optimum cut-off values, the values that were automatically provided by the program were applied. The models were adjusted for age, physical activity, low-density lipoprotein cholesterol (LDL-C), total cholesterol (TC), alcohol, and smoking. Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 compares the participants' general characteristics based on the standard reference values of BMI, WC, and WtHR.

TABLE 1 Baseline of Participants

	BMI (23kg/m^2)		WC (men: 90 cm, women: 80 cm)		WtHR (0.5)	
	Low	High	Low	High	Low	High
Men(n=5,802)	33.1%	66.9%	83.7%	16.3%	53.7%	46.3%
Age, years	48.4±5.0	48.3±5.0	48.3±5.0	48.7±5.0*	47.9±4.9‡	48.9±5.0*,‡,§
Height, cm	170.8±5.6	170.3±5.6*	170.0±5.5†	172.8±5.7*,†	171.5±5.6‡,§	169.3±5.4*,‡,§
Weight, kg	62.8±5.4	73.3±6.6*	67.9±6.7†	79.5±6.7*,†	66.8±7.1‡,§	73.4±7.4*,‡,§
BMI, kg/m^2	21.5±1.2	25.2±1.6*	23.5±2.0†	26.6±1.9*,†	22.7±1.8‡,§	25.6±1.8*,‡,§
WC, cm	79.1±5.0	86.8±5.1*	82.4±4.9†	93.4±3.3*,†	80.3±4.7‡,§	88.8±4.3*,‡,§
WtHR	0.46±0.03	0.51±0.03*	0.48±0.02†	0.54±0.02*	0.47±0.02‡,§	0.52±0.02*
Body fat, %	10.0±2.3	15.0±3.2*	12.5±3.1†	17.8±3.5*,†	11.3±2.8‡,§	15.7±3.3*,‡,§
SBP, mmHg	118.4±13.0	121.5±12.7*	120.3±13.2	121.0±11.2,†	119.5±13.3	121.5±12.4*,‡,§
DBP, mmHg	74.2±8.7	76.2±8.5*	75.5±8.8	75.8±7.7	74.8±8.9	76.4±8.3*
TC, mg/dl	188.4±30.5	194.9±31.1*	192.1±31.0	195.8±31.4*,†	189.8±30.9	196.1±31.0*,§
HDL-C, mg/dl	55.6±12.4	51.5±10.9*	53.2±11.8	51.1±10.2*,†	54.5±12.2	50.9±10.4*,‡,§
LDL-C, mg/dl	120.0±27.3	127.8±27.7*	124.4±27.7	129.4±27.8*,†	121.9±27.7	129.1±27.5*,§
TG, mg/dl	113.0±56.6	129.9±67*	124.6±65.7†	122.8±56.0	117.3±63.2§	132.4±64.6*
Glucose, mg/dl	95.9±16.7	97±16.2*	96.9±16.8†	95.2±14.3*	96.4±16.6§	96.9±16.1
Women(n=3,303)	65.3%	34.7%	79.0%	21.0%	75.5%	24.5%
Age, years	47.5±4.7	48.8±4.8*	47.6±4.7†	49.5±4.8*	47.4±4.6‡	49.8±4.9*
Height, cm	159.1±4.7	157.7±4.9*	158.5±4.7†	158.9±5.1*,†	159.1±4.6‡,§	156.9±5.0*,‡,§
Weight, kg	53.1±4.4	61.8±5.4*	54.5±5.2	62.3±6.3*,†	54.7±5.4‡,§	60.6±6.7*,§
BMI, kg/m^2	21.0±1.4	24.8±1.7*	21.7±1.9	24.7±2.4*,†	21.6±1.8	24.6±2.3*,‡
Waist-C, cm	71.9±5.3	79.7±6.1*	72.0±4.6†	84.4±4.2*	71.9±4.6‡,§	83.2±4.8*
Waist-to-height ratio	0.45±0.03	0.51±0.04*	0.45±0.03†	0.53±0.03*,†	0.45±0.03‡	0.53±0.03*,§

	BMI (23kg/m^2)		WC (men: 90 cm, women: 80 cm)		WtHR (0.5)	
	Low	High	Low	High	Low	High
Body fat, %	12.4±2.6	18.3±3.4*	13.3±3.2	18.6±4.1*,†	13.2±3.2	18.2±4.0*b
SBP, mmHg	110.2±12.8	115.2±13.8*	111.1±13.2	115.2±13.5*	110.8±13.1	115.5±13.6*
DBP, mmHg	69.7±8.4	72.6±9.0*	70.2±8.6	72.8±8.9*	70.1±8.7	72.6±8.8*
TC, mg/dl	188.2±32.2	197.1±34.5*	189±32.9	199.6±33.5*	188.5±32.9	199.7±32.9*
HDL-C, mg/dl	63.4±13.6	59.7±12.3*	62.8±13.6	59.4±11.5*	63.0±13.6	59.5±11.7*
LDL-C, mg/dl	115.8±27.7	126.1±30.1*	116.9±28.4	128.5±29.6*	116.5±28.4	128.3±29*
TG, mg/dl	86.8±39.0	97.2±46.1*	88.2±41.8	98.7±41.1*	87.3±40.9	100.0±43.3*
Glucose, mg/dl	90.0±9.2	91.7±9.7*	90.2±9.1	91.9±10.3*	90.2±9.2	91.8±10.1*

$^{*}p<0.05$; †, BMI vs. WC; ‡, BMI vs. WtHR; §, WC vs. WtHR
BMI = body-mass index; DBP = diastolic blood pressure; HDL-C = high density lipoprotein cholesterol; LDL-C = low density lipoprotein cholesterol; SBP = systolic blood pressure; TC = total cholesterol; TG = triglyceride; WC = waist circumference; WtHR = waist-to-height ratio.

TABLE 2 Pearson's Correlation of Metabolic Syndrome Risk Factors and Body Mass Index, Waist Circumference, and Waist-To-Height Ratio

	SBP	DBP	Glucose	TG	HDL-C
Men					
BMI	0.110**	0.118**	0.025	0.131**	-0.188**
WC	0.108**	0.102**	0.030*	0.135**	-0.208**
WtHR	0.139**	0.127**	0.027*	0.154**	-0.208**
Women					
BMI	0.242**	0.198**	0.119**	0.152**	-0.181**
WC	0.196**	0.177**	0.121**	0.172**	-0.189**
WtHR	0.210**	0.188**	0.117**	0.187**	-0.181**

$^{*}p<0.05$, $^{**}p<0.01$
BMI = body-mass index; DBP = diastolic blood pressure; HDL-C = high density lipoprotein cholesterol; HDL-C = high density lipoprotein cholesterol; SBP = systolic blood pressure; TG = triglyceride; WC = waist circumference; WtHR = waist-to-height ratio.

Pearson's Correlation of MetS Risk Factors and Anthropometric Measurements

Table 2 shows the analysis of the correlation between BMI, WC, WtHR, and MetS risk factors. In men, the highest correlations were for SBP ($r = 0.139$), diastolic blood pressure (DBP) ($r = 0.127$), TG ($r = 0.154$), and HDL-C ($r = -0.208$) were found in WtHR ($p < 0.01$). Only glucose and BMI showed no correlation ($p > 0.05$), but WC and glucose were correlated ($r = 0.030$) ($p < 0.05$). In women, BMI had the highest R values for SBP (r = 0.242) and DBP (r = 0.198), WC had the highest for glucose (r = 0.121) and HDL-C (r = -0.189), and WtHR had the highest for TG (r = 0.187); the results for women were significantly different than those for men ($p < 0.05$).

ROC Curves According to BMI, Waist Circumference, and WtHR

Table 3 shows the optimum cut-off values related to MetS incidence according to BMI, WC, and WtHR after a 7-year follow-up. The optimum BMI in men was 24.8 (AUC 0.701, 95% confidence interval [CI] 0.690–0.713, p = 0.006) which is higher than the existing reference value of 23.0. The optimum cut-off of WC in men was 87.0 (AUC 0.709, 95% CI 0.697–0.720, p = 0.009), which is lower than the reference value of 90 cm. The WtHR cut-off in men was 0.49 (AUC 0.702, 95% CI 0.679-0.713, p = 0.008), which is similar to the recommended value of 0.5. The optimum BMI in women was 22.6 (AUC 0.750, 95% CI 0.735-0.765, p = 0.012) and WC was 78.0 (AUC 0.746, 95% CI 0.730-0.760, p = 0.010,) which are slightly lower than the recommended values, and WtHR was 0.47 (AUC 0.742, 95% CI 0.727–0.757, p = 0.009), which is similar to the existing reference value of 0.5.

Relative Risk According to BMI, WC, and WtHR

A total of 1,724 men (29.7%) and 627 women (19.0%) were evaluated for MetS over 7 years. Table 4 shows the 7-year MetS relative risk (RR) according to anthropometric measurements calculated in this longitudinal study. In these calculations, because the high group was set to the reference value, the RR of the low group decreased. Model 1 applied the traditional standards, and model 2 applied the cut-off values generated ROC analysis. In model 1, 15.1% of men with low BMI and 37.0% of men with high BMI developed MetS, and the RR was 0.393 (95% CI 0.349-0.443, $p < 0.001$). In model 1, 25.5% of men with WC >90 cm and 51.4% of men with WC >90 cm developed MetS, and the RR was 0.442 (95% CI 0.389-0.502, $p < 0.001$). In model 1, WtHR showed an RR of 0.388 (95% CI 0.350-0.430, $p < 0.001$), which was the lowest and was similar to that in model 2. In model 2, the RRs of BMI, WC, and WtHR were 0.367, 0.363, and 0.339, respectively, which were similar but lower than the RRs in model 1; in addition, even though it was a small difference, WtHR in model 2 had the lowest RR value ($p < 0.05$).

TABLE 3 Receiver Operating Characteristic Curve Analysis According To Body Mass Index, Waist Circumference, and Waist-To-Height Ratio

Variables	Cut-off	AUC(95% CI)	Sensitivity	Specificity	*p*
Men					
BMI	24.8	0.701(0.690-0.713)	55.5	73.4	0.006**
WC	87.0	0.709(0.697-0.720)	65.1	66.9	0.009**
WtHR	0.49	0.702(0.679-0.713)	69.7	58.6	0.008**
Women					
BMI	22.6	0.750(0.735-0.765)	70.8	67.1	0.012*
WC	78.0	0.746(0.730-0.760)	77.7	59.1	0.010*
WtHR	0.47	0.742(0.727-0.757)	72.1	63.6	0.009**

**p<0.05, **p<0.01*
AUC = area under curve; BMI = body mass index; CI = confidence interval; WtHR = waist-to-height ratio; WC = waist circumference.

TABLE 4 Relative Risk According to Body Mass Index, Waist Circumference, and Waist-To-Height Ratio

	Incidence, % Low / High	Model 1 RR(95% CI)	*p*	Incidence, % Low / High	Model 2 RR(95% CI)	*p*
Men	Total 29.7%					
BMI	15.1/37.0	0.393(0.349-0.443)	<0.001***	20.2/46.6	0.367(0.334-0.404)	<0.001***
WC	25.5/51.4	0.442(0.389-0.502)	<0.001***	18.1/45.4	0.363(0.307-0.375)	<0.001***
WtHR	18.6/42.6	0.388(0.350-0.430)	<0.001***	16.5/40.0	0.339(0.325-0.405)	<0.001***
Women	Total 19.0%					
BMI	10.2/35.5	0.290(0.249-0.319)	<0.001***	9.2/33.2	0.263(0.221-0.313)	<0.001***
WC	13.6/39.2	0.346(0.295-0.407)	<0.001***	8.1/30.8	0.292(0.243-0.352)	<0.001***
WtHR	12.7/38.2	0.341(0.290-0.401)	<0.001***	8.8/30.8	0.266(0.219-0.321)	<0.001***

Model 1, Traditional cut off; adjusted age, LDL-C, TC, alcohol, smoking, exercise
Model 2, ROC curve cut off; adjusted age, LDL-C, TC, alcohol, smoking, exercise
****p<0.001*
BMI = body mass index; CI = confidence interval; LDL-C = low-density lipoprotein cholesterol; RR = relative risk; TC = total cholesterol; WtHR = waist-to-height ratio; WC = waist circumference.

In model 1, 10.2% of women with low BMI and 35.5% of women with high BMI developed MetS, and the RR was 0.290 (95% CI 0.249-0.319, p <0.001). In model 1, 13.6% of women with WC <80 cm and 39.2% of women with WC >80 cm developed MetS, and the RR was 0.346 (95% CI 0.295–0.407, p <0.001). In model 1,12.7% of women with WtHR <0.5 and 38.2% of women with WtHR >0.5 developed MetS, and the RR was 0.341 (95% CI 0.290–0.401, p <0.001). For women, BMI in model 2 showed the lowest RR, which was different than for men.

DISCUSSION

This study is meaningful because it had a relatively large sample size and investigated the longitudinal relationship between WtHR and MetS over 7 years. Many studies have evaluated the risk factors of cardiovascular disease, such as hypertension, diabetes, and hyperlipidemia, but few studies have compared WC, BMI, and WtHR with regard to the development of MetS.

As described earlier, BMI involves a complicated calculation, and WC is an absolute value that does not consider height despite emphasizing abdominal obesity, limiting its application in children, adolescents, and the elderly. Nevertheless, BMI is the most widely used diagnostic tool worldwide and is very useful in health care guideline because it contributes to disease prediction.

The most important result of this study is in Table 4, which shows very good RRs of BMI, WC, and WtHR in both men and women; however, there were some small and notable differences. In both models, the lowest RR for men was with WtHR, but for women, it was with BMI. Previous studies of WtHR over the past 20 years report that WtHR is more useful than BMI in terms of disease association. Savva et al. reported that WC and WtHR are more useful than BMI in predicting the risk factors of cardiovascular disease such as TC, TG, HDL-C, LDL-C, SBP, and DBP in children.[18] A study conducted in Asia also showed a better predictability of WtHR compared with %fat, waist-to-hip ratio, and BMI.[21] A study of adults older than 20 years showed that WtHR is better than BMI as an obesity measurement tool for diabetes, hypertension, and hyperlipidemia.[22] These results are similar to the results for men, but not for women, in the present study. We assume that this difference is because our study adapted 23 kg/m^2 as the adult criteria for BMI (according to WHO guidelines), whereas previous studies use 25 kg/m^2.

In our study, the cut-off values for WC and WtHR in men, and the cut-off values for BMI, WC, and WtHR in women, were slightly lower than the traditionally used obesity criteria; for men, however, the cut-off value of BMI was 24.8. For WtHR, we determined cut-off values of 0.49 and 0.47 for men and women, respectively. According to a study of optimal cut-off values by Lin et al, the WtHR cut-offs for cardiovascular risk factors were 0.48–0.50 and 0.45–0.48 in men and women, respectively, which is similar to the results of the present study, indicating no obvious difference between this longitudinal study and the cross-sectional study.[23] In a systematic review journal, 0.5 was suggested as the optimal value.[16] In this study, model 1 applied a value of 0.5 and model 2 used a cut-off value determined by ROC curve analysis; there was no significant difference between the two, indicating that a value of 0.5 value is optimal in terms of convenience of calculation and familiarity.

Previous studies of anthropometric measurements in children have suggested clear pediatric reference values for BMI and WC based on adult criteria.[18,21,24] In the present study, however, we did not believe it was proper to apply these values. For example, in the obesity criteria for children, the 85th percentile is overweight and the 95th percentile is obese, but these are relative values, not absolute values, and can vary according to race, residence, and population.[25] Also, studies of WtHR were usually conducted in Asian populations.[21,23,26,27] This indicates that WHO guidelines should apply different BMI and WC values to different races. However, using different criteria for each race lowers the reliability and complicates guidelines. The same WtHR values can be applied in guidelines, regardless of race. Considering the above issues, Ashwell and Hsieh summarized the following advantages of WtHR: WtHR is more sensitive and easy to calculate than BMI, and a WtHR value of 0.5 can be applied regardless of sex, race, or age.[17]

Anthropometric measurements, which have been used for years, are applied for two primary purposes: one is to measure the arm or head circumference in newborn infants to monitor growth development[28] and another is to evaluate obesity. The representative anthropometric parameter for obesity has been BMI, and WC has been measured to describe the importance of abdominal obesity. In addition, the American College of Sports Medicine has measured the circumference of various areas and used the skinfold method in an attempt to predict body fat mass.[4]

In the past, anthropometrics was usually measured for obesity, and higher values (or very low values) were interpreted negatively. However, some anthropometric measurements used in recent decades have an inverse relationship with disease; for example, larger thigh and calf measurements are considered healthy. According to Heitmann et al., thigh circumference <60 cm was associated with a higher mortality in 2816 people with a mean follow-up of 12.5 years[29] because smaller thigh circumference implies a greater possibility of sarcopenia. In sum, smaller abdominal circumference and larger thigh circumference are considered healthy. One limitation of anthropometric measurements is the inability to distinguish between fat and muscle mass in the case of large thigh or abdominal circumference. Also, anthropometrics is unable to identify body composition because it is difficult to analyze components such as bone, muscle, and fat using surface measurements. Individuals with normal growth grow in height until the adolescent period and have increases in muscle mass until their early 30s.[30] After then, muscle mass tends to decrease despite a lack of change in height; therefore, the ratio of muscle and fat corresponding to body composition, can theoretically change even though the individual has maintained the same BMI for 30 years. WC measures abdominal obesity, and the increase in height in the growth period naturally accompanies a horizontal increase, that is, an increase in WC.[15] Thus, simple WC has limitations. It has the limitation of all anthropometric measurements in that it is unable to measure muscle and fat mass; WtHR is the most useful measurement for this. Solving this problem requires dual energy X-ray absorptiometry, computerized tomography, and magnetic resonance imaging, which have the limitations of being expensive, requiring a specialist to perform, and requiring a doctor's diagnosis.[5]

One limitation of this study is its 7-year follow-up (mean 4.5 years) despite it being a longitudinal study. Furthermore, elderly people, who have a rapid increase in cardiovascular disease incidence, were excluded because this study focused on men and women in their 40s and 50s with the most socioeconomic activity. In addition, as previously mentioned, children and young adults were excluded from this study. Finally, because the participants were not subjected to annual measurements, we were unable to analyze the change in MetS among people who were obese during the first year and then lost weight and were categorized in the normal group. Similarly, the results of this study are unable reflect changes in the development of MetS among participants in whom the condition was resolved by diet and exercise. There is also one limitation inherent to WtHR: Although WtHR is easy to use for individuals who are familiar with cm and kg units, it might be difficult to calculate for those who usually measure weight in pounds and length in inches or feet. Future studies of anthropometric parameters should consider these points.

Furthermore, males have a higher WtHR, BMI, body size, and prevalence of metabolic syndrome than females. It is assumed that cultural characteristics and higher social and economic activity of males compared to females may contribute to a low health status, but this study could not accurately analyze this association. Future studies are needed to more accurately compare males and females in this regard.

CONCLUSION

On the basis of the results of Pearson's correlation, ROC curve, and RR analysis, WtHR is the optimal obesity scale because it shows no significant differences or a better performance in predicting MetS and risk factors compared with BMI and WC. WtHR is easy to calculate and remember and can be a marker of abdominal obesity.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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