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ORIGINAL RESEARCH

The relationship between waist-to-height ratio, health-related physical fitness, and metabolic disease factors in middle-aged men in South Korea

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Abstract

Background: The purpose of this study was to analyze the correlation between waist-to-height ratio (WHtR), health-related physical fitness, and metabolic disease risk factors in middle-aged men and to evaluate the impact of WHtR on these variables to validate its utility as an obesity index. **Methods**: A total of 1012 middle-aged men aged 30 to 60 years (205 in their 30s, 408 in their 40s, 319 in their 50s and 80 in their 60s) were selected as participants and classified into high and low WHtR groups based on a threshold of 0.5. The study variables included physical characteristics, health-related physical fitness (muscular strength, muscular endurance, flexibility and cardiorespiratory endurance), and metabolic disease factors (diastolic blood pressure, triglycerides, hemoglobin A1c, Triglyceride/High-Density Lipoprotein-Chlesterol ratio (TG/HDL) and Low-Density Lipoprotein-Cholesterol (LDL-C)). Group comparisons and multiple regression analyses were performed. **Results**: The results showed that the high WHtR group had significantly lower muscular endurance, flexibility and cardiorespiratory endurance but higher muscular strength than the low WHtR group. Additionally, the high WHtR group exhibited significantly higher diastolic blood pressure, triglycerides, glycated hemoglobin, and TG/HDL ratio than the low WHtR group ($p < 0.05$). Multiple regression analysis indicated that WHtR was significantly negatively correlated with cardiorespiratory endurance and muscular endurance, while it showed a significant positive correlation with TG/HDL ratio, glycated hemoglobin, diastolic blood pressure and LDL-C ($p < 0.05$). **Conclusions**: These findings suggest that WHtR is closely related to decreased physical fitness and increased metabolic disease risk in middle-aged men and can serve as a useful index for predicting obesity-related health risks.

Keywords

WHtR; Middle-aged men; Physical fitness; Metabolic dieases factor

1. Introduction

Globally, metabolic diseases and obesity are known to be closely related. A decline in physical activity levels and an increase in sedentary lifestyles can lead to a rise in obesity prevalence. According to an analysis by the Korea Disease Control and Prevention Agency (KDCA), the percentage of adults engaging in moderate-intensity or higher physical activity decreased from 24.7% in 2019 to 19.8% in 2020 and 19.7% in 2021. Additionally, the obesity prevalence among adults aged 19 and older in Korea increased from 30.9% in 2014 to 33.8% in 2019, peaking at 38.3% in 2020, and slightly declining to 37.1% in 2021 [1, 2].

Previous studies have reported that obesity significantly increases the risk of various diseases and complications while decreasing physical fitness, which is essential for maintaining a healthy lifestyle [3–5]. Obesity rates are also reported to increase with age, highlighting the importance of continuous monitoring and management as individuals grow older [3, 6]. From the age of 50, muscle strength decreases by approximately 15% every decade, and individuals with obesity tend to have significantly lower muscle strength, cardiorespiratory endurance, and flexibility compared to non-obese individuals as they age [7–10]. This decline in health-related physical fitness can further accelerate reductions in physical activity, insulin resistance and obesity. Therefore, analyzing the correlation between obesity indices and refining them is crucial.

Common methods for assessing obesity include Body Mass Index (BMI), Waist Circumference (WC) and Waist-to-Hip Ratio (WHR). However, BMI lacks the ability to differentiate between fat and muscle mass and has limitations in identifying differences in body fat distribution. For instance, even with the same BMI, a higher WC a key indicator of abdominal obesity is associated with an increased risk of various obesity-related diseases and complications [11, 12]. Abdominal obesity is a stronger predictor of metabolic complications than overall obesity, making it challenging to rely solely on BMI [13]. WHR, while simple to measure and closely related to visceral fat and coronary artery disease risk factors, can overestimate or underestimate cardiovascular disease risk depending on an individual's height [14]. Additionally, changes in body weight can affect both waist and hip circumference, limiting WHR's ability to accurately reflect weight changes [15].

Due to these limitations, some studies have suggested the Waist-to-Height Ratio (WHtR) as an alternative indicator of abdominal obesity [14, 16]. Height is inversely associated with cardiovascular disease risk, and adjusting WC by height has been reported to better predict cardiovascular disease risk [17]. In addition, the highest rates of obesity in middle age are reported for men in Korea, with 51.4% in the 30–39 age group, 57.7% in the 40–49 age group and 41.9% in the 50–59 age group [1]. While various studies in Korea have examined WHtR, few have analyzed its correlation with physical fitness levels. Therefore, analyzing the relationship between WHtR, health-related physical fitness, and metabolic disease factors is necessary to provide foundational data for predicting fitness levels and metabolic diseases using WHtR.

2. Methods

2.1 Participants

This study targeted adult men aged 35 to 64 who underwent health examinations at the National Fitness Center from 2022 to 2024, when all social distancing policies due to the COVID-19 pandemic were lifted. Individuals with missing essential data or other diseases and conditions that could confound the study results were excluded. The final study sample included 1012 participants, comprising 205 men in their 30s, 408 in their 40s, 319 in their 50s and 80 in their 60s. The study data were retrospectively reviewed and collected through examination records after selecting the study participants.

2.2 Analysis variables

2.2.1 Anthropometric measurements

Anthropometric measurements were taken with participants wearing light clothing. Body weight and height were measured to one decimal place in kilograms (kg) and centimeters (cm), respectively. Body composition, including muscle mass, body fat mass and body fat percentage, was assessed using bioelectrical impedance analysis (InBody 770, Seoul, Korea).

2.2.2 Physical fitness factors

Physical fitness factors were assessed using standardized tests conducted by the National Fitness Center of Korea, including Sit-up, Push-up, Sit and reach, Handgrip strength, Sidestep and Vertical jumps. In addition, cardiorespiratory endurance and muscle strength were evaluated through respiratory gas analysis and isokinetic dynamometry, respectively. Maximal oxygen uptake (VO_2max) was measured using a respiratory gas analyzer (Cosmed, Quark CPET, Rome, Italy) with a breath-by-breath method on a treadmill, following the Bruce Protocol. Muscle strength of the knee joint was assessed using the Biodex System 3 dynamometer (Biodex Medical Systems, Biodex System 3, New York, NY, USA). To evaluate the functional capacity of knee flexors and extensors, participants performed three repetitions at an angular velocity of 60°/s. The peak torque relative to body weight (Peak Torque/BW) for flexors and extensors was used as the measurement index.

2.2.3 Metabolic disease factors

Metabolic disease factors included systolic and diastolic blood pressure, as well as blood biomarkers such as total cholesterol, HDL-C (High-Density Lipoprotein-Cholesterol), LDL-C (Low-Density Lipoprotein-Cholesterol), triglycerides and fasting glucose levels. Blood samples were collected after verifying an 8-hour fasting state during health examinations. A clinical pathologist collected 10 mL of blood from the brachial vein, which was stored at room temperature for approximately 15–30 minutes before being centrifuged at 3000 rpm for analysis.

2.3 Data analysis

All data were analyzed using SPSS software (version 25.0, IBM, Chicago, IL, USA). Means and standard deviations (SD) were calculated for all variables. The cutoff value for obesity using the waist-to-height ratio (WHtR) was set at 0.5, and differences in health-related physical fitness and metabolic disease factors between the high and low WHtR groups were analyzed using independent t-tests. Correlation analysis was performed to examine the relationships between WHtR, physical fitness and metabolic disease factors. Multiple regression analysis was conducted to determine the effects of WHtR on physical fitness and metabolic disease factors. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Physical characteristics of study subjects (WHtR)

Descriptive statistics for the physical characteristics of the study participants are presented in (Table 1). The mean age of the participants was 47.27 ± 8.43 years, with an average height of 170.89 ± 5.45 cm and body weight of 72.24 ± 9.89 kg. The mean lean body mass (LBM) was 55.06 ± 6.22 kg, and the average body fat percentage (BFP) was 23.41 ± 4.49%. The WHR was 0.92 ± 0.06, and the mean WC was 84.33 ± 7.42 cm.

3.2 Differences in physical characteristics based on waist-to-height ratio (WHtR)

The differences in physical characteristics according to the WHtR among the study participants are summarized in (Table 2). An analysis stratified by age groups revealed statistically significant differences in all categories between the higher WHtR group and the lower WHtR group. However, no significant difference in height was observed in the 30s and 60s age groups.

TABLE 1. Physical characteristics of study subjects (n = 1012).

	All (n = 1012)	30s (n = 205)	40s (n = 408)	50s (n = 319)	60s (n = 80)
Age (yr)	47.27 ± 8.43	34.84 ± 2.75	45.83 ± 2.73	54.04 ± 2.83	61.74 ± 1.69
Height (cm)	170.89 ± 5.45	173.60 ± 5.75	171.37 ± 4.89	169.32 ± 5.21	167.76 ± 4.73
Weight (kg)	72.24 ± 9.89	75.57 ± 11.34	72.79 ± 9.64	70.40 ± 8.77	68.18 ± 8.48
LBM (kg)	55.06 ± 6.22	57.50 ± 6.75	55.61 ± 6.01	53.61 ± 5.62	51.80 ± 5.34
BMI (kg/m^2)	21.11 ± 2.61	21.73 ± 2.94	21.22 ± 2.60	20.78 ± 2.37	20.30 ± 2.31
BFP (%)	23.41 ± 4.49	23.50 ± 4.78	23.19 ± 4.67	23.58 ± 4.05	23.58 ± 4.49
WHR	0.92 ± 0.06	0.88 ± 0.05	0.93 ± 0.04	0.94 ± 0.04	0.94 ± 0.11
WC (cm)	84.33 ± 7.42	85.26 ± 8.00	84.29 ± 7.43	83.97 ± 7.07	83.58 ± 7.11

LBM: Lean Body Mass; BMI: Body Mass Index; BFP: Body Fat Percentage; WHR: Waist Hip Ratio; WC: Waist Circumference.

TABLE 2. Age-specific differences in anthropometric characteristics according to WHtR.

	WHtR		*t*	*p*
	Lower	Upper		
Height (cm)				
All	171.64 ± 5.55	169.91 ± 5.17	5.068	<0.001
30s	174.01 ± 5.88	173.00 ± 5.55	1.239	0.217
40s	171.83 ± 5.03	170.71 ± 4.62	2.291	0.022
50s	170.45 ± 5.46	168.05 ± 4.61	4.271	<0.001
60s	168.65 ± 5.08	166.72 ± 4.11	1.841	0.069
Weight (kg)				
All	67.86 ± 7.75	77.90 ± 9.49	−18.036	<0.001
30s	70.07 ± 8.00	83.33 ± 10.83	−10.084	<0.001
40s	68.31 ± 7.65	79.12 ± 8.56	−13.370	<0.001
50s	66.61 ± 7.35	74.67 ± 8.29	−9.212	<0.001
60s	64.11 ± 7.15	72.90 ± 7.45	−5.379	<0.001
LBM (%)				
All	53.46 ± 5.54	57.13 ± 6.45	−9.528	<0.001
30s	55.33 ± 5.59	60.58 ± 7.08	−5.925	<0.001
40s	53.98 ± 5.40	57.90 ± 6.08	−6.711	<0.001
50s	52.19 ± 5.24	55.21 ± 5.62	−4.972	<0.001
60s	50.38 ± 5.08	53.45 ± 5.22	−2.662	0.009
BMI (kg/m^2)				
All	19.74 ± 1.89	22.88 ± 2.33	−23.661	<0.001
30s	20.10 ± 1.89	24.04 ± 2.60	−12.552	<0.001
40s	19.86 ± 1.94	23.15 ± 2.16	−16.108	<0.001
50s	19.52 ± 1.81	22.19 ± 2.12	−12.181	<0.001
60s	18.98 ± 1.74	21.84 ± 1.93	−6.994	<0.001
BFP (%)				
All	21.28 ± 3.98	26.16 ± 3.52	−20.290	<0.001
30s	20.99 ± 3.82	27.05 ± 3.62	−11.425	<0.001
40s	21.31 ± 4.47	25.86 ± 3.53	−11.495	<0.001
50s	21.43 ± 3.40	25.99 ± 3.31	−12.113	<0.001
60s	21.40 ± 3.73	26.12 ± 3.95	−5.496	<0.001

TABLE 2. Continued.

	WHtR		t	p
	Lower	Upper		
WHR				
All	0.90 ± 0.06	0.95 ± 0.04	−14.027	<0.001
30s	0.85 ± 0.04	0.91 ± 0.04	−9.669	<0.001
40s	0.91 ± 0.04	0.95 ± 0.04	−9.950	<0.001
50s	0.92 ± 0.03	0.97 ± 0.03	−11.613	<0.001
60s	0.91 ± 0.15	0.97 ± 0.04	−2.567	0.012
WC (cm)				
All	79.70 ± 4.98	90.32 ± 5.54	−32.202	<0.001
30s	80.44 ± 5.20	92.06 ± 6.11	−14.651	<0.001
40s	79.64 ± 4.91	90.86 ± 5.03	−22.521	<0.001
50s	79.43 ± 4.90	89.07 ± 5.48	−16.587	<0.001
60s	79.02 ± 4.97	88.86 ± 5.34	−8.525	<0.001

Data shown as Mean ± S.E. Lower: WHtR <0.5, Upper: WHtR >0.5.
LBM: Lean Body Mass; BMI: Body Mass Index; BFP: Body Fat Percentage; WHR: Waist-Hip Ratio; WC: Waist Circumference; WHtR: waist-to-height ratio.

3.3 Differences in physical fitness factors based on waist-to-height ratio (WHtR)

The differences in physical fitness factors according to the WHtR of the study participants are presented in (Table 3). An analysis of the differences in physical fitness factors between the higher WHtR group and the lower WHtR group revealed statistically significant differences across all physical fitness variables in the overall age groups. When analyzed by age group, the following significant differences were observed: In participants in their 30s, significant differences were found in Push-up, Vertical jump, VO_2max, Exercise duration and Extension strength per body weight (EXBW). In participants in their 40s, significant differences were observed in Sit-up, Push-up, Sit and reach, Handgrip strength, Vertical jump, VO_2max, Exercise duration, EXBW and Flexion strength per body weight (FXBW). In participants in their 50s, significant differences were identified in Sit-up, Push-up, Sit and reach, VO_2max, Exercise duration and FXBW. In participants in their 60s, a significant difference was observed only in Sit and reach.

3.4 Comparison of metabolic disease factors based on waist-to-height ratio (WHtR)

The differences in metabolic disease factors according to the WHtR of the study participants are presented in (Table 4). The analysis revealed statistically significant differences across the entire age group in Diastolic Blood Pressure (DBP), Triglycerides (TG), Hemoglobin A1C (HbA1c) and Triglyceride/High-Density Lipoprotein-Cholesterol ratio (TG/HDL-C ratio) between the higher WHtR group and the lower WHtR group. When analyzed by age group, the following significant differences were observed: in participants in their 30s, significant differences were found in all factors except HDL cholesterol. In participants in their 40s, significant differences were observed in Systolic Blood Pressure (SBP), DBP, TG, HbA1c and TG/HDL-C ratio. In participants in their 50s, significant differences were identified in DBP and HbA1c. In participants in their 60s, significant differences were observed in SBP and DBP.

3.5 Correlation analysis between WHtR and physical fitness factors

The results of the correlation analysis between the WHtR and physical fitness factors of the study participants are presented in (Table 5). The analysis revealed significant ($p < 0.05$) negative correlations between WHtR and most physical fitness factors, whereas significant ($p < 0.05$) positive correlations were observed with EXBW and FXBW. When analyzed by age group, the following significant correlations were identified: in participants in their 30s, significant ($p < 0.05$) negative correlations were found with Sit-up, Push-up, Vertical jump, Exercise duration, VO_2max and HRmax, while significant ($p < 0.05$) positive correlations were observed with Handgrip strength, EXBW and FXBW. In participants in their 40s, significant ($p < 0.05$) negative correlations were identified with Sit-up, Push-up, Sit and reach, Vertical jump, Exercise duration, VO_2max and HRmax, whereas significant ($p < 0.05$) positive correlations were observed with EXBW and FXBW. In participants in their 50s, significant ($p < 0.05$) negative correlations were found with Push-up, Sit and reach, and VO_2max, while significant ($p < 0.05$) positive correlations were observed with EXBW and FXBW. In participants in their 60s, significant ($p < 0.05$) negative correlations were observed with Push-up, Exercise duration, VO_2max and HRmax, while a significant ($p < 0.05$) positive correlation was identified with FXBW.

TABLE 3. Age-specific differences in physical fitness factors according to WHtR.

	WHtR		t	p
	Lower	Upper		
Sit-up (times)				
All	27.40 ± 7.62	25.25 ± 7.95	4.368	<0.001
30s	28.76 ± 7.20	27.48 ± 6.92	1.271	0.205
40s	28.17 ± 7.35	25.96 ± 7.96	2.886	0.004
50s	26.70 ± 7.60	24.47 ± 8.15	2.530	0.012
60s	22.02 ± 7.95	19.97 ± 6.78	1.230	0.222
Push-up (times)				
All	23.28 ± 11.07	19.93 ± 9.52	5.177	<0.001
30s	25.05 ± 11.51	22.01 ± 8.70	2.151	0.033
40s	24.48 ± 10.52	20.96 ± 9.70	3.435	0.001
50s	21.27 ± 10.76	18.58 ± 9.30	2.371	0.018
60s	19.60 ± 12.24	15.86 ± 9.64	1.500	0.138
Sit and reach (cm)				
All	6.74 ± 9.28	4.63 ± 8.89	3.654	<0.001
30s	4.37 ± 10.41	2.51 ± 8.10	1.442	0.151
40s	8.42 ± 7.92	5.83 ± 8.40	3.180	0.002
50s	7.19 ± 9.68	4.02 ± 9.73	2.909	0.004
60s	2.20 ± 8.78	6.46 ± 8.31	−2.221	0.029
Handgrip strength (kg)				
All	43.69 ± 8.58	44.91 ± 8.30	−2.269	0.023
30s	45.37 ± 7.56	46.13 ± 7.63	−0.706	0.481
40s	45.18 ± 8.45	47.22 ± 8.56	−2.392	0.017
50s	41.67 ± 9.00	42.86 ± 7.58	−1.266	0.207
60s	38.70 ± 6.73	39.87 ± 7.46	−0.736	0.464
Sidestep (times)				
All	32.44 ± 6.64	32.13 ± 5.85	0.776	0.438
30s	34.83 ± 6.13	34.56 ± 5.04	0.332	0.740
40s	33.65 ± 6.46	33.91 ± 5.19	−0.431	0.667
50s	30.51 ± 5.75	30.04 ± 5.53	0.750	0.454
60s	26.58 ± 6.91	26.86 ± 5.65	−0.199	0.843
Vertical jump (cm)				
All	35.27 ± 7.83	33.37 ± 7.06	4.010	<0.001
30s	39.21 ± 8.68	36.19 ± 6.64	2.822	0.005
40s	36.75 ± 6.67	35.39 ± 6.44	2.066	0.039
50s	32.05 ± 6.73	30.81 ± 6.36	1.689	0.092
60s	28.73 ± 6.52	28.02 ± 7.14	0.467	0.642
VO_2max (mL/kg/min)				
All	40.99 ± 6.10	38.09 ± 5.68	7.711	<0.001
30s	42.19 ± 5.96	39.17 ± 5.13	3.774	<0.001
40s	41.64 ± 6.29	39.11 ± 5.55	4.196	<0.001
50s	40.16 ± 5.81	37.06 ± 5.68	4.804	<0.001
60s	37.30 ± 4.72	35.18 ± 5.85	1.796	0.076

TABLE 3. Continued.

	WHtR		*t*	*p*
	Lower	Upper		
Exercise duration (s)				
All	549.47 ± 93.61	510.50 ± 88.85	6.713	<0.001
30s	579.38 ± 88.09	532.11 ± 77.43	3.978	<0.001
40s	552.05 ± 90.37	515.73 ± 81.26	4.167	<0.001
50s	539.59 ± 98.49	503.69 ± 94.45	3.312	0.001
60s	490.51 ± 72.89	464.62 ± 105.68	1.290	0.201
HRmax (bpm)				
All	169.60 ± 14.60	166.49 ± 15.25	3.295	0.001
30s	180.05 ± 12.92	177.40 ± 12.08	1.486	0.139
40s	171.25 ± 11.01	169. 00 ± 12.89	1.894	0.059
50s	163.50 ± 14.64	160.81 ± 13.81	1.686	0.093
60s	155.21 ± 13.63	153. 00 ± 17.42	0.636	0.527
EXBW (%)				
All	160.60 ± 35.50	169.46 ± 37.15	−3.860	<0.001
30s	179.88 ± 30.42	190.19 ± 36.11	−2.211	0.028
40s	163.78 ± 35.22	155.76 ± 29.37	−4.235	<0.001
50s	149.71 ± 31.36	155.76 ± 29.37	−1.772	0.077
60s	131.91 ± 32.84	134.93 ± 32.46	−0.411	0.682
FXBW (%)				
All	74.30 ± 19.20	77.93 ± 19.01	−3.000	0.003
30s	80.93 ± 18.62	81.88 ± 18.31	−0.364	0.716
40s	75.77 ± 19.08	80.87 ± 18.52	−2.696	0.007
50s	70.66 ± 18.27	74.89 ± 19.04	−2.022	0.044
60s	61.92 ± 16.60	67.77 ± 17.64	−1.528	0.131

Data shown as Mean ± S.E. Lower: WHtR <0.5, Upper: WHtR >0.5.
VO_2max: maximal oxygen uptake; EXBW: Knee Extension Peak Torque/Body Weight; FXBW: Knee Flexion Peak Torque/Body Weight; WHtR: waist-to-height ratio; HRmax: Maximal Heart Rate.

TABLE 4. Age-specific differences in metabolic disease factors according to WHtR.

	WHtR		*t*	*p*
	Lower	Upper		
SBP (mmHg)				
All	123.26 ± 38.88	125.93 ± 11.36	−1.397	0.163
30s	121.57 ± 12.47	126.94 ± 11.03	−3.256	0.001
40s	122.04 ± 12.55	125.86 ± 12.18	−3.062	0.002
50s	127.31 ± 68.84	125.37 ± 10.82	0.345	0.733
60s	118.91 ± 11.19	126.27 ± 10.55	−3.012	0.003
DBP (mmHg)				
All	74.10 ± 8.77	76.76 ± 8.30	−4.897	<0.001
30s	72.58 ± 8.18	76.59 ± 8.24	−3.438	0.001
40s	75.03 ± 8.94	76.86 ± 8.84	−2.049	0.041
50s	74.46 ± 8.98	76.79 ± 7.73	−2.491	0.013
60s	71.72 ± 7.73	76.51 ± 8.40	−2.656	0.010

TABLE 4. Continued.

	WHtR		t	p
	Lower	Upper		
TC (mg/dL)				
All	194.66 ± 78.46	197.51 ± 32.55	−0.718	0.473
30s	186.16 ± 27.84	203.01 ± 31.49	−4.043	<0.001
40s	193.02 ± 34.36	199.65 ± 34.68	−1.914	0.056
50s	203.33 ± 135.05	191.42 ± 31.31	1.055	0.292
60s	193.42 ± 34.20	199.78 ± 26.70	−0.917	0.362
HDL-C (mg/dL)				
All	50.50 ± 32.17	48.44 ± 21.47	1.161	0.246
30s	48.31 ± 10.57	46.74 ± 9.51	1.090	0.277
40s	49.88 ± 10.48	50.93 ± 32.37	−0.469	0.639
50s	53.38 ± 56.92	46.69 ± 8.95	1.424	0.155
60s	48.77 ± 9.86	48.05 ± 12.34	0.287	0.775
TG (mg/dL)				
All	121.27 ± 66.02	147.85 ± 65.67	−6.366	<0.001
30s	112.58 ± 67.61	167.31 ± 71.68	−5.568	<0.001
40s	125.71 ± 68.57	151.72 ± 69.10	−3.763	<0.001
50s	121.62 ± 63.23	133.95 ± 57.09	−1.820	0.070
60s	119.47 ± 56.79	141.81 ± 56.04	−1.765	0.081
LDL-C (mg/dL)				
All	118.83 ± 30.71	121.40 ± 31.61	−1.303	0.193
30s	116.13 ± 24.8	124.00 ± 31.53	−2.000	0.047
40s	117.64 ± 31.91	121.69 ± 32.06	−1.259	0.209
50s	121.36 ± 32.71	119.04 ± 31.89	0.638	0.524
60s	123.07 ± 30.61	123.68 ± 29.06	−0.090	0.928
HbA1c (%)				
All	5.37 ± 0.44	5.58 ± 0.49	−7.374	<0.001
30s	5.22 ± 0.36	5.45 ± 0.43	−3.850	<0.001
40s	5.31 ± 0.42	5.61 ± 0.50	−6.377	<0.001
50s	5.49 ± 0.48	5.62 ± 0.49	−2.309	0.022
60s	5.56 ± 0.42	5.64 ± 0.48	−0.773	0.442
TG/HDL Ratio				
All	2.64 ± 1.69	3.32 ± 1.82	−6.028	<0.001
30s	2.54 ± 1.83	3.82 ± 1.98	−4.706	<0.001
40s	2.67 ± 1.59	3.31 ± 1.89	−3.713	<0.001
50s	2.69 ± 1.81	3.05 ± 1.60	−1.900	0.058
60s	2.57 ± 1.33	3.22 ± 1.73	−1.882	0.064

Data shown as Mean ± S.E. Lower: WHtR <0.5, Upper: WHtR >0.5.
SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; HDL-C: High Density Lipoprotein-Cholesterol; TG: Triglyceride; LDL-C: Low Density Lipoprotein-Cholesterol; WHtR: waist-to-height ratio; HbA1c: Hemoglobin A1c.

TABLE 5. Correlation analysis between WHtR and physical fitness factors.

	All	30s	40s	50s	60s
Sit-up	−0.151**	−0.187**	−0.154**	−0.105	−0.140
Push-up	−0.183**	−0.173*	−0.190**	−0.140*	−0.238*
Sit and reach	−0.115**	−0.103	−0.128**	−0.134*	−0.005
Handgrip strength	0.081**	0.148*	0.092	0.083	0.081
Sidestep	−0.067*	−0.079	−0.065	−0.003	−0.070
Vertical jump	−0.141**	−0.239**	−0.111*	−0.090	−0.042
Exercise duration	−0.246*	−0.345**	−0.242**	−0.185**	−0.222*
VO_2max	−0.301**	−0.319**	−0.273**	−0.304**	−0.339**
HRmax	−0.147**	−0.210**	−0.118*	−0.100	−0.222*
EXBW	0.166**	0.239**	0.224**	0.173**	0.136
FXBW	0.147**	0.172*	0.161**	0.147*	0.243*

$*p < 0.05$, $**p < 0.01$.
VO_2max: maximal oxygen uptake; EXBW: Knee Extension Peak Torque/Body Weight; FXBW: Knee Flexion Peak Torque/Body Weight; HRmax: Maximal Heart Rate.

3.6 Correlation analysis between WHtR and metabolic disease factors

The results of the correlation analysis between the WHtR and metabolic disease factors of the study participants are presented in (Table 6). The analysis revealed significant ($p < 0.05$) positive correlations between WHtR and most metabolic disease factors. When analyzed by age group, the following correlations were identified: In participants in their 30s, significant ($p < 0.05$) positive correlations were observed with SBP, DBP, TC, TG, LDL-C, HbA1c and TG/HDL-C ratio. In participants in their 40s, significant ($p < 0.05$) positive correlations were identified with SBP, DBP, total cholesterol, TG, HbA1c and TG/HDL-C ratio. In participants in their 50s, significant ($p < 0.05$) positive correlations were found with DBP, TG, HbA1c and TG/HDL-C ratio. In participants in their 60s, significant ($p < 0.05$) positive correlations were observed with SBP, DBP and TG/HDL-C ratio.

3.7 Results of multiple regression analysis between WHtR and variables

The results of the multiple regression analysis conducted to examine the effects of physical fitness and metabolic disease factors on the WHtR are presented in (Tables 7 and 8). The significance of the multiple regression analysis for physical fitness factors was confirmed at $p \leq 0.001$, with Durbin-Watson (D-W) statistics of 2.031 and 2.044, indicating no autocorrelation. Tolerance values exceeded 0.1, and the variance inflation factor (VIF) was less than 10, confirming the absence of multicollinearity.

The regression coefficient significance tests for physical fitness factors revealed that Push-up ($\beta = -0.093$, $p = 0.004$), Vertical jump ($\beta = -0.150$, $p \leq 0.001$), VO_2max ($\beta = -0.234$, $p = 0.004$), EXBW ($\beta = 0.199$, $p \leq 0.001$) and FXBW ($\beta = 0.103$, $p = 0.007$) were significantly associated to WHtR. Based on the standardized coefficients, the order of influence was VO_2max, EXBW, Vertical jump, FXBW and Push-up.

The regression coefficient significance tests for metabolic disease factors showed that DBP ($\beta = 0.153$, $p \leq 0.001$), LDL-C ($\beta = 0.088$, $p = 0.009$), HbA1c ($\beta = 0.201$, $p \leq 0.001$) and TG/HDL-C ratio ($\beta = 0.258$, $p = 0.004$) significantly influenced WHtR. According to the standardized coefficients, the order of influence was TG/HDL-C ratio, HbA1c, DBP and LDL-C.

4. Discussion

This study aimed to confirm the utility of Waist-to-Height Ratio (WHtR) as an obesity assessment index among middle-aged men in Korea, to identify the correlations between WHtR, health-related physical fitness and metabolic disease factors, and to propose strategies for obesity management and prevention for middle-aged men based on these findings. To achieve this objective, 1012 Korean adult men aged 35–64 were classified into higher and lower WHtR groups based on the WHtR cutoff value of 0.5 [18, 19]. Subsequently, the relationships between WHtR, physical fitness and metabolic disease factors were analyzed.

As previously mentioned, among the indices used for assessing obesity, body mass index (BMI) considers only height and weight, limiting its ability to account for variations in muscle mass. Similarly, waist circumference (WC) and waist-to-hip ratio (WHR) have limitations in evaluating obesity with individual differences [20]. In contrast, WHtR includes height in its calculation, allowing it to more precisely reflect physical characteristics compared to BMI, WC or WHR, and better predict the risk of cardiovascular diseases and metabolic syndrome [15, 21, 22]. International studies also demonstrate that WHtR exhibits superior discriminatory power in predicting the early risk of metabolic syndrome compared to BMI or WC, and its universal cutoff point—regardless of age, sex or ethnicity—enhances its utility in public health and clinical settings [23, 24]. This study discusses the utility of WHtR and its implications for health management strategies based on the results.

The American College of Sports Medicine [25] catego-

TABLE 6. Correlation analysis between WHtR and metabolic disease factors.

	All	30s	40s	50s	60s
SBP	0.068*	0.307**	0.183**	0.001	0.387**
DBP	0.202**	0.275**	0.132**	0.236**	0.286*
TC	0.062*	0.281**	0.128**	0.005	0.038
HDL-C	−0.048	−0.105	−0.043	−0.053	−0.075
TG	0.235**	0.355**	0.220**	0.186**	0.191
LDL-C	0.070*	0.177*	0.089	0.014	−0.084
HbA1c	0.265**	0.262**	0.348**	0.165**	0.186
TG/HDL ratio	0.242**	0.327**	0.224**	0.212**	0.236**

*$p < 0.05$, **$p < 0.01$.

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; HDL-C: High Density Lipoprotein-Cholesterol; TG: Triglyceride; LDL-C: Low Density Lipoprotein-Cholesterol; HbA1c: Hemoglobin A1c.

TABLE 7. Multiple regression analysis of WHtR and physical fitness factors.

	B	SE	β	t	p	Tol.	VIF
(constant)	0.566	0.015		38.237	<0.001		
Sit-up	0.000	0.000	−0.042	−1.241	0.215	0.731	1.368
Push-up	0.000	0.000	−0.093	−2.858	0.004	0.773	1.294
Sit and reach	0.000	0.000	−0.039	−1.272	0.204	0.886	1.129
Handgrip strength	0.000	0.000	0.056	1.706	0.088	0.749	1.336
Sidestep	−0.000	0.000	−0.006	−0.196	0.845	0.765	1.308
Vertical jump	−0.001	0.000	−0.150	−4.488	<0.001	0.731	1.369
Exercise duration	−0.000	0.000	−0.002	−0.055	0.956	0.894	1.118
VO_2max	−0.002	0.000	−0.234	−6.740	<0.001	0.675	1.481
HRmax	0.000	0.000	−0.064	−1.909	0.057	0.732	1.365
EXBW	0.000	0.000	0.199	4.778	<0.001	0.472	2.118
FXBW	0.000	0.000	0.103	2.680	0.007	0.552	1.811
R^2 = 0.181, adj-R^2 = 0.172, D-W = 2.031, F = 20.174, $p < 0.001$							

VO_2max: maximal oxygen uptake; EXBW: Knee Extension Peak Torque/Body Weight; FXBW: Knee Flexion Peak Torque/Body Weight; VIF: variance inflation factor; D-W: Durbin-Watson; HRmax: Maximal Heart Rate; B: Unstandardized Regression Coefficient; SE: Standard Error; Tol.: Tolerance; adj-R^2: Adjusted R-squared.

TABLE 8. Multiple regression analysis of WHtR and metabolic disease factors.

	B	SE	β	t	p	Tol.	VIF
(constant)	0.309	0.018		17.034	<0.001		
SBP	0.000	0.000	0.009	0.303	0.762	0.918	1.089
DBP	0.001	0.000	0.153	4.859	<0.001	0.870	1.150
TC	0.000	0.000	0.001	0.041	0.968	0.745	1.343
HDL	0.000	0.000	0.010	0.291	0.771	0.802	1.247
TG	−0.000	0.000	−0.073	−0.824	0.410	0.109	9.133
LDL	0.000	0.000	0.088	2.599	0.009	0.758	1.319
HbA1c	0.018	0.003	0.201	6.576	<0.001	0.925	1.081
TG/HDL ratio	0.006	0.002	0.258	2.873	0.004	0.107	9.366
R^2 = 0.136, adj-R^2 = 0.129, D-W = 2.044, F = 19.698, $p < 0.001$							

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; HDL: High Density Lipoprotein; TG: Triglyceride; LDL: Low Density Lipoprotein; VIF: variance inflation factor; D-W: Durbin-Watson; HbA1c: Hemoglobin A1C; B: Unstandardized Regression Coefficient; SE: Standard Error; Tol.: Tolerance; adj-R^2: Adjusted R-squared.

rizes physical fitness components into health-related fitness and skill-related fitness. Among these, muscular strength, cardiorespiratory endurance, muscular endurance, flexibility, and body composition are identified as health-related fitness components. In this study, the relationship between WHtR and health-related fitness components revealed that individuals in the higher WHtR group exhibited significantly higher body weight, body fat percentage and abdominal obesity ratio. Conversely, they demonstrated lower levels of cardiorespiratory endurance, muscular endurance and flexibility compared to the lower WHtR group. The findings of this study are supported by previous research, which analyzed differences in physical fitness factors based on WHtR among Korean male and female university students and reported that the higher WHtR group had lower levels of muscular endurance, cardiorespiratory endurance and flexibility [16], as well as by another study that analyzed data from Korean male and female older adults and similarly found that the higher WHtR group exhibited reduced muscular endurance, cardiorespiratory endurance and flexibility [26]. Interestingly, regarding muscular strength, the higher WHtR group showed greater values than the lower WHtR group. This finding may be explained by the general tendency for obese individuals to have higher absolute muscular strength due to increases in both fat mass and lean mass [27, 28]. The greater absolute muscular strength observed in obese individuals is often attributed to the training effect of supporting greater body weight during physical activity or exercise [28]. In the present study, the higher muscular strength observed in the higher WHtR group is likely a result of increased muscle mass. These findings underscore the strong association between WHtR and health-related fitness, suggesting that increased WHtR can serve as a predictive marker for declines in health-related fitness.

Furthermore, abdominal obesity is closely linked to increased risks of metabolic and cardiovascular diseases, highlighting the importance of measuring abdominal obesity indicators for better health risk prediction [29]. While WC is commonly used to assess abdominal obesity, it cannot distinguish between visceral fat and subcutaneous fat and may overestimate or underestimate cardiovascular risk depending on stature [14]. Previous studies have shown that visceral fat thickness measured via ultrasound is a critical factor in metabolic syndrome prevalence and exhibits significant correlations with WC and WHtR [30]. Additionally, higher WHtR has been associated with increased coronary artery calcification [31] and a significant relationship with metabolic diseases when exceeding 0.5 [29]. Thus, WHtR has emerged as a pivotal predictor of health risks, including metabolic syndrome, warranting further investigation [32]. In the current study, correlation analysis revealed that individuals in the higher WHtR group exhibited significantly worse values for diastolic blood pressure (DBP), blood triglycerides (TG), glycated hemoglobin (HbA1c) and TG/HDL-C ratio. These results demonstrate that WHtR is an effective predictor of metabolic disease risk, particularly in its associations with glucose metabolism and lipid metabolism. HbA1c, a hemoglobin molecule bound to glucose, reflects average blood glucose levels over the past three months and is considered a more reliable marker for diabetes diagnosis than fasting blood glucose [33, 34]. Similarly, the TG/HDL-C ratio is a strong predictor of cardiovascular disease, with higher ratios indicating greater risk [35]. Multivariate regression analysis in this study identified cardiorespiratory endurance and the TG/HDL-C ratio as the most influential factors on WHtR, suggesting that WHtR serves as a critical link between physical fitness and metabolic disease management. Prior studies have also demonstrated high reproducibility of WHtR in predicting diabetes and hypertension among men [36] and its superior predictive power for dyslipidemia and type 2 diabetes [37]. Moreover, WHtR has been reported to predict not only the prevalence of metabolic syndrome but also mortality [18].

Synthesizing these findings, the reduced cardiorespiratory endurance and muscular endurance alongside the elevated HbA1c and TG/HDL ratio observed in the higher WHtR group are consistent across all age groups. This indicates that WHtR reflects abdominal obesity and physical characteristics while exhibiting strong correlations with fitness and metabolic disease factors. The findings suggest that WHtR can be a valuable predictive marker for declines in health-related fitness and increased metabolic disease risk. Physical activity is a key factor in improving cardiorespiratory endurance and muscular function. Given the relationship between WHtR, fitness and metabolic disease factors, combining aerobic and resistance exercises appears effective for WHtR management. Previous studies have reported that exercise at 70–95% of heart rate reserve (HRR), a high-energy expenditure zone, resulted in WHtR reduction and improvements in cardiorespiratory endurance, muscular strength and muscular endurance [38, 39]. However, high-intensity exercise should be carefully tailored to individual characteristics to minimize injury risks [39].

In conclusion, the increased risks of cardiovascular and metabolic diseases associated with higher WHtR underscore the necessity of developing systematic health management and prevention programs, including high-intensity exercise for effective WHtR control. Future research should evaluate the appropriateness of WHtR cut-off values across gender and age groups and validate its applicability in diverse populations. Customized health management based on WHtR is expected to contribute effectively to obesity prevention and the reduction of metabolic disease risks.

5. Conclusions

The analysis of 1012 participants revealed that the higher WHtR group exhibited significantly higher values in weight, lean body mass, body mass index, body fat percentage, abdominal fat percentage, and waist circumference compared to the lower WHtR group. Additionally, the higher WHtR group significant lower muscular endurance, flexibility, cardiorespiratory endurance and power, while exhibiting significantly higher muscular strength, levels of blood triglycerides (TG), glycated hemoglobin (HbA1c) and the TG/HDL ratio. These findings suggest that an elevated WHtR is associated with decreased physical fitness and increased risk of metabolic diseases.

Furthermore, WHtR demonstrated a negative correlation with physical fitness factors and a positive correlation with metabolic disease factors. Among these, cardiorespiratory endurance and HbA1c were identified as the most influential factors affecting WHtR. These results highlight the close interrelationship between declines in physical fitness and the risk of metabolic diseases, supporting the notion that WHtR serves as a useful index for predicting not only obesity but also physical fitness levels and the risk of metabolic diseases in an integrated manner.

In conclusion, WHtR enables an effective assessment of obesity through a simple measurement and serves as a predictive marker for health-related physical fitness and metabolic disease risk. Future studies should further investigate the applicability of WHtR across broader populations, including diverse genders, to expand its utility as a health assessment tool.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

TJK—designed the study and the methodology; drafted the manuscript. TJK and GCH—provided the software; contributed to the resource and data curation; supervised the study. JWL and GCH—contributed to the formal analysis; revised the manuscript. GCH—contributed to data curation. JWL—contributed to data visualization; responsible for project administration. All authors contributed to the editorial changes in the manuscript. All authors have read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the Ethics Committee of the Myongji Hospital, Deoyang-gu, Goyang-si, Gyenggi-do, Republic of Korea (2025-01-009) and conformed to the standards set by the latest revision of the Declaration of Helsinki. Written informed consent was obtained from all study participants.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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