보건학석사 학위논문

Association between Cardiorespiratory Fitness and the Metabolic Syndrome in Korean adults

한국인에서 심폐 체력과 대사증후군의 연관성 연구

2019년 2월

서울대학교 보건대학원

보건학과 보건학전공

배 예 슬

Association between Cardiorespiratory Fitness and the Metabolic Syndrome in Korean adults

한국인에서 심폐 체력과 대사증후군의 연관성 연구

지도교수 조 성 일

이 논문을 보건학 석사학위논문으로 제출함

2017 년 11 월

서울대학교 대학원

보건학과 보건학 전공

배 예 슬

배예슬의 석사학위논문을 인준함

2019 년 2 월

위 원 장 성 주 헌 (인)

부위원장 박 상 민 (인)

위 원 조 성 일 (인)

Abstract

Association between Cardiorespiratory Fitness and the Metabolic Syndrome in Korean adults

Ye Seul Bae

Department of Epidemiology

The Graduate School of Public Health

Seoul National University

Introduction The prevalence of metabolic syndrome is continuously increasing worldwide. Such condition is a major risk factor for cardiovascular disease, stroke, and various types of cancer. Cardiorespiratory fitness reflects the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity. Cardiorespiratory fitness is commonly expressed as maximal oxygen consumption (VO_{2max}). Previous studies have shown that cardiorespiratory fitness can attenuate the risk of developing metabolic syndrome. However, studies on Asian populations that included both sexes and various age groups are limited. Thus, this study aimed to evaluate the association between cardiorespiratory fitness and metabolic syndrome in Korean adults.

Methods We conducted a cross-sectional study that used data obtained from the database of Seoul National University Hospital Health Promotion Center. The total population was 43,369, which included individuals aged over 20 years who underwent health screenings, such as fitness testing using a cycle ergometer. The level of cardiorespiratory fitness was defined as low ($VO_{2max} \leq 21$ mL/kg/min), moderate (21 mL/kg/min $< VO_{2max} \leq 28$ mL/kg/min), or high ($VO_{2max} >28$ mL/kg/min). In the multivariate logistic analysis, we assessed the association between VO_{2max} and metabolic syndrome after adjusting for age, sex, smoking status, alcohol intake, physical activity, and family history of cardiovascular diseases in model 1 and for variable in model 1 plus fat ratio in model 2. In addition, we conducted a stratified analysis in both sexes and various age groups.

Results Approximately 17.37% of participants presented with metabolic syndrome, of which 20.94% were men and 12.55% were women. Among each of metabolic abnormalities, the prevalence of high blood pressure (47.77%) was the highest. In the multivariate logistic regression analysis, the adjusted prevalent odds ratios (adjusted pORs) of participants with moderate and high cardiorespiratory fitness were 0.59 (95% CI: 0.55−0.63) and 0.47 (95% CI: 0.44−0.50) in model 1, 0.72 (95% CI: 0.67−0.77) and 0.70(95% CI: 0.65−0.76) in model 2 respectively. A similar inverse association was observed after stratification in both sexes and all age groups.

Conclusions A significant inverse association was observed between cardiorespiratory fitness and metabolic syndrome in Korean adults. The participants with a high level of fitness were less likely to have metabolic syndrome. The results were clear and significant in both sexes and various age groups. Further prospective studies must be conducted to validate our findings.

Keywords: Cardiorespiratory fitness, Metabolic syndrome, Cardiometabolic risk factors, Physical activity, Obesity, Hypertension, Dyslipidemia, Glycemic dysfunction

Student Number: 2016−24006

CONTENTS

TABLES

FIGURE

1. Introduction

1.1 Background

Metabolic syndrome is characterized by a cluster of interrelated cardio−metabolic risk factors that can promote the development of atherosclerotic cardiovascular disease (CVD).(1) The pathology of metabolic syndrome is unclear. However, it is thought that insulin resistance causes glycemic dysfunction, which elevates blood pressure or triglyceride levels and lowers high−density lipoprotein (HDL) cholesterol and abdominal obesity.(2, 3)

The prevalence of metabolic syndrome is continuously increasing with the increase in the proportion of obese individuals. In Korea, approximately one in four individuals has metabolic syndrome.(4) The prevalence of metabolic syndrome is higher in the group with irregular exercise.(4) Such condition is a major risk factor for CVD, stroke, and various types of cancer. A meta−analysis (5) has shown that metabolic syndrome was associated with an increased risk of CVD (relative risk [RR]: 2.35; 95% confidence interval [CI]: 2.02–2.73) and CVD−related mortality

(RR: 2.40; 95% CI: 1.87—3.08) according to 87 studies. The Northern Manhattan study (6) has revealed that metabolic syndrome was associated with an increased risk of stroke (Hazard ratio: 1.5; 95% CI: 1.1–2.2) and vascular events (HR: 1.6; 95% CI: 1.3–2.0) after adjusting for sociodemographic and risk factors. Moreover, several studies have suggested that metabolic syndrome is significantly related to liver,(7, 8) colorectal,(7, 9, 10) breast,(7, 11−14), endometrial,(7, 15), bladder,(7) and prostate cancer.(16)

Finally, the increased prevalence of diabetes mellitus, dyslipidemia, hypertension, coronary artery diseases, stroke, chronic renal failure, heart failure, and cancers is highly associated with metabolic syndrome,(17) which likely increases the social burden of metabolic syndrome in the future.

Cardiorespiratory fitness reflects the ability of the circulatory and respiratory system to supply oxygen during sustained physical activity. Cardiorespiratory fitness is commonly expressed as maximal oxygen consumption (VO_{2max}). VO_{2max} can be measured directly or estimated based on the peak work rate during fitness testing using a treadmill or cycle ergometer. Although a directly measured VO_{2max} is accurate, an estimated cardiorespiratory fitness is easier to obtain, and it can predict health outcome. Thus, it is commonly used in clinical practice.(18–21)

Several studies on the association between cardiorespiratory fitness and health outcome have been published within the last two decades. To date, the fact that cardiorespiratory fitness is an independent and strong risk factor for CVD and all–cause mortality is well documented in several studies.(22–26) Moreover, high levels of fitness have a beneficial effect on the development of certain cancers, including lung, breast, or gastrointestinal cancers, and all–cause cancer mortality.(27–31) Meanwhile, a low level of cardiorespiratory fitness is a major contributing risk factor for metabolic syndrome. In addition, numerous studies have supported the evidence showing that cardiorespiratory fitness can attenuate the risk of metabolic syndrome.(32–36) Knaeps et al. evaluated the 10–year change in physical activity, cardiorespiratory fitness, and cardiometabolic risk.(36) They concluded that the combination of decreased sedentary behavior and increased moderate–to–vigorous physical activity resulted in a positive change in cardiorespiratory fitness, and it is likely most beneficial for cardiometabolic health. In other words, maintaining a high level of cardiorespiratory fitness would be beneficial in maintaining health. Similarly, the American Heart Association has stated the importance of assessing cardiorespiratory fitness in clinical practice and encouraged the routine assessment of cardiorespiratory fitness.(37)

By contrast, age and sex significantly affected fitness levels.(38, 39) Since cardiorespiratory fitness is significantly associated with cardiac output, hemoglobin levels, and skeletal muscle mass, men have higher fitness level than women of the same age.(38, 39) Fitness level is more likely to decline with age. Moreover, ethnicity is an important determinant. That is, a lower fitness level was observed in Blacks than in Whites.(40–42) This result implies that age, sex, and ethnicity should be considered when evaluating cardiorespiratory fitness.

However, previous Asian studies compared to white, black, or Hispanic populations are limited. In addition, only few studies on the association between cardiorespiratory fitness and metabolic syndrome in Korean adults have been conducted. Hong et al.(43)

have shown that low cardiorespiratory fitness and obesity were a predictor of metabolic syndrome in Korean adults. However, the study population was small (N=1,007), and cardiorespiratory fitness was evaluated via a simple step test instead of a sustained exercise test, such as an exercise that uses a treadmill or cycle ergometer. Kim et al.(44) have revealed the combined impact of cardiorespiratory fitness and visceral adiposity on metabolic syndrome. However, the study population consisted of overweight and obese adults. Thus, it cannot be applied to the general population. Kang et al.(45) have evaluated the resting heart rate and cardiorespiratory fitness of individuals with metabolic syndrome. However, the study was limited to male adults in Korea. Thus, it could not be generalized to women.

Therefore, in Korea, the relationship between fitness and metabolic syndrome must be evaluated among large, both sexes and various age groups. Furthermore, it can support the public health strategy of mediation to prevent metabolic syndrome by measuring fitness level in clinical settings.

1.2 Objectives

The purpose of this study is to investigate the association between cardiorespiratory fitness and metabolic syndrome among large Korean populations. Especially, cardiorespiratory fitness is regarded to evaluate according to sex and age group, this study would identify the relationship regarding both sexes and various age groups.

2. Methods

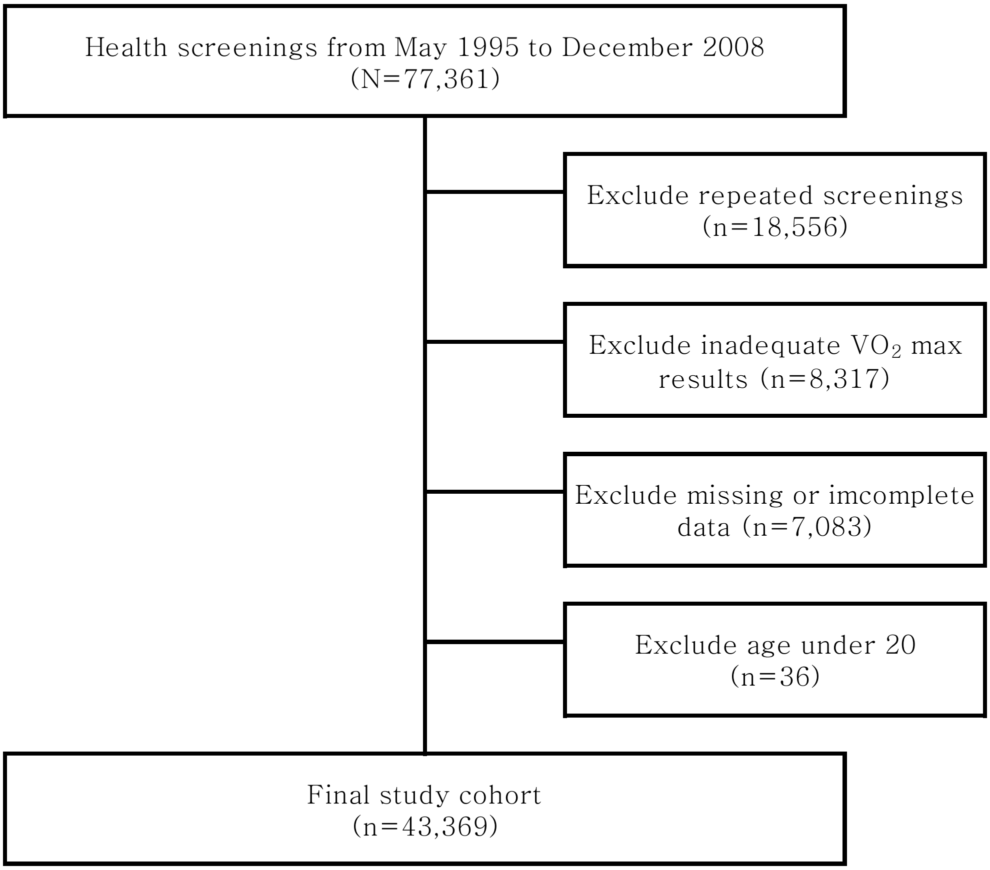
2.1 Study population

From May 1995 to December 2008, 77,361 cases of health screening exams were conducted at the Seoul National University Hospital Health Promotion Center (SNUH−HPC). SNUH−HPC provides comprehensive health check−ups for prevention and early detection of diseases to identify high−risk populations among those in an asymptomatic stage.

We excluded 18,556 cases with repeated screenings and included the most recent examination to reflect current health information. To the next, 8,317 subjects with inadequate VO_{2max} results, 7,083 subjects with missing or incomplete of metabolic syndrome components, and 36 subjects under age 20. Finally, 43,369 participants were enrolled this study. (Figure 1)

This study was approved by the Seoul National University Hospital institutional review board (IRB number: C−1808−099−967) and Seoul National University institutional review board (IRB number: 1811/003−006), and the requirement for informed consent was waived.

Figure 1. Study population



2.2 Measurement of maximum oxygen uptake

Maximum oxygen uptake (VO_{2max}) was evaluated with an exercise test using a cycle ergometer (Cateye Ergociser, EC 1600, Osaka, Japan). The subjects exercised to a pulse rate of 85% of their predicted maximum unless stopped due to dyspnea, fatigue, chest pain, or systolic blood pressure 250 mmHg or higher. VO_{2max} was estimated with individual regression using age, weight, and a 75% maximal heart rate. The data of participants who could not reach 75% of their predicted maximum heart rate were excluded from the analyses.

2.3 Definition of metabolic syndrome

Metabolic syndrome was defined according to the American Association of Clinical Endocrinologists (AACE) guideline. Metabolic markers and thresholds included obesity (BMI ≥ 25 kg/m2), high blood pressure (systolic blood pressure ≥135mmHg and/or diastolic blood pressure ≥ 85), impaired fasting glucose (fasting glucose ≥ 110), hypertriglyceridemia (triglyceride ≥ 150 mg/dL), low high density lipoprotein (HDL) cholesterol (HDL-cholesterol <40mg/dL for men or <50mg/dL for women).

Height and weight were used for calculation of body mass index [BMI=weight (kg)/height^2 (m^2)]. Blood pressure was measured using an automated device (Jawon, Busan, Korea) after the subject had rested for at least 20 min in the sitting position. Blood samples were drawn after subjects had fasted 12 hours.

The presence of the metabolic syndrome was defined as meeting obesity and 2 or more among high blood pressure, impaired fasting glucose, hypertriglyceridemia, or low HDL- cholesterol.

2.4 Clinical variables

Participants' personal history of diabetes, hypertension, 1st-degree's cardiovascular history, smoking status, alcohol consumption, and physical activity was obtained using a structured self−reported questionnaire and the information was validated by trained nurses. Smoking status was classified into 3 categories as current smoker, ex−smoker, or non−smoker. Regular drinker was defined as those who drank alcoholic beverages at least once a week. Regular exerciser referred to those who had light, moderate, or vigorous activities for more than 30 minutes at least 3 times a week. We measured body fat ratio by bioelectrical impedance analysis (ZEUS 9.9, Jawon Medical, Seoul, Korea).

2.5. Statistical analysis

Data were expressed as percentages with number for categorical variables and mean ± standard deviation (SD) for continuous variables. χ^2 test was performed to compare the categorical variables and t test was used to test the difference of continuous variables according to gender.

Multivariate logistic regression model was used to determine the prevalent odds ratios (pOR) and 95% confidence intervals (CIs) for association between cardiorespiratory fitness and metabolic syndrome. The considered covariates included smoking, physical activity, alcohol consumption, history of 1^{st} degree's cardiovascular disease in model 1 and body fat ratio was additionally adjusted in model 2.

cardiorespiratory fitness was used as categorical variable divided into tertiles (low cardiorespiratory fitness, $VO_{2max} \leq 21$ ml/kg/min; moderate cardiorespiratory fitness, 21 ml/kg/min < $VO_{2max} \leq 28$ ml/kg/min; high cardiorespiratory fitness, $VO_{2max} > 28$ ml/kg/min) and all results were presented with being divided into gender. Stratified analysis according to age group (19-39, 40-49, 50-59, and 60-89 years) was conducted to investigate the association between cardiorespiratory fitness and metabolic syndrome regarding the difference of age.

Statistical significance was defined as having a *p* value of less than 0.05 in a two-sided manner. All statistical analyses were performed with STATA version 14.1 (Stata Corporation, College Station, Texas, USA).

3. Results

3.1. Baseline characteristics of the participants

Table 1 shows the descriptive characteristics of the study population. Among the 43,369 participants, 24,929 were men and 18,440 were women. The mean age of the total population was 48.4 years (48.71 years in men and 47.99 years in women). The mean values of VO_{2max} (standard deviation) was 48.40 (10.46), 27.05 (7.61), and 20.95 (6.67) in the total, male, and female populations, respectively. This result indicates that men are more likely to have a higher level of fitness than women.

In terms of metabolic risk factors, the male participants were likely to be overweight and have higher blood pressure and triglyceride and glucose levels. However, the female participants were more likely to have a higher fat ratio, total cholesterol level, HDL cholesterol level, and LDL cholesterol level. Approximately 15% of the total population had ever taken medications for hypertension (15.62% for men and 14.17% for women). Moreover, 6.43% of participants had ever taken diabetes medications (8.22% for men and 3.99% for women).

In terms of behavioral aspect, compared to women, men are more likely current smokers and regular drinkers, and less regular exercisers.

Table 1. Characteristics of the study populations

Variables (mean ± SD)		Men			Women			Total		
		(n=24,929)			(n=18,440)			(n=43,369)		
VO_{2max}	(ml/kg/min)	27.05	±	7.61	20.95	±	6.67	24.46	±	7.83
Age	(years)	48.71	±	10.91	47.99	±	9.82	48.40	±	10.46
Height	(cm)	169.19	±	5.77	156.92	±	5.12	163.97	±	8.19
Weight	(kg)	69.67	±	9.56	57.67	±	7.81	64.57	±	10.66
BMI	(kg/m2)	24.31	±	2.86	23.44	±	3.06	23.94	±	2.98
Waist circumference	(cm)	86.85	±	7.76	82.33	±	8.71	84.89	±	8.48
Fat ratio	(%)	21.80	±	4.95	29.22	±	4.79	24.95	±	6.11
Systolic BP	(mmHg)	130.29	±	19.20	126.57	±	20.43	128.71	±	19.82
Diastolic BP	(mmHg)	80.53	±	12.43	77.00	±	12.20	79.03	±	12.45
Heart rate at rest	(beats/min)	73.62	±	11.34	77.13	±	11.44	75.11	±	11.51
Total cholesterol	(mg/dl)	199.96	±	35.08	200.78	±	37.29	200.31	±	36.04
Triglyceride	(mg/dl)	154.24	±	109.06	112.55	±	73.15	136.51	±	97.66
HDL cholesterol	(mg/dl)	49.51	±	12.21	57.48	±	13.93	52.90	±	13.55
LDL cholesterol	(mg/dl)	121.22	±	34.23	123.45	±	36.91	122.15	±	35.39
Glucose	(mg/dl)	100.27	±	26.52	94.27	±	19.22	97.72	±	23.87
Hypertension	n (%)	3,893		(15.62)	2,612		(14.17)	6,505		(15.00)

Diabetes	n (%)	1,933	(8.22)	691	(3.99)	2,624	(6.43)
Smoking	n (%)						
Non−smoker		4,698	(20.09)	15,649	(92.38)	20,347	(50.46)
Ex−smoker		8,118	(34.71)	534	(3.15)	8,652	(21.45)
Current smoker		10,571	(45.20)	757	(4.47)	11,328	(28.09)
Regular drinker	n (%)	16,992	(72.98)	4,177	(24.63)	21,169	(52.61)
Regular exerciser	n (%)	13,898	(57.43)	11,062	(61.14)	24,960	(59.02)
Family history of cardiovascular disease	n (%)	1,215	(4.89)	929	(5.05)	2,144	(4.96)

3.2. Prevalence of metabolic components and metabolic syndrome

The prevalence of metabolic syndrome and metabolic abnormalities is shown in Table 2A. Approximately 17.37% of participants presented with metabolic syndrome, of which 20.94% were men and 12.55% were women. In terms of metabolic components, the prevalence of high blood pressure (47.77%) was the highest, followed by (34.52%), hypertriglyceridemia (30.31%), low HDL cholesterol level (24.61%), and impaired fasting glucose (13.35%). The results were consistent in the all fitness groups. Approximately 29.22% of the participants had 1 metabolic abnormality. The prevalence of the components, number of abnormalities, and metabolic syndrome is more likely to decline in the high fitness group than in the low and moderate fitness groups.

A same analysis was conducted with stratification by sex (male: Table 2B and female: Table 2C). High blood pressure was the most prevalent in both sexes. In male participants, the prevalence of metabolic components was high in order of high blood pressure (52.21%), obesity (39.41%), hypertriglyceridemia

(38.72%), low HDL cholesterol level (20.28%), and impaired fasting glucose (16.85%). Meanwhile, in the female participants, the prevalence of metabolic components was high in order of high blood pressure (41.77%), low HDL cholesterol level (30.45%), obesity (27.92%), hypertriglyceridemia (18.94), and impaired fasting glucose (8.62%). The prevalence of one metabolic abnormality was highest in the male participants. However, those who did not have any metabolic abnormalities were predominantly women (32.47%). The high fitness group was less likely to have metabolic abnormalities and metabolic syndrome, and this result was similar to that of the main analysis.

Table 2A. Prevalence of metabolic syndrome and metabolic abnormalities.

Components, % (n)	VO_{2max}						Total (N=43,369)	
	Low		Moderate		High			
Obesity	38.91	(6,324)	32.48	(4,401)	31.31	(4,248)	34.52	(14,973)
High blood pressure	55.17	(8,966)	44.74	(6,062)	41.94	(5,690)	47.77	(20,718)
Impaired fasting glucose	15.43	(2,508)	12.75	(1,727)	11.47	(1,556)	13.35	(5,791)
Hypertriglyceridemia	30.91	(5,023)	30.46	(4,127)	29.44	(3,995)	30.31	(13,145)
Low HDL−cholesterol	29.97	(4,871)	23.72	(3,213)	19.07	(2,587)	24.61	(10,671)
Number of metabolic abnormalities % (n)								
0	19.34	(3,143)	26.49	(3,589)	30.98	(4,203)	25.21	(10,935)
1	28.25	(4,592)	30.43	(4,122)	29.19	(3,960)	29.22	(12,674)
2	25.69	(4,175)	22.84	(3,094)	21.54	(2,922)	23.50	(10,191)
3	17.70	(2,876)	13.88	(1,881)	12.94	(1,756)	15.02	(6,513)
4	7.46	(1,213)	5.41	(733)	4.65	(631)	5.94	(2,577)
5	1.56	(254)	0.95	(129)	0.71	(96)	1.10	(479)
Metabolic syndrome % (n)	20.71	(3,366)	16.09	(2,180)	14.65	(1,988)	17.37	(7,534)

Table 2B. Prevalence of metabolic syndrome and metabolic abnormalities in men.

Components, % (n)	VO_{2max} Low		Moderate		High		Men (N=24,929)	
Obesity	47.05	(2,667)	38.93	(3,309)	35.77	(3,849)	39.41	(9,825)
High blood pressure	64.83	(3,675)	51.74	(4,398)	45.93	(4,942)	52.21	(13,015)
Impaired fasting glucose	23.51	(1,333)	17.01	(1,446)	13.22	(1,422)	16.85	(4,201)
Hypertriglyceridemia	46.08	(2,612)	39.58	(3,364)	34.16	(3,676)	38.72	(9,652)
Low HDL−cholesterol	22.63	(1,283)	21.34	(1,814)	18.21	(1,959)	20.28	(5,056)
Number of metabolic abnormalities % (n)								
0	10.83	(614)	18.38	(1,562)	25.75	(2,771)	19.84	(4,947)
1	24.33	(1,379)	29.45	(2,503)	29.34	(3,157)	28.24	(7,039)
2	28.74	(1,629)	26.52	(2,254)	23.80	(2,561)	25.85	(6,444)
3	24.10	(1,366)	17.79	(1,512)	14.89	(1,602)	17.97	(4,480)
4	10.05	(570)	6.60	(561)	5.41	(582)	6.87	(1,713)
5	1.96	(111)	1.27	(108)	0.81	(87)	1.23	(306)
Metabolic syndrome % (n)	28.68	(1,626)	20.68	(1,758)	17.05	(1,835)	20.94	(5,219)

Table 2C. Prevalence of metabolic syndrome and metabolic abnormalities in women.

Components, % (n)	VO_{2max}						Women (N=18,440)	
	Low		Moderate		High			
Obesity	34.55	(3,657)	21.63	(1,092)	14.21	(399)	27.92	(5,148)
High blood pressure	49.99	(5,291)	32.96	(1,664)	26.64	(748)	41.77	(7,703)
Impaired fasting glucose	11.10	(1,175)	5.57	(281)	4.77	(134)	8.62	(1,590)
Hypertriglyceridemia	22.78	(2,411)	15.11	(763)	11.36	(319)	18.94	(3,493)
Low HDL−cholesterol	33.90	(3,588)	27.71	(1,399)	22.36	(628)	30.45	(5,615)
Number of metabolic abnormalities % (n)								
0	23.89	(2,529)	40.15	(2,027)	51.00	(1,432)	32.47	(5,988)
1	30.36	(3,213)	32.07	(1,619)	28.60	(803)	30.56	(5,635)
2	24.06	(2,546)	16.64	(840)	12.86	(361)	20.32	(3,747)
3	14.27	(1,510)	7.31	(369)	5.48	(154)	11.02	(2,033)
4	6.08	(643)	3.41	(172)	1.75	(49)	4.69	(864)
5	1.35	(143)	0.42	(21)	0.32	(9)	0.94	(173)
Metabolic syndrome % (n)	16.44	(1,740)	8.36	(422)	5.45	(153)	12.55	(2,315)

3.3. Association between cardiorespiratory fitness and metabolic syndrome

In the univariate logistic regression analysis, the pOR of the participants with moderate cardiorespiratory fitness (21 mL/kg/min $< VO_{2max} \leq$ 28 mL/kg/min) and high cardiorespiratory fitness (VO_{2max} >28 mL/kg/min) were 0.73 (95% confidence interval [CI]: 0.69−0.78) and 0.66 (95% CI: 0.62−0.70), respectively compared with subjects of low cardiorespiratory fitness ($VO_{2max} \leq$ 21 ml/kg/min). After adjusting for covariates, the adjusted pORs of participants with moderate and high cardiorespiratory fitness were 0.59 (95% CI: 0.55−0.63) and 0.47 (95% CI: 0.44−0.50) in model 1, 0.72 (95% CI: 0.67−0.77) and 0.70(95% CI: 0.65−0.76) in model 2 respectively (Table 3A).

The inverse association between the level of fitness and the pOR of metabolic syndrome. A consistent association was observed after stratified by sex. The pORs of the moderate and high fitness groups were 0.65 (95% CI: 0.60−0.70) and 0.51 (95% CI: 0.47−0.55) in men (Table 3B), and 0.46 (95% CI: 0.41−0.52) and (95%

CI: 0.25−0.35) in women (Table 3C), respectively in the univariate logistic analysis. The adjusted pORs in the moderate and high fitness groups were 0.64 (95% CI: 0.59−0.69) and 0.49 (95% CI: 0.45−0.53) in men (Table 3B) and 0.61 (95% CI: 0.54−0.69) and 0.40 (95% CI: 0.33−0.49) in women (Table 3C) respectively in model 1. After additional adjustment of fat ratio in model 2, the adjusted pORs in the moderate and high fitness groups were0.75 (95% CI: 0.69−0.82) and 0.71 (95% CI: 0.65−0.77) in men (Table 3B) and 0.74 (95% CI: 0.65−0.85) and 0.61 (95% CI: 0.50−0.75) in women (Table 3C), respectively. The pORs tended to be attenuated with additional adjustment for fat ratio in model 2.

Table 3A. Logistic regression analysis of cardiorespiratory fitness with metabolic syndrome

		Unadjusted		Model 1		Model 2	
		OR	95% CI	aOR	95% CI	aOR	95% CI
Sex (Female)		0.54	(0.51 0.57)	0.46	(0.42 0.50)	0.10	(0.09 0.11)
Age (1-year difference)		1.02	(1.02 1.02)	1.01	(1.01 1.02)	1.01	(1.00 1.01)
VO_{2max} (ml/kg/min)							
	Low (≤21)	1.00		1.00		1.00	
	Moderate (21-28)	0.73	(0.69 0.78)	0.59	(0.55 0.63)	0.72	(0.67 0.77)
	High (>28)	0.66	(0.62 0.70)	0.47	(0.44 0.50)	0.70	(0.65 0.76)
Smoking							
	Non-smoker	1.00		1.00		1.00	
	Ex-smoker	1.61	(1.51 1.72)	1.08	(1.00 1.18)	1.08	(0.98 1.18)
	Current smoker	1.43	(1.34 1.51)	1.09	(1.01 1.19)	1.20	(1.10 1.32)
Regular drinker		1.26	(1.19 1.32)	1.05	(0.99 1.12)	0.96	(0.90 1.03)
Regular exerciser		0.96	(0.91 1.01)	1.01	(0.96 1.07)	0.92	(0.87 0.98)
Family history of cardiovascular disease		1.00	(0.89 1.12)	0.97	(0.85 1.10)	0.84	(0.74 0.96)
Fat ratio (%)		1.10	(1.09 1.10)			1.23	(1.22 1.24)

Table 3B. Logistic regression analysis of cardiorespiratory fitness with metabolic syndrome in men

	Unadjusted		Model 1		Model 2	
	OR	95% CI	aOR	95% CI	aOR	95% CI
Age (1−year difference)	1.00	(1.00 1.00)	1.00	(0.99 1.00)	1.00	(0.99 1.00)
VO_{2max} (ml/kg/min)						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.65	(0.60 0.70)	0.64	(0.59 0.69)	0.75	(0.69 0.82)
High (>28)	0.51	(0.47 0.55)	0.49	(0.45 0.53)	0.71	(0.65 0.77)
Smoking						
Non−smoker	1.00		1.00		1.00	
Ex−smoker	1.15	(1.05 1.26)	1.15	(1.05 1.26)	1.13	(1.02 1.24)
Current smoker	1.02	(0.94 1.11)	1.06	(0.97 1.16)	1.17	(1.07 1.29)
Regular drinker	1.11	(1.04 1.20)	1.16	(1.07 1.25)	1.04	(0.96 1.13)
Regular exerciser	1.07	(1.00 1.14)	1.10	(1.03 1.18)	0.98	(0.91 1.05)
Family history of cardiovascular disease	1.08	(0.94 1.24)	1.06	(0.91 1.23)	0.91	(0.78 1.06)
Fat ratio (%)	1.21	(1.21 1.22)			1.21	(1.20 1.22)

Table 3C. Logistic regression analysis of cardiorespiratory fitness with metabolic syndrome in women

		Unadjusted		Model 1		Model 2	
		OR	95% CI	aOR	95% CI	aOR	95% CI
Age (1−year difference)		1.06	(1.06 1.07)	1.06	(1.05 1.06)	1.03	(1.02 1.04)
VO_{2max} (ml/kg/min)							
	Low (≤21)	1.00		1.00		1.00	
	Moderate (21−28)	0.46	(0.41 0.52)	0.61	(0.54 0.69)	0.74	(0.65 0.85)
	High (>28)	0.29	(0.25 0.35)	0.40	(0.33 0.49)	0.61	(0.50 0.75)
Smoking							
	Non−smoker	1.00		1.00		1.00	
	Ex−smoker	0.77	(0.58 1.03)	1.07	(0.79 1.45)	0.93	(0.67 1.29)
	Current smoker	0.67	(0.52 0.86)	1.11	(0.85 1.45)	1.25	(0.94 1.66)
Regular drinker		0.64	(0.57 0.72)	0.92	(0.81 1.05)	0.85	(0.74 0.97)
Regular exerciser		0.83	(0.76 0.90)	0.87	(0.79 0.95)	0.84	(0.76 0.93)
Family history of cardiovascular disease		0.86	(0.70 1.07)	0.78	(0.62 1.00)	0.72	(0.56 0.92)
Fat ratio (%)		1.29	(1.28 1.31)			1.27	(1.25 1.28)

Abbreviations: OR, prevalent odds ratio; CI, confidence interval; aOR, adjusted prevalent odds ratio

Model 1 and 2 are multivariate analysis model adjusted for each following variables including VO_{2max};

Model 1: age, smoking status, alcohol intake, physical activity, and family history of cardiovascular disease;

Model 2: model 1+ body fat ratio.

3.4. Association between cardiorespiratory fitness and metabolic syndrome according to sex and age groups

Considering the importance of age in estimating VO_{2max}, we performed a stratified analysis in terms of sex and age groups. Table 4A and Table 4B depicts the association between cardiorespiratory fitness and metabolic syndrome according to sex and age groups. A similar association was observed in all age groups, which showed that the participants with high level of fitness were less likely to have metabolic syndrome.

In the young adult groups (aged 19–39 years) with moderate and high fitness, the pORs were 0.53 (95% CI: 0.45−0.64) and 0.31 (95% CI: 0.26−0.37) in the male participants, respectively, and 0.42 (95% CI: 0.30−0.60) and 0.23 (95% CI: 0.14−0.37) in the female participants respectively in univariate logistic analysis. A consistent association was observed in multivariate logistic analysis. This result showed that the association is more likely stronger in younger aged group. However, after adjusting fat ratio in model 2, the inverse association was attenuated in all age groups.

Especially, female oldest age group (aged 60 to 89 years) showed statistically insignificant association between level of cardiorespiratory fitness and metabolic syndrome in model 2.

Table 4A. Association between cardiorespiratory fitness and metabolic syndrome according to age strata in men

	Unadjusted		Model 1		Model 2	
VO_{2max} (ml/kg/min)	OR	(95% CI)	aOR	95% CI	aOR	(95% CI)
19−39 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.53	(0.45 0.64)	0.55	(0.46 0.66)	0.72	(0.58 0.89)
High (>28)	0.31	(0.26 0.37)	0.31	(0.26 0.37)	0.61	(0.50 0.75)
40−49 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.61	(0.53 0.71)	0.62	(0.53 0.72)	0.72	(0.61 0.85)
High (>28)	0.47	(0.41 0.54)	0.45	(0.39 0.52)	0.63	(0.54 0.74)
50−59 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.68	(0.59 0.78)	0.66	(0.57 0.77)	0.74	(0.63 0.86)
High (>28)	0.63	(0.55 0.72)	0.62	(0.53 0.71)	0.78	(0.67 0.91)
60−89 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.68	(0.57 0.82)	0.68	(0.56 0.82)	0.77	(0.63 0.94)
High (>28)	0.65	(0.54 0.78)	0.62	(0.51 0.77)	0.82	(0.66 1.02)

Table 4B. Association between cardiorespiratory fitness and metabolic syndrome according to age strata in women

	Unadjusted		Model 1		Model 2	
VO_{2max} (ml/kg/min)	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
19−39 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.42	(0.30 0.60)	0.46	(0.32 0.67)	0.79	(0.53 1.19)
High (>28)	0.23	(0.14 0.37)	0.19	(0.11 0.35)	0.51	(0.27 0.96)
40−49 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.47	(0.38 0.59)	0.50	(0.40 0.63)	0.66	(0.52 0.84)
High (>28)	0.35	(0.26 0.48)	0.37	(0.27 0.52)	0.66	(0.46 0.94)
50−59 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.61	(0.52 0.73)	0.63	(0.53 0.76)	0.74	(0.61 0.89)
High (>28)	0.39	(0.29 0.52)	0.39	(0.29 0.54)	0.52	(0.37 0.73)
60−89 years						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.76	(0.56 1.02)	0.81	(0.59 1.13)	0.94	(0.67 1.33)
High (>28)	0.75	(0.50 1.13)	0.79	(0.51 1.22)	1.06	(0.66 1.68)

Abbreviations: OR, odds ratio; CI, confidence interval; aOR, adjusted odds ratio

Model 1 and 2 are multivariate analysis model adjusted for each following variables including VO_{2max};

Model 1: age, smoking status, alcohol intake, physical activity, and family history of cardiovascular disease;

Model 2: model 1+ body fat ratio.

3.5. Association between cardiorespiratory fitness and components of metabolic syndrome

To show the association between cardiorespiratory fitness and each component of metabolic syndrome, we performed additional regression analysis regarding each of obesity, high blood pressure, impaired fasting glucose, hypertriglyceridemia, or low HDL cholesterol level. Table 5A showed the association between cardiorespiratory fitness and components of metabolic syndrome in overall population and Table 5B and Table 5C were presented to subgroup analysis according to sex. For the analysis, we adjusted for metabolic components to exclude the confounding effects of other metabolic abnormalities.

High blood pressure was the most prevalent in overall population (Table 2), and it was inversely associated with fitness level. In terms of high blood pressure, the adjusted pORs for the total population, male participants, and female participants with moderate and high fitness level were 0.72 (95% CI: 0.68−0.76) and 0.69 (95% CI: 0.65−0.73), 0.68 (95% CI: 0.63−0.74) and 0.62

(95% CI: 0.57−0.66), and 0.72 (95% CI: 0.66−0.78) and 0.70 (95% CI: 0.57−0.87),respectively in model 1 and 0.73 (95% CI: 0.70−0.78) and 0.72 (95% CI: 0.67−0.76), 0.70(95% CI: 0.65−0.76) and 0.66 (95% CI: 0.61−0.71), and 0.73(95% CI: 0.67−0.79) and 0.63 (95% CI: 0.56−0.70) respectively in model 2. A similar inverse association was generally observed in terms of obesity, impaired fasting glucose, hypertriglyceridemia, and low HDL cholesterol level in the total population and both of sexes.

Meanwhile, in terms of obesity, the adjusted pOR became statistically insignificant among moderate fitness group (adjusted pOR: 1.02, [95% CI: 0.96−1.08]) and significantly increased in high fitness group (adjusted pOR: 1.26, [95% CI: 1.18−1.35]) in model 2. When stratified by sex, the similar significantly inverse association was observed in women (adjusted pOR was 0.79 [95% CI: 0.71−0.88] in moderate fitness group and adjusted pOR was 0.70 [95% CI: 0.60−0.81] in high fitness group) but insignificant in men (adjusted pOR was 0.93 [95% CI: 0.86−1.02] in moderate fitness group and adjusted pOR was 1.05 [95% CI: 0.96−1.14] in high fitness group).

Table 5A. Association between cardiorespiratory fitness and components of metabolic syndrome

Metabolic component	Unadjusted		Model 1		Model 2	
VO2 max (ml/kg/min)	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Obesity						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.76	(0.72 0.79)	0.75	(0.71 0.79)	1.02	(0.96 1.08)
High (≥28)	0.72	(0.68 0.75)	0.70	(0.66 0.75)	1.26	(1.18 1.35)
High blood pressure						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.66	(0.63 0.69)	0.72	(0.68 0.76)	0.73	(0.70 0.78)
High (≥28)	0.59	(0.56 0.61)	0.69	(0.65 0.73)	0.72	(0.67 0.76)
Impaired fasting glucose						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.80	(0.75 0.86)	0.85	(0.78 0.91)	0.84	(0.78 0.91)
High (≥28)	0.71	(0.66 0.76)	0.78	(0.72 0.84)	0.77	(0.71 0.84)
Hypertriglyceridemia						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.98	(0.93 1.03)	0.92	(0.87 0.98)	0.96	(0.90 1.02)

High (≥28)	0.93	(0.89 0.98)	0.82	(0.77 0.87)	0.87	(0.82 0.93)
Low HDL−cholesterol						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.73	(0.69 0.77)	0.86	(0.81 0.91)	0.91	(0.86 0.97)
High (≥28)	0.55	(0.52 0.58)	0.73	(0.68 0.78)	0.81	(0.76 0.87)

Table 5B. Association between cardiorespiratory fitness and components of metabolic syndrome in men.

Metabolic component	Unadjusted		Model 1		Model 2	
VO2 max (ml/kg/min)	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Obesity						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.72	(0.67 0.77)	0.80	(0.74 0.86)	0.93	(0.86 1.02)
High (≥28)	0.63	(0.59 0.67)	0.71	(0.66 0.76)	1.05	(0.96 1.14)
High blood pressure						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.58	(0.54 0.62)	0.68	(0.63 0.74)	0.70	(0.65 0.76)
High (≥28)	0.46	(0.43 0.49)	0.62	(0.57 0.66)	0.66	(0.61 0.71)
Impaired fasting glucose						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.67	(0.61 0.72)	0.81	(0.74 0.89)	0.81	(0.74 0.89)
High (≥28)	0.50	(0.46 0.54)	0.70	(0.64 0.77)	0.72	(0.65 0.79)
Hypertriglyceridemia						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.77	(0.72 0.82)	0.81	(0.75 0.88)	0.84	(0.78 0.91)

High (≥28)	0.61	(0.57	0.65)	0.65	(0.60	0.70)	0.72	(0.67	0.78)
Low HDL−cholesterol									
Low (≤21)	1.00			1.00			1.00		
Moderate (21−28)	0.93	(0.86	1.01)	0.99	(0.90	1.08)	1.00	(0.91	1.09)
High (≥28)	0.76	(0.70	0.82)	0.89	(0.81	0.97)	0.90	(0.82	0.99)

Table 5C. Association between cardiorespiratory fitness and components of metabolic syndrome in women.

Metabolic component	Unadjusted		Model 1		Model 2	
VO2 max (ml/kg/min)	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Obesity						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.52	(0.48 0.57)	0.68	(0.62 0.74)	0.79	(0.71 0.88)
High (≥28)	0.31	(0.28 0.35)	0.46	(0.40 0.52)	0.70	(0.60 0.81)
High blood pressure						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.49	(0.46 0.53)	0.72	(0.66 0.78)	0.73	(0.67 0.79)
High (≥28)	0.36	(0.33 0.40)	0.61	(0.54 0.68)	0.63	(0.56 0.70)
Impaired fasting glucose						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.47	(0.41 0.54)	0.74	(0.63 0.86)	0.75	(0.64 0.87)
High (≥28)	0.40	(0.33 0.48)	0.70	(0.57 0.87)	0.73	(0.59 0.91)
Hypertriglyceridemia						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.60	(0.55 0.66)	0.95	(0.85 1.06)	0.97	(0.87 1.08)

High (≥28)	0.43	(0.38	0.49)	0.79	(0.68	0.92)	0.83	(0.72	0.97)
Low HDL−cholesterol									
Low (≤21)	1.00			1.00			1.00		
Moderate (21−28)	0.75	(0.69	0.80)	0.91	(0.83	0.99)	0.92	(0.84	1.00)
High (≥28)	0.56	(0.51	0.62)	0.77	(0.69	0.86)	0.80	(0.71	0.89)

Abbreviations: OR, prevalent odds ratio; CI, confidence interval; aOR, adjusted prevalent odds ratio.

Model 1 and 2 are multivariate analysis model adjusted for each following variables including VO_{2max};

Model 1: age, smoking status, alcohol intake, physical activity, and family history of cardiovascular disease;

Model 2: model 1+ body fat ratio.

For body mass index, blood pressure, glucose, triglyceride and HDL−cholesterol were additionally adjusted.

For blood pressure, body mass index, glucose, triglyceride and HDL−cholesterol were additionally adjusted.

For glucose, body mass index, blood pressure, triglyceride and HDL−cholesterol were additionally adjusted.

For triglyceride, body mass index, blood pressure, glucose and HDL−cholesterol were additionally adjusted.

For HDL−cholesterol, body mass index, blood pressure, glucose and triglyceride were additionally adjusted.

3.6. Association between cardiorespiratory fitness and metabolic syndrome among those who have never taken medications for hypertension or diabetes

For the definition of metabolic syndrome, we used the definition by the AACE guidelines. However, the European Group for the Study of Insulin Resistance (EGIR), National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III), and International Diabetes Federation (IDF) recommended to include the treatments for hypertension, diabetes, or dyslipidemia as a definition criterion for metabolic syndrome. Due to the limitation of this retrospective cross-sectional study, we obtained information regarding the previous treatment for hypertension or diabetes using a questionnaire. However, we could not assess the information regarding the history of treatment for dyslipidemia.

To minimize the effect of previous treatment for metabolic syndrome, we conducted a subgroup analysis among those who had never taken medications for hypertension or diabetes (Table 6A, Table 6B, Table 6C). The results were in accordance with those of the main analysis, which showed an inverse association between cardiorespiratory fitness and metabolic syndrome compared to the reference with low level of fitness, with an aOR of 0.55 (95% CI: 0.51−0.60) in the moderate fitness group and 0.43 (95% CI: 0.40−0.47) in the high fitness group in model 1 and 0.68 (95% CI: 0.63−0.74) and 0.66 (95% CI: 0.60−0.72) in model 2 among overall population. In the subgroup analysis classified based on sex, the results were consistent with those of the main analysis. Further evaluation considering information regarding the treatment of dyslipidemia is required validate the original findings.

Table 6A. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome among those who have never taken medications of hypertension or diabetes.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Sex (Female)	0.51	(0.48 0.54)	0.43	(0.39 0.47)	0.10	(0.09 0.11)
Age (1−year difference)	1.01	(1.01 1.02)	1.01	(1.00 1.01)	1.00	(1.00 1.01)
VO_{2max} (ml/kg/min)						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.72	(0.67 0.77)	0.55	(0.51 0.60)	0.68	(0.63 0.74)
High (>28)	0.65	(0.60 0.70)	0.43	(0.40 0.47)	0.66	(0.60 0.72)
Smoking						
Non−smoker	1.00		1.00		1.00	
Ex−smoker	1.68	(1.56 1.81)	1.11	(1.00 1.22)	1.10	(0.99 1.22)
Current smoker	1.60	(1.50 1.72)	1.16	(1.06 1.28)	1.28	(1.15 1.42)
Regular drinker	1.34	(1.26 1.43)	1.07	(0.99 1.15)	0.98	(0.90 1.06)
Regular exerciser	0.92	(0.86 0.98)	1.00	(0.94 1.06)	0.92	(0.86 0.99)
Family history of cardiovascular disease	0.84	(0.72 0.98)	0.84	(0.72 0.99)	0.75	(0.64 0.89)
Fat ratio (%)	1.09	(1.09 1.10)			1.23	(1.22 1.24)

Table 6B. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome among those who have never taken medications of hypertension or diabetes in men.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Age (1-year difference)	1.00	(0.99 1.00)	0.99	(0.99 1.00)	0.99	(0.99 1.00)
VO_{2max} (ml/kg/min)						
Low (≤21)	1.00		1.00			
Moderate (21-28)	0.62	(0.56 0.68)	0.60	(0.55 0.66)	0.71	(0.64 0.78)
High (>28)	0.48	(0.44 0.53)	0.45	(0.41 0.49)	0.66	(0.60 0.73)
Smoking						
Non-smoker	1.00		1.00			
Ex-smoker	1.18	(1.06 1.32)	1.19	(1.07 1.33)	1.16	(1.03 1.31)
Current smoker	1.14	(1.03 1.26)	1.16	(1.04 1.29)	1.27	(1.13 1.42)
Regular drinker	1.17	(1.07 1.27)	1.18	(1.08 1.29)	1.06	(0.96 1.16)
Regular exerciser	1.04	(0.96 1.11)	1.10	(1.02 1.18)	0.99	(0.91 1.07)
Family history of cardiovascular disease	0.93	(0.77 1.11)	0.90	(0.74 1.08)	0.79	(0.65 0.97)
Fat ratio (%)	1.21	(1.20 1.22)			1.21	(1.19 1.22)

Table 6C. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome among those who have never taken medications of hypertension or diabetes in women.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Age (1−year difference)	1.06	(1.05 1.07)	1.05	(1.05 1.06)	1.02	(1.02 1.03)
VO_{2max} (ml/kg/min)						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.44	(0.39 0.51)	0.58	(0.50 0.67)	0.72	(0.62 0.83)
High (>28)	0.26	(0.21 0.32)	0.36	(0.29 0.46)	0.57	(0.45 0.72)
Smoking						
Non−smoker	1.00		1.00		1.00	
Ex−smoker	0.80	(0.58 1.10)	1.12	(0.79 1.58)	0.94	(0.64 1.36)
Current smoker	0.67	(0.50 0.89)	1.07	(0.79 1.45)	1.23	(0.89 1.69)
Regular drinker	0.67	(0.59 0.77)	0.95	(0.82 1.10)	0.87	(0.75 1.01)
Regular exerciser	0.79	(0.71 0.88)	0.84	(0.75 0.94)	0.84	(0.74 0.94)
Family history of cardiovascular disease	0.72	(0.54 0.95)	0.74	(0.55 1.00)	0.69	(0.51 0.94)
Fat ratio (%)	1.09	(1.09 1.10)			1.27	(1.25 1.28)

Abbreviations: OR, prevalent odds ratio; CI, confidence interval; aOR, adjusted prevalent odds ratio.

Model 1 and 2 are multivariate analysis model adjusted for each following variables including VO_{2max};

Model 1: age, smoking status, alcohol intake, physical activity, and family history of cardiovascular disease;

Model 2: model 1+ body fat ratio.

3.7. Association between cardiorespiratory fitness and metabolic syndrome using waist circumference

In addition to considering the current history for the intake of medications for hypertension, diabetes, or dyslipidemia for the diagnosis of metabolic syndrome, waist circumference has been used as an important marker of central obesity. The NCEP ATP III, IDF, and EGIR included waist circumference as a diagnostic criterion for metabolic syndrome. Information about waist circumference was available in our database from 2002 to 2008 (N=17,904). Thus, we performed a subgroup analysis by setting the waist circumference instead of BMI for the definition of obesity. Abdominal obesity was defined as a waist circumference ≥90 cm in men and ≥85 cm in women.

The results were consistent with those of the main analysis. In men, the adjusted pORs were 0.59 (95% CI: 0.51−0.66) in the moderate fitness group and 0.46 (95% CI: 0.40−0.52) in the high fitness group in model 1 and 0.70 (95% CI: 0.60−0.80) and 0.69 (95% CI: 0.60−0.78) in model 2 (Table 7B). Likewise, the adjusted pORs were 0.67 (95% CI: 0.57−0.79) in the moderate fitness group and 0.46 (95% CI: 0.37−0.57) in the high fitness group in model 1 and 0.77 (95% CI: 0.65−0.91) and 0.65 (95% CI: 0.51−0.82) in model 2 in women.

Table 7A. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome using waist circumference.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Sex (Female)	0.72	(0.67 0.78)	0.74	(0.66 0.84)	0.14	(0.12 0.17)
Age (1−year difference)	1.03	(1.03 1.04)	1.03	(1.02 1.03)	1.02	(1.02 1.03)
VO_{2max} (ml/kg/min)						
Low (≤21)	1.00		1.00		1.00	
Moderate (21−28)	0.63	(0.58 0.69)	0.57	(0.52 0.63)	0.70	(0.63 0.78)
High (>28)	0.54	(0.49 0.58)	0.46	(0.41 0.51)	0.69	(0.61 0.77)
Smoking						
Non−smoker	1.00		1.00		1.00	
Ex−smoker	1.34	(1.22 1.47)	1.20	(1.06 1.36)	1.16	(1.01 1.33)
Current smoker	1.36	(1.24 1.49)	1.52	(1.34 1.72)	1.75	(1.52 2.00)
Regular drinker	1.10	(1.02 1.19)	1.09	(0.99 1.19)	1.04	(0.94 1.16)
Regular exerciser	0.92	(0.84 1.00)	0.96	(0.88 1.05)	0.91	(0.82 1.00)
Family history of cardiovascular disease	1.12	(0.98 1.28)	1.08	(0.93 1.25)	1.03	(0.88 1.21)
Fat ratio (%)	1.13	(1.13 1.14)			1.27	(1.26 1.29)

Table 7B. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome using waist circumference in men.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Age (1−year difference)	1.01	(1.00 1.01)	1.08	(1.07 1.09)	1.01	(1.01 1.02)
VO_{2max} (ml/kg/min)						
Low (≤21)			1.00			
Moderate (21−28)	0.59	(0.53 0.67)	0.67	(0.57 0.79)	0.70	(0.60 0.80)
High (>28)	0.48	(0.43 0.53)	0.46	(0.37 0.57)	0.69	(0.60 0.78)
Smoking						
Non−smoker			1.00			
Ex−smoker	1.29	(1.13 1.48)	1.17	(0.78 1.75)	1.24	(1.07 1.45)
Current smoker	1.31	(1.15 1.50)	1.51	(1.06 2.16)	1.73	(1.49 2.03)
Regular drinker	1.15	(1.03 1.29)			1.11	(0.98 1.26)
Regular exerciser	0.99	(0.88 1.10)	1.06	(0.89 1.25)	0.94	(0.83 1.06)
Family history of cardiovascular disease	1.18	(0.99 1.39)	0.89	(0.76 1.05)	1.08	(0.89 1.32)
Fat ratio (%)	1.28	(1.26 1.30)	0.97	(0.76 1.25)	1.28	(1.26 1.30)

Table 7C. Logistic regression analysis between cardiorespiratory fitness and metabolic syndrome using waist circumference in women.

	Unadjusted		Model 1		Model 2	
	OR	(95% CI)	aOR	(95% CI)	aOR	(95% CI)
Age (1−year difference)	1.08	(1.08 1.09)	1.01	(1.00 1.01)	1.06	(1.05 1.07)
VO_{2max} (ml/kg/min)						
Low (≤21)			1.00			
Moderate (21−28)	0.51	(0.45 0.59)	0.59	(0.51 0.66)	0.77	(0.65 0.91)
High (>28)	0.32	(0.26 0.39)	0.46	(0.40 0.52)	0.65	(0.51 0.82)
Smoking						
Non−smoker			1.00			
Ex−smoker	0.71	(0.49 1.03)	1.31	(1.14 1.50)	1.02	(0.66 1.57)
Current smoker	0.78	(0.56 1.08)	1.46	(1.27 1.69)	1.65	(1.13 2.40)
Regular drinker	0.65	(0.55 0.75)			1.01	(0.84 1.21)
Regular exerciser	0.87	(0.75 1.00)	1.18	(1.05 1.33)	0.87	(0.73 1.03)
Family history of cardiovascular disease	1.05	(0.84 1.30)	1.02	(0.91 1.14)	0.96	(0.74 1.25)
Fat ratio (%)	1.28	(1.26 1.30)	1.14	(0.95 1.37)	1.25	(1.22 1.27)

Abbreviations: OR, prevalent odds ratio; CI, confidence interval; aOR, adjusted prevalent odds ratio.

Model 1 and 2 are multivariate analysis model adjusted for each following variables including VO_{2max};

Model 1: age, smoking status, alcohol intake, physical activity, and family history of cardiovascular disease;

Model 2: model 1+ body fat ratio.

4. Discussion

4.1 Results summary and Discussion

The present study investigated the association between cardiorespiratory fitness and metabolic syndrome in Korean adults. The results show the inverse association between cardiorespiratory fitness and metabolic syndrome. Moreover, a dose-response relationship between cardiorespiratory fitness and metabolic syndrome in both sexes and all age groups was observed. Thus, maintaining a high level of fitness is important in preventing metabolic syndrome. Male participants are more likely to have a high fitness than the female participants. Thus, the current study evaluated the effect of cardiorespiratory fitness on metabolic syndrome according to both sexes.

Cardiorespiratory fitness has been associated with several attributable factors, such as age, sex, heredity, adiposity, muscle mass, fat obesity, CVD, smoking, alcohol consumption, physical activity, and medications (46-53). So, we conducted multivariate logistic analysis with adjustment of age, sex, life−style factors such as smoking, alcohol consumption, physical activity and family history of cardiovascular diseases in model 1 and same variables with model 1 plus body fat ratio in model 2. The inverse association was consistent in both of model 1 and model 2 among overall population and subgroup analysis divided into sex.

Moreover, age is an important determinant of cardiorespiratory fitness (38, 39). Thus, we conducted an additional analysis stratified by age groups according to sex. The relationship remained generally significant. The association was more evident in younger aged group. To show the association between cardiorespiratory fitness and each components of metabolic syndrome, we performed another regression analysis of obesity, high blood pressure, impaired fasting glucose, hypertriglyceridemia, and low HDL cholesterol level. All metabolic components were inversely associated with the level of $VO_{2max,}$ and the strength of the association was the highest in individuals with high blood pressure, which was most prevalent component in metabolic abnormalities among the total population.

Our current findings were consistent with that of previous studies.(32−36, 43, 44, 54) A dose−response relationship was observed between cardiorespiratory fitness and metabolic syndrome in both sexes and all age groups, and this result showed that a high level of cardiorespiratory fitness would reduce the risk of developing metabolic syndrome.

Physical activity appears is the most powerful contributor to cardiorespiratory fitness. (55) Aerobic training can improve an individual's VO_{2max} in the range of 15% to 25% in healthy adults. (56, 57) However, even in healthy adults, bed rest for 3 weeks has been shown to reduce VO_{2max} by 26%. (58) Thus, encouraging physical activity with exercise training can be a best strategy to enhance the level of cardiorespiratory fitness. Lin et al. (59) demonstrated that moderate and vigorous exercise training significantly improved cardiorespiratory fitness and some cardiometabolic biomarkers. Exercise training improves cardiorespiratory fitness via increases in stroke volume and arteriovenous O2 difference. An increase in muscle capillary density enable to increase mean transit time of oxygen diffusion during endurance−type exercise. (60) It is also related to an increases in the size and number of skeletal muscle mitochondria and oxidative enzymes. (61)

Nevertheless, cardiorespiratory fitness is more than a marker of physical activity. Animal and human studies have shown that cardiorespiratory fitness is a stronger predictor of cardiovascular disease compared to physical activity alone. (25, 62, 63) Physical activity can vary from day to day, whereas cardiorespiratory fitness remains relatively static. (64) Cardiorespiratory reflects the maximal capacity for oxygen consumption and acquires time to change. In fact, CRF is determined by the result of interaction among environmental, constitutional, and genetic factors. (57) Smoking habit and an individual's adiposity and muscle mass can impact the cardiorespiratory fitness. (65) Moreover, genetic variations determine a person's VO_{2max} and account for 40 to 50% in the VO_{2max} change in response to sustained exercise training. (66)

Thus, our results suggest that public health strategies for the improvement of cardiorespiratory fitness and maintenance of high level of fitness are crucial in the prevention of metabolic syndrome. The American Heart Association proposed that cardiorespiratory fitness should be routinely assessed in clinical practice and encouraged to increase the awareness of individuals about the added value of cardiorespiratory fitness to improve the prediction of cardiovascular risk. (37) Cardiorespiratory fitness as a screening test can be possible with regular health check-ups or national health mandatory screenings. Although a direct measurement of cardiorespiratory fitness is the most accurate, an indirect but easily accessible method, such as a 3-step test, had already been validated and useful in real clinical settings.(20, 21) When an individual is suspected with impaired fasting glucose, high blood pressure, or dyslipidemia, they should receive an advisory opinion from a doctor regarding suggestions for maintaining healthy lifestyle and a recommendation for follow-up. In addition, when an individual is suspected with low level of fitness, then such individual should be encouraged to do regular exercise to enhance fitness level. Moreover, public health interventions including not only regular physical activity but other modifiable risk factors such as dietary or alcohol consumption or smoking problem can be recommended for all adults through assessing an individual's level of cardiorespiratory fitness.

Our study had several limitations. First, this is a cross-sectional study. Thus, we cannot validate causality between cardiorespiratory fitness and metabolic syndrome. Second, we were not able to consider the detailed information regarding physical activity, including aerobic or nonaerobic exercise, intensity, or duration. Numerous studies have shown that physical activity is associated with cardiorespiratory fitness. However, recent studies have suggested that cardiorespiratory fitness can predict cardiometabolic risk factor compared to physical activity alone. Third, a previous diagnosis of dyslipidemia and waist circumference for the definition of metabolic syndrome were not considered. However, a subgroup analysis among those who never took medications for hypertension and diabetes have shown results that were consistent with those of the main analysis. Meanwhile, a subgroup analysis that considered waist circumference as a definition of obesity for metabolic syndrome has revealed similar results.

4.2. Conclusion

This study showed a significant inverse association between cardiorespiratory fitness and metabolic syndrome in Korean adults.

The participants with high level of fitness were less likely to have metabolic syndrome. The results were clear and significant in both sexes and various age groups. The present study suggests that the public health interventions, including regular physical activity, are recommended to enhance fitness among all adults. Moreover, regular screening of cardiorespiratory fitness could be considered in predicting metabolic risks. Further prospective studies must be conducted to validate our findings.

References

1. Grundy SM, BryanBrewer Jr H, Cleeman JI, Smith Jr SC. Definition of metabolic syndrome. Circulation. 2004.

2. Reaven GM. Banting lecture 1988: role of insulin resistance in human disease. Nutrition. 1997;13(1):64.

3. Kaplan NM. The deadly quartet: upper-body obesity, glucose intolerance, hypertriglyceridemia, and hypertension. Archives of internal medicine. 1989;149(7):1514-20.

4. Lee S, Han K, Kang Y, Kim S, Cho Y, Ko K, et al. Taskforce Team of Diabetes Fact Sheet of the Korean Diabetes Association. Trends in the prevalence of metabolic syndrome and its components in South Korea: findings from the Korean National Health Insurance Service Database (2009-2013). PLoS One. 2018;13(3):e0194490.

5. Mottillo S, Filion KB, Genest J, Joseph L, Pilote L, Poirier P, et al. The metabolic syndrome and cardiovascular risk: a systematic review and meta-analysis. Journal of the American College of Cardiology. 2010;56(14):1113-32.

6. Boden-Albala B, Sacco RL, Lee H-S, Grahame-Clarke C, Rundek T, Elkind MV, et al. Metabolic syndrome and ischemic stroke risk: Northern Manhattan Study. Stroke. 2008;39(1):30-5.

7. Esposito K, Chiodini P, Colao A, Lenzi A, Giugliano D. Metabolic syndrome and risk of cancer: a systematic review and meta-analysis. Diabetes care. 2012;35(11):2402-11.

8. Welzel TM, Graubard BI, Zeuzem S, El- Serag HB, Davila JA, McGlynn KA. Metabolic syndrome increases the risk of primary liver cancer in the United States: a study in the SEER- Medicare database. Hepatology. 2011;54(2):463-71.

9. Ahmed RL, Schmitz KH, Anderson KE, Rosamond WD, Folsom AR. The metabolic syndrome and risk of incident colorectal cancer. Cancer: Interdisciplinary International Journal of the American Cancer Society. 2006;107(1):28-36.

10. Russo A, Autelitano M, Bisanti L. Metabolic syndrome and cancer risk. European Journal of Cancer. 2008;44(2):293-7.

11. Rosato V, Bosetti C, Talamini R, Levi F, Montella M, Giacosa A, et al. Metabolic syndrome and the risk of breast cancer in postmenopausal women. Annals of Oncology. 2011;22(12):2687-92.

12. Maiti B, Kundranda M, Spiro T, Daw H. The association of metabolic syndrome with triple-negative breast cancer. Breast cancer research and treatment. 2010;121(2):479-83.

13. Agnoli C, Berrino F, Abagnato CA, Muti P, Panico S, Crosignani P, et al. Metabolic syndrome and postmenopausal breast cancer in the ORDET cohort: a nested case-control study. Nutrition, Metabolism and Cardiovascular Diseases. 2010;20(1):41-8.

14. Vona- Davis L, Howard- McNatt M, Rose D. Adiposity, type 2 diabetes and the metabolic syndrome in breast cancer. Obesity Reviews. 2007;8(5):395-408.

15. Rosato V, Zucchetto A, Bosetti C, Dal Maso L, Montella M, Pelucchi C, et al. Metabolic syndrome and endometrial cancer risk. Annals of oncology. 2010;22(4):884-9.

16. Grundmark B, Garmo H, Loda M, Busch C, Holmberg L, Zethelius B. The metabolic syndrome and the risk of prostate cancer under competing risks of death from other causes. Cancer Epidemiology and Prevention Biomarkers. 2010:1055-9965. EPI-10-0112.

17. Schmidt C, Bergström GM. The metabolic syndrome predicts cardiovascular events: results of a 13-year follow-up in initially healthy 58-year-old men. Metabolic syndrome and related disorders. 2012;10(6):394-9.

18. Williford HN, Sport K, Wang N, Olson MS, Blessing D. The

prediction of fitness levels of United States Air Force officers: validation of cycle ergometry. Military medicine. 1994;159(3):175-8.

19. Jones NL, Makrides L, Hitchcock C, Chypchar T, McCartney N. Normal standards for an incremental progressive cycle ergometer test. American Review of Respiratory Disease. 1985;131(5):700-8.

20. Francis K. Fitness assessment using step tests. Comprehensive therapy. 1987;13(4):36-41.

21. Mcardle WD, Katch FI, Pechar GS, Jacobson L, Ruck S. Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. Medicine and science in sports. 1972;4(4):182-6.

22. Myers J, McAuley P, Lavie CJ, Despres J-P, Arena R, Kokkinos P. Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. Progress in cardiovascular diseases. 2015;57(4):306-14.

23. Blair SN. Physical inactivity: the biggest public health problem of the 21st century. British journal of sports medicine.

2009;43(1):1-2.

24. Kokkinos P, Myers J. Exercise and physical activity: clinical outcomes and applications. Circulation. 2010;122(16):1637-48.

25. Swift DL, Lavie CJ, Johannsen NM, Arena R, Earnest CP, O'Keefe JH, et al. Physical activity, cardiorespiratory fitness, and exercise training in primary and secondary coronary prevention. Circulation Journal. 2013;77(2):281-92.

26. Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. Jama. 2009;301(19):2024-35.

27. Peel JB, Sui X, Matthews CE, Adams SA, Hébert JR, Hardin JW, et al. Cardiorespiratory fitness and digestive cancer mortality: findings from the aerobics center longitudinal study. Cancer Epidemiology and Prevention Biomarkers. 2009;18(4):1111-7.

28. Sui X, Lee D-c, Matthews CE, Adams SA, Hébert JR, Church TS, et al. The influence of cardiorespiratory fitness on lung cancer mortality. Medicine and science in sports and exercise. 2010;42(5):872.

29. Thompson AM, Church TS, Janssen I, Katzmarzyk PT, Earnest CP, Blair SN. Cardiorespiratory fitness as a predictor of cancer mortality among men with pre-diabetes and diabetes. Diabetes care. 2008;31(4):764-9.

30. Peel JB, Sui X, Adams SA, Hébert JR, Hardin JW, Blair SN. A prospective study of cardiorespiratory fitness and breast cancer mortality. Medicine and science in sports and exercise. 2009;41(4):742.

31. Schmid D, Leitzmann M. Cardiorespiratory fitness as predictor of cancer mortality: a systematic review and meta-analysis. Annals of oncology. 2014;26(2):272-8.

32. Lee D-c, Sui X, Church TS, Lee I-M, Blair SN. Associations of cardiorespiratory fitness and obesity with risks of impaired fasting glucose and type 2 diabetes in men. Diabetes care. 2009;32(2):257-62.

33. Sieverdes JC, Sui X, Lee D-c, Church TS, McClain A, Hand GA, et al. Physical activity, cardiorespiratory fitness and the incidence of type 2 diabetes in a prospective study of men. British journal of sports medicine. 2010;44(4):238-44.

34. Earnest CP, Artero EG, Sui X, Lee D-c, Church TS, Blair SN,

editors. Maximal estimated cardiorespiratory fitness, cardiometabolic risk factors, and metabolic syndrome in the aerobics center longitudinal study. Mayo Clinic Proceedings; 2013: Elsevier.

35. Sui X, Hooker SP, Lee I-M, Church TS, Colabianchi N, Lee C-D, et al. A prospective study of cardiorespiratory fitness and risk of type 2 diabetes in women. Diabetes care. 2008;31(3):550-5.

36. Knaeps S, Bourgois JG, Charlier R, Mertens E, Lefevre J, Wijndaele K. Ten-year change in sedentary behaviour, moderate-to-vigorous physical activity, cardiorespiratory fitness and cardiometabolic risk: independent associations and mediation analysis. Br J Sports Med. 2018;52(16):1063-8.

37. Ross R, Blair SN, Arena R, Church TS, Després J-P, Franklin BA, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. Circulation. 2016:CIR. 0000000000000461.

38. Jackson AS, Sui X, O'Connor DP, Church TS, Lee D-c, Artero EG, et al. Longitudinal cardiorespiratory fitness algorithms

for clinical settings. American journal of preventive medicine. 2012;43(5):512-9.

39. Nes BM, Janszky I, Vatten LJ, Nilsen T, Aspenes ST, Wisloff U. Estimating VO 2peak from a nonexercise prediction model: the HUNT Study, Norway. Med Sci Sports Exerc. 2011;43(11):2024-30.

40. Sanders LF, Duncan GE. Population-based reference standards for cardiovascular fitness among US adults: NHANES 1999-2000 and 2001-2002. Medicine and science in sports and exercise. 2006;38(4):701-7.

41. Duncan GE, Li SM, Zhou X-h. Cardiovascular fitness among US adults: NHANES 1999-2000 and 2001-2002. Medicine and science in sports and exercise. 2005;37(8):1324-8.

42. Pandey A, Park BD, Ayers C, Das SR, Lakoski S, Matulevicius S, et al. Determinants of racial/ethnic differences in cardiorespiratory fitness (from the Dallas Heart Study). The American journal of cardiology. 2016;118(4):499-503.

43. Hong S, Lee J, Park J, Lee M, Kim JY, Kim K-C, et al. Association between cardiorespiratory fitness and the prevalence of metabolic syndrome among Korean adults: a cross sectional study.

BMC public health. 2014;14(1):481.

44. Kim S, Kim J-Y, Lee D-C, Lee H-S, Lee J-W, Jeon JY. Combined impact of cardiorespiratory fitness and visceral adiposity on metabolic syndrome in overweight and obese adults in Korea. PloS one. 2014;9(1):e85742.

45. Kang S-J, Ha G-C, Ko K-J. Association between resting heart rate, metabolic syndrome and cardiorespiratory fitness in Korean male adults. Journal of Exercise Science & Fitness. 2017;15(1):27-31.

46. Leon AS, JACOBS Jr DR, DEBACKER G, TAYLOR HL. Relationship of physical characteristics and life habits to treadmill exercise capacity. American Journal of Epidemiology. 1981;113(6):653-60.

47. Kohl HW, Blair SN, PAFFENBARGER Jr RS, Macera CA, Kronenfeld JJ. A mail survey of physical activity habits as related to measured physical fitness. American journal of epidemiology. 1988;127(6):1228-39.

48. . !!! INVALID CITATION !!! {}.

49. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise standards for testing and training: a

statement for healthcare professionals from the American Heart Association. Circulation. 2001;104(14):1694-740.

50. Bouchard C, Boulay MR, Simoneau J-A, Lortie G, Pérusse L. Heredity and Trainability of Aerobic and Anaerobic Performances an Update. Sports Medicine. 1988;5(2):69-73.

51. Rankinen T, PÉrusse L, Rauramaa R, Rivera MA, Wolfarth B, Bouchard C. The human gene map for performance and health-related fitness phenotypes. Medicine and Science in Sports and Exercise. 2001;33(6):855-67.

52. Blair SN, Kannel WB, Kohl HW, Goodyear N, Wilson PW. Surrogate measures of physical activity and physical fitness: evidence for sedentary traits of resting tachycardia, obesity, and low vital capacity. American journal of epidemiology. 1989;129(6):1145-56.

53. Sandvik L, Erikssen G, Thaulow E. Long term effects of smoking on physical fitness and lung function: a longitudinal study of 1393 middle aged Norwegian men for seven years. Bmj. 1995;311(7007):715-8.

54. Kelley E, Imboden MT, Harber MP, Finch H, Kaminsky LA,

Whaley MH. Cardiorespiratory Fitness Is Inversely Associated With Clustering of Metabolic Syndrome Risk Factors: The Ball State Adult Fitness Program Longitudinal Lifestyle Study. Mayo Clinic Proceedings: Innovations, Quality & Outcomes. 2018;2(2):155-64.

55. Carrick-Ranson G, Hastings JL, Bhella PS, Fujimoto N, Shibata S, Palmer MD, et al. The effect of lifelong exercise dose on cardiovascular function during exercise. Journal of Applied Physiology. 2014;116(7):736-45.

56. Skinner JS, Wilmore KM, Krasnoff JB, JaskÓlski A, JaskÓlska A, Gagnon J, et al. Adaptation to a standardized training program and changes in fitness in a large, heterogeneous population: the HERITAGE Family Study. Medicine and science in sports and exercise. 2000;32(1):157-61.

57. Bouchard C, Sarzynski MA, Rice TK, Kraus WE, Church TS, Sung YJ, et al. Genomic predictors of the maximal O2 uptake response to standardized exercise training programs. Journal of applied physiology. 2010;110(5):1160-70.

58. Saltin B. Response to exercise after bed rest and after training. Circulation. 1968;38:1-78.

59. Lin X, Zhang X, Guo J, Roberts CK, McKenzie S, Wu WC, et al. Effects of exercise training on cardiorespiratory fitness and biomarkers of cardiometabolic health: a systematic review and meta- analysis of randomized controlled trials. Journal of the American Heart Association. 2015;4(7):e002014.

60. Saltin B. Hemodynamic adaptations to exercise. American Journal of Cardiology. 1985;55(10):D42-D7.

61. Holloszy JO, Booth FW. Biochemical adaptations to endurance exercise in muscle. Annual review of physiology. 1976;38(1):273-91.

62. Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? Medicine & Science in Sports & Exercise. 2001;33(6):S379-S99.

63. Myers J, Kaykha A, George S, Abella J, Zaheer N, Lear S, et al. Fitness versus physical activity patterns in predicting mortality in men. The American journal of medicine. 2004;117(12):912-8.

64. Steele RM, Brage S, Corder K, Wareham NJ, Ekelund U. Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. Journal of Applied Physiology. 2008;105(1):342-51.

65. Suminski RR, Wier LT, Poston W, Arenare B, Randles A, Jackson AS. The effect of habitual smoking on measured and predicted VO2max. Journal of Physical Activity and Health. 2009;6(5):667-73.

66. Bouchard C, An P, Rice T, Skinner JS, Wilmore JH, Gagnon J, et al. Familial aggregation ofV o 2 max response to exercise training: results from the HERITAGE Family Study. Journal of applied physiology. 1999;87(3):1003-8.

국문초록

한국인에서 심폐 체력과 대사증후군의 연관성 연구

배예슬

보건학과 역학전공

서울대학교 보건대학원

연구배경 대사증후군의 유병률은 전세계적으로 지속적으로 증가하고 있다. 대사증후군은 심혈관 질환, 뇌졸중, 그리고 여러 종류의 암의 주요 위험인자로 작용한다. 심폐체력은 지속적인 신체활동을 하는 동안 순환계와 호흡계로 산소를 공급하는 능력을 반영한다. 심폐체력은 보통 최대산소섭취량 (VO_{2max}) 으로 표현한다. 심폐체력의 대사증후군의 위험을 약화시킨다는 것은 기존의 연구를 통해 잘 알려져 있다. 그러나 남녀와 다양한 연령층을 반영한 아시아 인구를 대상으로 한 연구는 거의 보고되지 않았다. 따라서 본 연구에서는 한국 성인을 대상으로 심폐체력과 대사증후군의 연관성을 보고자 한다.

방법 본 연구는 서울대학교병원 건강증진센터 검진 자료를 토대로 단면연구로 수행되었다. 건강검진을 받은 수진자 중 20세 이상이며

심폐체력을 측정한 총 43,369명이 연구에 최종적으로 포함되었다. 최대산소섭취량은 저등도 VO_{2max} ≤ 21 mL/kg/min), 중등도 (21 mL/kg/min < VO_{2max} ≤ 28 mL/kg/min) 또는 고등도 (VO_{2ma}x >28 mL/kg/min)로 분류하였다. 심폐체력과 대사증후군의 연관성을 분석하기 위해 다변량 로지스틱 회귀모형을 사용하여 오즈비 (Prevalent odds ratio, pOR)를 산출하였다. 또한 남녀와 연령군에 따른 층화분석을 추가로 수행하였다.

결과 약 17.37%의 연구 대상자가 대사증후군을 가지고 있었으며, 남성에서는 20.94%, 여성에서는 12.55%의 유병률을 보였다. 대사 위험인자 중에서는 고혈압 (high blood pressure)의 유병률 (47.77%)이 가장 높았다. 다변량 로지스틱 회귀 분석 결과, 연령, 성별, 흡연력, 음주 섭취, 신체활동, 심뇌혈관질환의 가족력을 보정한 모델 1에서는 중등도 심폐체력군에서는 adjusted pOR 0.59 (95% confidence interval [CI]: 0.55–0.63), 고등도 심폐체력군에서는 adjusted pOR 0.47 (95% CI: 0.44–0.50)을 보였다. 모델 1의 변수에 총 체지방량(%)을 포함하여 보정한 모델 2에서는 중등도 심폐체력군에서는 adjusted pOR 0.72 (95% CI: 0.67–0.77), 고등도 심폐체력군에서는 adjusted pOR 0.70(95% CI: 0.65–0.76)을 보였다. 즉, 심폐체력이 좋은 군일수록 OR값이 작아지는 경향성이 관찰되었다. 또한 남녀 및 연령군으로 층화 하였을 때도 동일한

경향성을 보였다.

결론 본 연구에서는 심폐체력과 대사증후군과의 유의한 역연관성이 관찰되었다. 즉, 심폐체력이 좋을 수록 대사증후군을 덜 가지고 있는 것으로 보인다. 또한 남녀 및 연령군으로 층화하였을 때도 동일한 결과를 보였다. 본 연구의 결과는 추후 다른 전향적인 코호트 연구를 사용하여 연관성을 더욱 확실히 알 수 있는 후속 연구를 제안해 볼 수 있다.

주요어: 심폐 체력, 대사증후군, 대사 위험인자, 신체 활동, 비만, 고혈압, 이상지질혈증, 내당능 장애

학번: 2016-24006