

The impact of educational attainment on cardiorespiratory fitness and metabolic syndrome in Korean adults

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Abstract

The aim of this study was to evaluate the relationship between educational attainment and cardiorespiratory fitness (CRF) as a predictor of metabolic syndrome in a Korean population.

In this single-center, retrospective cross-sectional study, 988 healthy adults (601 men and 387 women) who underwent regular health check-up in Seoul St. Mary's Hospital were analyzed. Educational attainment was categorized into 3 groups according to their final grade of educational course: middle or high school (≤ 12 years of education), college or university (12–16 years of education), and postgraduate (≥ 16 years of education). CRF was assessed by cardiopulmonary exercise testing, biceps strength, hand grip strength, bioelectrical impedance analysis, and echocardiography. Metabolic syndrome was diagnosed according to the 3rd report of the National Cholesterol Education Program.

Among the subjects, 357 (36.1%) had metabolic syndrome. The postgraduate group had significantly higher peak oxygen consumption (VO_2), biceps strength, hand grip strength, and peak expiratory flow than other groups (all $P < .001$). This group showed better left ventricular diastolic function, in terms of deceleration time of mitral inflow, maximal tricuspid valve regurgitation velocity, and left atrial volume index than other groups. Peak VO_2 (%) was significantly correlated with all the parameters of metabolic syndrome, including insulin resistance ($r = -0.106$, $P = .002$), waist circumference ($r = -0.387$, $P < .001$), triglyceride ($r = -0.109$, $P = .001$), high density lipoprotein-cholesterol ($r = 0.219$, $P < .001$), systolic blood pressure ($r = -0.143$, $P < .001$), and diastolic blood pressure ($r = -0.177$, $P < .001$). And Peak VO_2 (%) was found to be a predictor of metabolic syndrome (adjusted $\beta = .988$, $P < .001$). However, the level of education was not able to predict metabolic syndrome (postgraduate group; $\beta = .955$, $P = .801$).

Although the postgraduate group had better CRF than other groups, the educational attainment could not exclusively predict metabolic syndrome in this study. Further research is needed to reveal the socioeconomic mechanism of developing metabolic syndrome.

Abbreviations: BMI = body mass index, CRF = cardiorespiratory fitness, DT = deceleration time, HDL-cholesterol = high-density lipoprotein cholesterol, HOMA-IR = homeostatic model assessment insulin resistance, LA = left atrium, LDL-cholesterol = low-density lipoprotein-cholesterol, LV = left ventricular, OECD = Organization for Economic Co-operation and Development, VO_2 = oxygen consumption.

Keywords: cardiorespiratory fitness, education, metabolic syndrome, peak oxygen consumption

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1. Introduction

Health risks are usually higher among groups with lower education and socioeconomic status.^[1,2] Lifestyle-related factors play a pivotal role in the clinical management of metabolic syndrome,^[3] and those factors, including physical activity, smoking behavior, and dietary habit, are primarily determined by the social learning process during an individual's lifetime.^[4] The association between socioeconomic status and metabolic syndrome of cardiovascular mortality has been well described.^[1,2] The level of education has been extensively used as an indicator of overall socioeconomic status, and it has been suggested as the most constant determinant among the components; it can be measured with much accuracy, and it affects various socioeconomic factors robust over the lifespan.^[5,6] As recent studies reported that parental education affected their offspring's risk of cardiovascular disease, education became so essential to improving both individual and public health.^[7-9] Nonetheless, few studies had examined educational attainment to cardiorespiratory fitness (CRF) and metabolic syndrome.^[10-12] This study aims to assess the relationship between the level of education and CRF, which can explain the mechanism of the development of metabolic syndrome in a Korean population.

2. Material and methods

2.1. Subjects and study design

This study was conducted at the health promotion center in Seoul St. Mary's hospital in South Korea during 2009 to 2018. In this retrospective cross-sectional study, a total of 1164 asymptomatic healthy Korean subjects aged ≥ 25 who underwent a cardiopulmonary exercise test as part of cardiovascular health surveillance program were identified automatically from electronic medical records. Of these literate subjects, 101 were excluded with the following reasons: self-administered questionnaires (Supplement 1, <http://links.lww.com/MD/E78>) were not completed; or having a history of proven coronary or peripheral artery disease, and cerebrovascular disease; or having a history of lung disease, including chronic obstructive pulmonary disease, asthma, and pulmonary tuberculosis; or foreign residents in Korea. A total of 988 subjects were included in the final analysis of this study. The institutional committee of the Catholic medical center approved the study protocol (KC18RESE0823).

In the questionnaires, the subjects were asked to provide information about their components of socioeconomic status, including the level of education, annual family income, smoking status, and physical activity. The subjects were classified into 3 groups based on their final educational level; middle/high school (≤ 12 years of education), college or university (12–16 years of education), and postgraduate (≥ 16 years of education). Annual family income was categorized into 3 classes: low-income class ($< \$30,000$), middle class (between $\$30,000$ and $\$100,000$), and high-income class ($> \$100,000$) according to Organization for Economic Co-operation and Development (OECD) database.^[13] Smoking status was categorized into 3 groups: never-smoker, former smoker, and current smoker. Physical activity was categorized into 3 groups depending on the frequency of moderate intensity exercise in a week (none, once or twice, and three times or more).

2.2. Measurements

Weight and height were measured using digital balance with the participant wearing indoor clothing without shoes, and body mass index (BMI, kg/m^2) was calculated. Waist circumference

was measured at the narrowest region between the lower margin of the rib cage and the iliac crest in a standing position. Hip circumference was measured at the maximum circumference over the buttocks. Blood pressure was measured in a sitting position using an automated blood pressure monitoring device (TM-2665P, A&D Co., Ltd., Tokyo, Japan) with an appropriate-sized cuff. Body composition was assessed using the In-Body 720, direct segmental multi-frequency bioelectrical impedance analysis (InBody Co., Ltd., Seoul, Korea).^[14] Fitness assessments, including biceps strength, and hand grip strength were measured using the MicroFit FAS-2 System (MicroFit Inc., CA). Echocardiographic data were obtained using standard ultrasound systems (Vivid 7, GE Healthcare, Milwaukee, WI) according to the American Society of Echocardiography guideline.^[15] Subjects underwent a symptom-limited cardiopulmonary exercise test using the Bruce treadmill protocol.^[16] Peak oxygen consumption (VO_2) ($\text{mL}/\text{kg}/\text{min}$), which is representative of exercise capacity, was defined as the mean of the highest values over the last 10 seconds of exercise and was recorded during the test using CARDIOVIT CS-200 excellence ergospirometry (Schiller AG., Baar, Switzerland).^[17]

A venous blood sample was collected after fasting overnight in 12 hours. Serum concentrations of glucose, insulin, HbA1c, total cholesterol, high-density lipoprotein (HDL)-cholesterol, low-density lipoprotein (LDL)-cholesterol, and triglyceride were measured using commercial kits in a central laboratory authorized by the Korean Association of Quality Assurance for Clinical Laboratories. Insulin resistance was assessed with homeostatic model assessment insulin resistance (HOMA-IR) using following the formula: $\text{HOMA-IR} = \text{fasting insulin (mIU/L)} \times \text{fasting glucose (mmol/L)} / 22.5$.^[18] The definition of metabolic syndrome was derived from the 3rd report of the National Cholesterol Education Program (NCEP).^[3] Regarding the modified NCEP, current Adult Treatment Panel III (ATP III) criteria, metabolic syndrome was defined as the presence of ≥ 3 of the following 5 traits: abdominal obesity, defined as a waist circumference ≥ 80 cm in women and ≥ 90 cm in men (in accord with the International Obesity Task Force criteria for the Asian-Pacific population); triglyceride concentration ≥ 150 mg/dL; HDL-cholesterol concentration < 40 mg/dL in women and < 50 mg/dL in men; systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg or use of antihypertensive drugs; and fasting glucose ≥ 100 mg/dL or use of hypoglycemic agents.

2.3. Statistical analysis

Categorical variables were described as the frequency with percentage, while continuous variables with normal distribution were reported as mean with standard deviation. The authors identified differences in various parameters among 3 educational groups by analysis of variance (ANOVA) or chi-square test for independence. Correlations between peak VO_2 and the factors of CRF or peak VO_2 (%) and the components of metabolic syndrome were analyzed using Pearson correlation test. Further, logistic regression was performed to determine the predictor of metabolic syndrome. A 2-tailed $P < .05$ was considered statistically significant. All the analysis was conducted using PASW Statistics 21.0 software (SPSS, Inc., Chicago, IL).

3. Results

Table 1 showed the baseline characteristics of the 988 studied subjects. The postgraduate group was younger (mean

Table 1**Baseline characteristics of the participants according to the level of education.**

	Middle or High school graduate	College or University graduate	Postgraduate	P value
Total number	364 (36.8%)	447 (48.3%)	177 (17.9%)	
Clinical variables				
Male, %	166 (45.6%)	288 (64.4%)	147 (83.1%)	<.001
Age, y	60.8±9.7	57.4±10.2	57.5±10.1	<.001
Hypertension, %	85 (27.8%)	95 (25.3%)	43 (28.7%)	.648
Diabetes, %	43 (14.3%)	43 (11.6%)	12 (8.3%)	.185
Dyslipidemia, %	45 (14.9%)	53 (14.2%)	21 (14.5%)	.976
Current smoker, %	59 (22.6%)	109 (30.8%)	36 (24.8%)	.064
Physical activity ≥3 times/wk	124 (37.9%)	157 (36.7%)	67 (40.1%)	.737
Annual family income				<.001
<\$30,000	67 (18.4%)	23 (5.1%)	7 (4.0%)	
\$30,000–100,000	212 (58.2%)	189 (42.3%)	66 (37.3%)	
≥\$100,000	85 (23.4%)	235 (52.6%)	104 (58.8%)	
Laboratory findings				
HDL cholesterol, mg/dL	51.2±13.2	50.4±12.7	48.4±11.9	.054
Triglyceride, mg/dL	109.9±80.4	118.3±73.5	127.6±90.0	.046
Fasting glucose, mg/dL	102.6±22.2	104.8±29.4	101.0±16.9	.189
HOMA-IR	2.3±2.6	2.3±2.9	2.6±2.3	.399
Metabolic syndrome, %	123 (33.8%)	169 (37.8%)	65 (36.7%)	.488
Anthropometric variables				
BMI, kg/m ²	24.0±3.4	24.1±3.1	24.4±3.2	.311
Waist/Hip ratio	0.93±0.04	0.91±0.04	0.91±0.04	<.001
Lean body mass, kg	25.2±5.8	27.4±5.9	29.4±5.3	<.001
Body fat, %	28.4±7.4	26.9±6.4	24.6±5.4	<.001
Cardiorespiratory fitness variables				
Metabolic equivalent of task	6.8±2.0	7.1±1.9	7.8±1.9	<.001
Peak VO ₂ , mL/min/kg	23.7±7.1	25.0±6.8	27.4±6.5	<.001
Biceps strength, kg	25.0±9.7	27.9±9.4	31.7±11.3	<.001
Hand grip strength, kg	59.2±19.5	65.2±18.8	70.1±17.9	<.001
Peak expiratory flow rate, L/min	92.6±20.1	96.9±18.3	101.0±17.4	<.001
Echocardiographic findings				
LV ejection fraction, %	67.1±4.9	66.7±4.9	66.4±5.0	.275
E/A ratio	1.0±0.3	1.0±0.3	1.0±0.3	.050
E/e' ratio	8.9±2.4	8.5±2.2	8.7±2.8	.218
DT of mitral inflow, ms	235.4±42.2	227.9±42.6	226.0±38.5	.024
Max TR velocity, m/s	2.2±0.2	2.2±0.3	2.1±0.2	.003
LA volume index, mL/m ²	29.1±8.5	27.2±8.2	28.1±9.1	.026
LV mass index, mL/m ²	92.7±23.0	89.4±23.1	90.9±21.1	.165

BMI=body mass index, DT=deceleration time, HDL-cholesterol=high-density lipoprotein cholesterol, HOMA-IR=homeostatic model assessment insulin resistance, LA=left atrium, LDL-cholesterol=low-density lipoprotein-cholesterol, LV=left ventricular, VO₂=oxygen consumption.

age 57.5±10.1) and predominantly men (83.1%). Among 988 subjects, 357 (36.1%) had metabolic syndrome according to the 3rd report of NCEP guideline, and the prevalence of metabolic syndrome was not different between groups. There was no significant difference in the prevalence of hypertension or diabetes mellitus among the groups. Neither LDL cholesterol nor fasting glucose was different among the groups. The percentage of current smokers or frequency of physical activity did not have a trend according to the level of education, whereas their annual family income status was significantly different according to their education status. The postgraduate group had annual family income ≥\$100,000 in 58.8%, while the middle to high school graduate group had that of income in 23.4% ($r=0.318$, $P<.001$).

The various factors of cardiorespiratory fitness were evaluated according to the level of education. The postgraduate group had a significantly better cardiorespiratory functions in all aspects, including waist/hip ratio, lean body mass, percentage of body fat, metabolic equivalent of task, peak VO₂, biceps strength, hand grip strength, and peak expiratory flow rate (Fig. 1). This group

showed the better left ventricular diastolic function, in terms of deceleration time of mitral inflow, maximal tricuspid regurgitation velocity, and left atrial volume index than other groups. However, there was no significant difference in left ventricular ejection fraction or left ventricular mass index according to the level of education.

The correlations between Peak VO₂, the most widely used and reliable parameter to assess CRF, and potential factors affecting CRF were presented in Table 2. Peak VO₂ was inversely correlated to age, E/e', deceleration time of mitral inflow, maximal tricuspid regurgitation velocity, and left atrial volume index. Biceps strength, hand grip strength, peak expiratory flow rate, E/A ratio, and left ventricular (LV) mass index had a positive correlation to peak VO₂.

As metabolic syndrome was associated with the aging process, the authors evaluated the correlations between the components of metabolic syndrome and peak VO₂, adjusted by age and sex. Although there was no correlation between fasting glucose and peak VO₂ ($r=-0.012$, $P=.715$), other components of metabolic

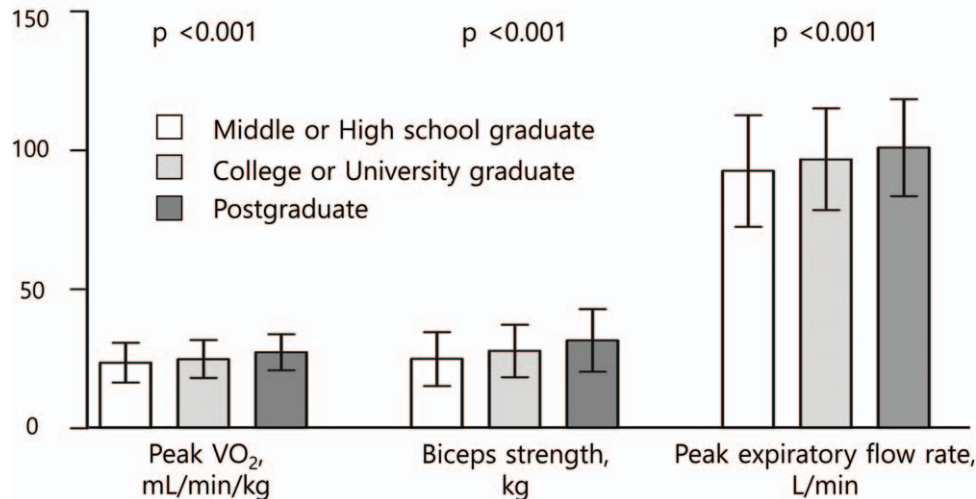


Figure 1. Various CRF according to the educational level. Peak VO₂, biceps strength, and peak expiratory flow rates were significantly different according to the level of education. CRF = cardiorespiratory fitness, VO₂ = oxygen consumption.

syndrome and HOMA-IR presented with good correlations to peak VO₂ (Fig. 2). Peak VO₂ had linear correlations to HOMA-IR, waist circumference, triglyceride, and blood pressure decreased, and inverse correlations to HDL-cholesterol. Among the components, the abdominal obesity showed the highest correlation with peak VO₂ ($r = -0.387$, $P < .001$).

In logistic regression for diagnosing metabolic syndrome, the level of education (postgraduate group; $\beta = 0.955$, $P = .801$), the frequency of physical activity (≥ 3 times/wk; $\beta = 0.969$, $P = .826$), and the annual family income status ($\geq \$100,000$; $\beta = 0.874$, $P = .334$) did not have power on prediction. Meanwhile, such CRF factors as peak VO₂ (%), biceps strength, hand grip strength, E/A ratio, E/e' ratio, and LV mass index, were found to be significant predictors of metabolic syndrome (Table 3).

When the peak VO₂ (%) were presented as interquartile, the lowest quartile range was 20% to 60% (Fig. 3). The frequency of metabolic syndrome was 47.2% in the lowest quartile range. As the peak VO₂ (%) increased, the frequency of metabolic syndrome decreased. For each interquartile range of peak VO₂ (%) showed different risk reduction rate, and the highest quartile

with peak VO₂ range 170% to 210% had a much lower risk of metabolic syndrome by 86.1% compared with the lowest quartile.

4. Discussion

In this cross-sectional study, the authors evaluated the association between the level of education and cardiorespiratory fitness as a predictor of metabolic syndrome. More than a third (36.1%) of 988 subjects met the ATP III criteria for the presence of metabolic syndrome, comparably higher than the estimates (20.3%) from representative samples of Korean adults.^[19] The prevalence of metabolic syndrome was not different according to the educational attainment; whereas, the postgraduate group had better CRF in many aspects, and most of the factors were significant predictors for metabolic syndrome. Among the several factors of CRF, peak VO₂ (%) was a strong predictor for metabolic syndrome, and the risk of metabolic syndrome was much lesser with the higher peak VO₂ (%). Despite no correlation between educational attainment and metabolic syndrome, those results from this study were important to reveal the relation between CRF and the educational attainment, linking peak VO₂ (%) as a predictor of metabolic syndrome. So far, this is the first study to present direct correlations between various components of CRF and metabolic syndrome according to educational attainment.

Previous research demonstrated a strong correlation between low socioeconomic status and metabolic syndrome,^[20,21] and those studies lacked the mechanism accounting for the development of metabolic syndrome. In a study done in Hong Kong adolescents, lower academic grading was an independent predictor for metabolic syndrome.^[22] The investigators proposed that the better awareness of the healthy lifestyles affected the results. In this dedicated study, the authors could not demonstrate the direct relationship between educational attainment and metabolic syndrome for some reasons. As both metabolic syndrome and the level of education were classified as a categorical variable, proving the correlation was more difficult

Table 2
Correlations between peak VO₂ and potential factors affecting cardiorespiratory fitness.

Variables	<i>r</i>	<i>P</i>
Age, y	-0.281	<.001
Biceps strength, kg	0.333	<.001
Hand grip strength, kg	0.320	<.001
Peak expiratory flow rate, L/min	0.143	<.001
LV ejection fraction, %	-0.081	.180
E/A ratio	0.184	<.001
E/e' ratio	-0.103	.003
DT of mitral inflow, ms	-0.110	.001
Max TR velocity, m/s	-0.037	.406
LA volume index, mL/m ²	-0.091	.018
LV mass index, mL/m ²	0.130	<.001

DT = deceleration time, LA = left atrium, LV = left ventricular, VO₂ = oxygen consumption.

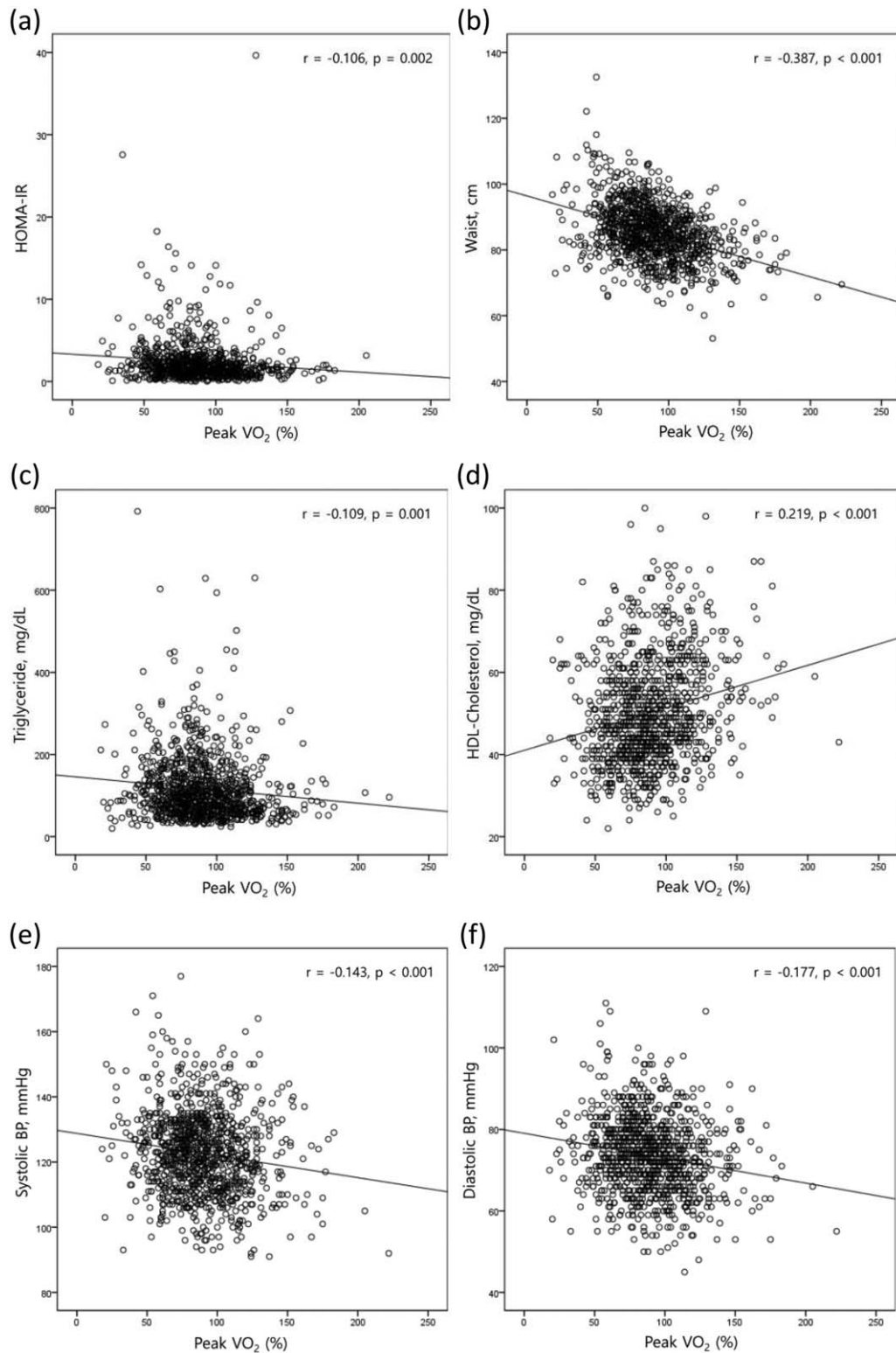


Figure 2. Correlations of peak VO_2 and the components of metabolic syndrome. (A) HOMA-IR, (B) waist circumferences, (C) the level of triglyceride, and (E, F) blood pressures were inversely correlated with peak VO_2 . (D) The level of HDL-cholesterol had a positive correlation with peak VO_2 . HDL=high-density lipoprotein, HOMA-IR=homeostatic model assessment insulin resistance, VO_2 =oxygen consumption.

Table 3
Logistic regression analysis of cardiorespiratory fitness in predicting metabolic syndrome in healthy adults.

	Univariate		Adjusted	
	β	<i>P</i>	β	<i>P</i>
Peak VO ₂ (%)	0.985	< 0.001	0.988	<0.001
Biceps strength, kg	0.950	<0.001	0.972	0.049
Hand grip strength, kg	0.975	<0.001	0.980	0.009
Peak expiratory flow rate, L/min	1.001	0.772		
E/A ratio	0.113	<0.001	0.147	<0.001
E/e' ratio	1.250	<0.001	1.269	<0.001
DT of mitral inflow, msec	1.007	<0.001		
LA volume index, mL/m ²	1.004	0.672		
LV mass index, mL/m ²	1.010	0.002	0.070	<0.001

than using continuous variables.^[23] Furthermore, adults had more complex, bio-psychosocial factors influencing metabolic syndrome than adolescents.^[4] Recently, an interesting study was published that genetic variants known to affect educational attainment had a significant association between lifestyle and coronary artery disease.^[24] Still, the correlation between education and cardiovascular disease is not clearly known, and it is even more challenging to establish how education impacts health-related behavior change.

In the current report, Korea demonstrated the inverse relationship between the level of education and the treatment of diabetes or hypertension in both men and women, while other countries did not.^[1] Given this phenomenon, the authors estimated that this has resulted in higher education opportunity and the national health insurance system for the Korean population. South Korea established the basic education law in 1949, and since 1984, 9-years of compulsory, free education is supplied by the government. As a result, the level of education has been improved every year, and in 2017, 48% of the Korean population obtained a university

or college course, which was much higher than the OECD average of 37%.^[25] From a Korean study, <6-years of education was associated with 2.0 (95% confidence interval 1.2–3.4) of increased risks of metabolic syndrome compared with university graduation.^[26] In Finland, where everyone is insured, there was an inverse association between socioeconomic status and mortality after myocardial infarction.^[27] Thus, various factors, such as the country's stage of economic development, education, and social and health policies, are needed to be considered for improving health-related outcomes.

There were some limitations in this study. Firstly, as a cross-sectional study, there was a selection and an observer bias. The present study population was highly educated and financially able to undergo their regular health check-up in a private tertiary hospital. Even regarding the high level of educational achievements in Koreans, this study population consisted of college graduates in 63.2%, which may weaken the statistical power of educational attainment in predicting metabolic syndrome. In addition, the proportion of men and age of subjects were different among

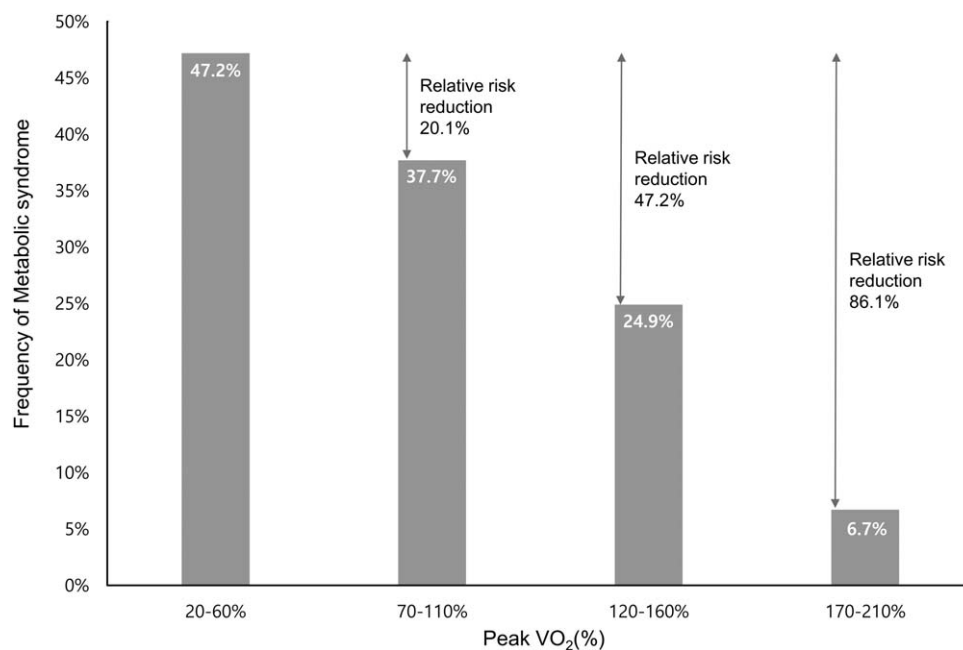


Figure 3. Risk of metabolic syndrome according to Peak VO₂ (%). The frequency of metabolic syndrome decreased with increasing peak VO₂, and the risk reduction rate was more extensive with the higher peak VO₂ range. VO₂ = oxygen consumption.

groups. Secondly, this independently developed questionnaire posed a recall bias. Since the results entirely depended on the accuracy of the subject's answers and the lack of standardized tool remained the reliability issue. Thirdly, the causal–result relationship was not clear. It is well known that CRF is an essential determinant of academic achievement in children.^[28] Biological explanations for the link between fitness and cognition have been proposed, such as improved memory, inhibition, and cognition across academic fields.^[29–31] With better CRF, the subjects might achieve higher educational attainment, as shown in this study. Lastly, because of the small study population confined to Koreans, this study could not reveal the direct correlation between the level of education and metabolic syndrome.

In spite of some limitations, this study has several important implications. Of the various risk factors of metabolic syndrome, the authors confirmed that CRF is a good predictor of metabolic syndrome, and the relation to educational attainment was weak but possible not been reported previously. Furthermore, peak VO_2 was evaluated directly for all the components of metabolic syndrome, and not only peak VO_2 but also the other factors of CRF were all checked and demonstrated good correlations to metabolic syndrome. Even though the direct correlation of education attainment and metabolic syndrome could not be established, it is crucial to evaluate the mechanism of how socioeconomic status affects cardiovascular disease. Understanding the mechanism can be efficient in promoting public health through specialized programs which meet the needs of individuals.

5. Conclusion

The association between socioeconomic status and metabolic syndrome of cardiovascular mortality has been well-described with the level of education being extensively used as an indicator of overall socioeconomic status. Yet this current study was not able to support educational attainment being exclusively used to predict metabolic syndrome. More research is needed to better understand which socioeconomic factors best predict metabolic syndrome.

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Jeom-Sik Kim, Sunyoung Park, Ju-Eun Chae, and Dong-Hun Lee contributed to the data collection. Kevin Zinck contributed to revise the manuscript.

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