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# Association between resting heart rate, metabolic syndrome and cardiorespiratory fitness in Korean male adults

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## ABSTRACT

**Background/Objective:** The present study aimed to investigate the association between metabolic syndrome and cardiorespiratory fitness according to resting heart rate of Korean male adults.

**Methods:** A total of 11,876 male adults aged 20–65 years who underwent health examinations from 2010 to 2015 at a National Fitness Centre in South Korea were included. Subjects' resting heart rate, cardiorespiratory fitness (VO<sub>2</sub>max), and metabolic syndrome parameters were collected. The subjects were divided into 5 categories (<60 bpm, 60–69 bpm, 70–79 bpm, 80–89 bpm, and ≥90 bpm) of resting heart rate for further analysis.

**Results:** We found that elevated resting heart rate was positively associated with body mass index, systolic blood pressure, diastolic blood pressure, triglycerides, and fasting blood glucose levels ( $p < 0.001$ , respectively); in contrast, elevated resting heart rate was inversely associated with VO<sub>2</sub>max ( $p < 0.001$ ). When resting heart rate of subjects was categorized into quintiles and analysed, the results showed that the relative risk of metabolic syndrome was 1.53-fold higher (95% CI, 1.34 to 1.82) in the range of 60–69 beats per minute (bpm), 2.08-fold higher (95% CI, 1.77 to 2.45) in the range of 70–79 bpm, 2.28-fold higher (95% CI, 1.73 to 3.00) in the range of 80–89 bpm, and 2.61-fold higher (95% CI, 1.62 to 4.20) in the range of ≥90 bpm, compared to those <60 bpm; this indicated that as resting heart rate increased, the relative risk of metabolic syndrome also increased.

**Conclusion:** Resting heart rate of male adults was found to be associated with cardiorespiratory fitness; the risk factors for metabolic syndrome and relative risk of metabolic syndrome increased as resting heart rate increased.

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## 1. Introduction

The human body performs an array of vital activities through homeostasis regulation that activates continuous interactions between the sympathetic nervous system and the parasympathetic nervous system. In particular, resting heart rate has been suggested as a useful method to evaluate the physiological and clinical health of the autonomic nervous.<sup>1</sup> In the clinical setting, the normal range of resting heart rate is 60–100 beats per minute (bpm),<sup>2</sup> however, it is known that cardiovascular dysfunction may occur when resting heart rate increases due to an increase in sympathetic.<sup>3,4</sup> Many

prospective studies have also demonstrated that a higher resting heart rate has negative effects on cardiovascular morbidity and.<sup>5–7</sup> The reason behind this association was believed to be due to a shortened diastolic phase during the cardiac cycle when resting heart rate is elevated, resulting in a decrease in coronary perfusion and increase in cardiac work.<sup>8–10</sup>

Meanwhile, metabolic syndrome with the co-occurrence of obesity, hypertension, dyslipidaemia, and impaired glucose tolerance is a risk factor for the development of atherosclerotic cardiovascular disease and type 2 diabetes mellitus.<sup>11</sup> According to the pathophysiology of metabolic syndrome, increased sympathetic activity, caused by insulin resistance and deteriorating autonomic regulation functions, is known to promote the development of cardiovascular disease.<sup>12</sup> Recent prospective studies have also identified that a high resting heart rate is of prognostic importance for the development of metabolic syndrome.<sup>13,14</sup>

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In addition,  $\text{VO}_2\text{max}$ , an indicator of cardiorespiratory fitness, is used as a predictor of metabolic syndrome and cardiovascular disease.<sup>15–17</sup> According to a number of studies have also found that a high cardiorespiratory fitness was associated with a lower risk of metabolic syndrome and cardiovascular disease compared with low cardiorespiratory fitness.<sup>18–20</sup> Like this high resting heart rate and low cardiorespiratory fitness reflect the risk of developing metabolic syndrome. The resting heart rate is decreased by the improvement of cardiovascular fitness.

However, there is a lack of large-scale studies on the relationship between resting heart rate and cardiorespiratory fitness, which affects the risk of developing metabolic syndrome. Therefore, the present study aimed to investigate the association of resting heart rate with metabolic syndrome, cardiorespiratory fitness and prevalence of metabolic syndrome by examining large-scale data on male adult population in Korea.

## 2. Methods

### 2.1. Participants

The present study used cardiorespiratory fitness data from health examinations that were performed at the National Fitness Center in Korea from 2010 to 2015. A total of 11,876 male adults aged 20–65 years with no missing data on variables used in the present study were included. The exclusion criteria consisted of any condition that might affect resting heart rate: heart disease, thyroid function abnormality, anemia patients. The self-report questionnaires were used to investigated medical history, exercise status (regular exercise,  $\geq 3$ /week, and  $\geq 30$  min), smoking status (current smoke  $\geq 1$  cigarettes dairy), and alcohol drinking status (alcohol consumption,  $\geq$ once/month).

Data analysis in this study began upon obtaining the approval of the Changwon National University clinical research review board (104027-201611-HR-019).

### 2.2. Clinical measurement

Subjects' height and weight were measured using a stadiometer (SH-9600A, Korea). The body mass index (BMI) was calculated by the division of weight (kg) over height ( $\text{m}^2$ ). Resting heart rate was measured as the lowest heart rate by echocardiograph (Cardisuny, Japan) during supine rest for 5 min. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured using automatic sphygmomanometer (FT-500R, Jawon, Korea) after 5 min rest. Venous blood was collected following a minimum of 8 h of fasting. After centrifugation at 3000 rpm for 15 min, the fasting blood glucose, HDL-cholesterol, and triglyceride were analysed using the appropriate clinical chemistry analysers (Selecta XL, Vital Scientific, Newton, MA).

To measure cardiorespiratory fitness, cardiopulmonary exercise system (Quinton, USA) and automatic breathalyzer system (Jaeger, Germany) were being used. Cardiorespiratory fitness measurements were taken at the Sports Medicine Center in the National Health Center. Maximum oxygen consumption was measured with transformed Balked protocol during treadmill test. The transformed Balked protocol is the method which start exercise in steady speed of 85 m/min with 0% of grade and gradually increase 2.5% of its grade minutely. The treadmill test was achieved with a respiratory exchange ratio of 1.05 higher or  $\text{HR}_{\text{max}} \geq 95\%$  of the age-predicted  $\text{HR}_{\text{max}}$  ( $220 - \text{age}$ ) or when the oxygen uptake did not increase  $\geq 2.0$  ml/kg/min despite increased workload.<sup>21</sup>

### 2.3. Metabolic syndrome diagnostic criteria

The metabolic syndrome diagnostic criteria consisted of the 5

components suggested by the National Cholesterol Education Program Treatment Panel III.<sup>22</sup> The BMI classification for Asian populations as suggested by the World Health Organization<sup>23</sup> was consulted. Subjects were diagnosed with metabolic syndrome if three or more of the following conditions were met: HDL-Cholesterol  $\leq 40$  mg/dL, triglycerides  $150$  mg/dL, SBP and DBP at rest  $130 \leq$  or  $85$  mmHg, fasting glucose  $100$  mg/dL, BMI  $\geq 25$  kg/m<sup>2</sup>.

### 2.4. Statistical analysis

Data analysis was performed using IBM SPSS statistics 18 (SPSS inc. Chicago, IL, USA). Results of the data analysis are as follows: subjects were divided into 5 categories of resting heart rate ( $< 60$  bpm, 60–69 bpm, 70–79 bpm, 80–89 bpm, and  $\geq 90$  bpm) for analysis. These classification criterion was based on a previous study suggesting cut-off of resting heart rate, cardiovascular risk factors and mortality from heart disease.<sup>24–26</sup> Frequency analysis, one-way ANOVA, and post-hoc test were performed to determine the differences in anthropometric data, physical characteristics (exercise status, smoking status, and drinking status), metabolic syndrome parameters, and maximal oxygen uptake between groups. Correlation analysis was performed to determine the association between resting heart rate, risk factors for metabolic syndrome, and  $\text{VO}_2\text{max}$ . The odds ratio for relative risk of metabolic syndrome were calculated using logistics regression analysis after adjusted age, exercise, smoking, drinking and  $\text{VO}_2\text{max}$ . Statistical significance was set at  $p < 0.05$ .

## 3. Results

### 3.1. Differences in physical characteristics, metabolic syndrome parameters and cardiorespiratory fitness depending on resting heart rate

When physical characteristics between the groups are compared according to resting heart rate, there was no significant difference in the age and height of subjects; however, there was significant difference in the body weight ( $p < 0.001$ ). There were also significant differences between groups in terms of BMI ( $p < 0.001$ ), SBP ( $p < 0.001$ ), DBP ( $p < 0.001$ ), triglycerides ( $p < 0.001$ ), and fasting blood glucose levels ( $p < 0.001$ ). No significant difference was seen for HDL-cholesterol. The prevalence of metabolic syndrome increased as the levels of resting heart rate increased ( $p < 0.001$ ). In addition,  $\text{VO}_2\text{max}$  increased as resting heart rate decreased ( $p < 0.001$ ) (Table 1).

### 3.2. Association of resting heart rate with metabolic syndrome parameters and cardiorespiratory fitness

Resting heart rate showed a positive association with BMI ( $r = 0.071$ ,  $p < 0.001$ ), SBP ( $r = 0.253$ ,  $p < 0.001$ ), DBP ( $r = 0.258$ ,  $p < 0.001$ ), triglycerides ( $r = 0.121$ ,  $p < 0.001$ ), and fasting blood glucose levels ( $r = 0.136$ ,  $p < 0.001$ ). There was no significant association between resting heart rate and HDL-cholesterol (Table 2). There was a negative association between resting heart rate and  $\text{VO}_2\text{max}$ , an indicator of cardiorespiratory fitness ( $r = -0.196$ ,  $p < 0.001$ ) (Table 2).

### 3.3. Odd ratios of metabolic syndrome depending on resting heart rate

The relative risk of developing metabolic syndrome depending on resting heart rate was increased 1.62-fold (95% CI, 1.44 to 1.82) for 60–69 bpm, 2.22-fold (95% CI, 1.94 to 2.54) for 70–79 bpm, 2.86-fold (95% CI, 2.28 to 3.58) for 80–89 bpm, and 3.31-fold (95%,

**Table 1**

Differences in physical characteristics, metabolic syndrome parameters and cardiorespiratory fitness depending on resting heart rate.

Variable	>60 <sup>a</sup> (n = 3640)	60–69 <sup>b</sup> (n = 5513)	70–79 <sup>c</sup> (n = 2184)	80–89 <sup>d</sup> (n = 426)	90 <sup>≤e</sup> (n = 113)	P value	Post hoc
Age (years)	48.2 ± 10.7	47.9 ± 10.8	47.5 ± 11.0	47.9 ± 11.2	49.1 ± 12.4	0.065	ns
Height (cm)	170.2 ± 5.8	170.1 ± 5.8	170.1 ± 5.9	169.8 ± 5.9	169.9 ± 6.4	0.768	ns
Weight (kg)	70.0 ± 9.0	70.9 ± 9.3	71.5 ± 10.0	71.1 ± 10.4	70.9 ± 10.6	0.001	a<b, c, d, e
RHR (bpm)	55.0 ± 3.5	64.2 ± 2.7	73.4 ± 2.7	83.2 ± 2.7	96.7 ± 6.5	0.001	a<b < c < d < e
Exercise status	1964 (64.7%)	2436 (54.4%)	844 (47.4%)	169 (48.0%)	40 (43.5%)	0.001	a>b > c, d, e
Smoking status	1571 (41.5%)	2193 (38.7%)	806 (35.8%)	154 (34.8%)	41 (34.2%)	0.001	a>b, c, d, e
Drinking status	2981 (78.8%)	4424 (77.8%)	1700 (75.8%)	312 (71.6%)	80 (66.1%)	0.001	a, b > c > d, e
MS risk factors							
BMI (kg/m <sup>2</sup> )	24.1 ± 2.7	24.5 ± 2.7	24.7 ± 3.0	24.6 ± 3.1	24.5 ± 3.3	0.001	a<b, c, d, e
SBP (mmHg)	120.3 ± 14.4	124.7 ± 14.6	128.8 ± 15.2	132.3 ± 15.5	135.5 ± 16.3	0.001	a<b < c < d < e
DBP (mmHg)	74.2 ± 10.4	77.5 ± 10.8	80.5 ± 11.4	83.2 ± 11.9	85.1 ± 10.3	0.001	a<b < c < d < e
TG (mg/dL)	120.3 ± 61.6	132.6 ± 65.1	140.1 ± 68.9	142.7 ± 71.6	131.0 ± 57.3	0.001	a<b < c < d
HDL-C (mg/dL)	51.2 ± 11.5	50.9 ± 11.6	51.4 ± 11.6	51.7 ± 11.4	51.3 ± 12.9	0.437	ns
FBG (mg/dL)	86.9 ± 12.3	88.4 ± 13.2	90.5 ± 14.9	91.7 ± 15.5	94.8 ± 19.6	0.001	a, b < c, d < e
MS status	482 (12.4%)	1085 (18.7%)	555 (24.0%)	130 (28.9%)	40 (32.0%)	0.001	a<b < c < d, e
VO <sub>2</sub> max (ml/kg/min)	41.1 ± 8.0	39.6 ± 7.4	38.5 ± 7.2	37.1 ± 7.0	35.2 ± 7.2	0.001	a>b > c > d > e

Data shown as Mean ± SD or n (%).

RHR = resting heart rate; bpm = beats per minute; MS = metabolic syndrome; CRF = cardiorespiratory fitness; VO<sub>2</sub>max = maximal oxygen uptake; BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; TG = triglycerides; HDL-C = high density lipoprotein cholesterol; FBG = fasting blood glucose. ns = no significant.**Table 2**

Association between resting heart rate, metabolic syndrome parameters and cardiorespiratory fitness.

		BMI	SBP	DBP	TG	HDL-C	FBG	VO <sub>2</sub> max
Resting heart rate	r	0.071	0.253	0.258	0.121	0.020	0.136	-0.196
	P value	0.001	0.001	0.001	0.001	0.054	0.001	0.001

BMI = body mass index; SBP = systolic blood pressure; DBP = diastolic blood pressure; TG = triglycerides; HDL-C = high density lipoprotein cholesterol; FBG = fasting blood glucose.

r = correlation coefficient.

Adjusted for age, exercise, smoking and drinking.

CI, 2.25 to 4.88) for  $\geq 90$  bpm, compared to that for a resting heart rate of <60 bpm; this indicated that as resting heart rate increased, the relative risk of developing metabolic syndrome also increased.

In addition, after adjusting for age, exercise, smoking, drinking, and VO<sub>2</sub>max, the relative risk of developing metabolic syndrome was increased 1.53-fold (95% CI, 1.34 to 1.82) for 60–69 bpm, 2.08-fold (95% CI, 1.77 to 2.45) for 70–79 bpm, 2.28-fold (95% CI, 1.73 to 3.00) for 80–89 bpm, and 2.61-fold (95% CI, 1.62 to 4.20) for  $\geq 90$  bpm, compared to that for resting heart rate of <60 bpm; this indicated that as resting heart rate increased, the relative risk of developing metabolic syndrome also increased (Table 3).

#### 4. Discussion

The present study was conducted to investigate the association between resting heart rate, metabolic syndrome, and cardiorespiratory fitness in male adults. For the purpose of this study, resting heart rate was categorized into quintiles of 10 bpm units. Our results showed that there were significant differences in BMI, SBP,

DBP, triglyceride, and fasting glucose levels as resting heart rate increased. In addition, we found that resting heart rate was associated with metabolic syndrome, and that the relative risk of developing metabolic syndrome was higher as resting heart rate increased. We also found that VO<sub>2</sub>max, an indicator of cardiorespiratory fitness, was lower as resting heart rate increased, indicating that resting heart rate was inversely associated with VO<sub>2</sub>max.

Resting heart rate is utilized as a valuable predictor of the risk of cardiovascular disease. The biological mechanism of elevated resting heart rate is related to autonomic nervous system with increased sympathetic activity. Increased sympathetic activity causes myocardial hypertrophy and vascular endothelial dysfunction, promoting progression to cardiovascular.<sup>27</sup> The importance of resting heart rate control is drawing attention for the primary prevention of cardiovascular disease. An increasing resting heart rate may have an adverse impact on the risk of developing cardiovascular diseases such as hypertension, coronary heart disease, and myocardial infarction.<sup>28</sup> The results of the present study also

**Table 3**

Odd ratios of metabolic syndrome according to resting heart rate.

Resting heart rate	Metabolic syndrome			
	Unadjusted OR	(95% CI)	Adjusted OR	(95% CI)
>60(bpm)	1.00		1.00	
60–69 (bpm)	1.62	(1.44 to 1.82)	1.53	(1.34 to 1.76)
70–79 (bpm)	2.22	(1.94 to 2.54)	2.08	(1.77 to 2.45)
80–89 (bpm)	2.86	(2.28 to 3.58)	2.28	(1.73 to 3.00)
90 (bpm) $\leq$	3.31	(2.25 to 4.88)	2.61	(1.62 to 4.20)

OR = odds ratio.

Adjusted for age, exercise, smoking, drinking and VO<sub>2</sub>max.

showed that BMI, SBP, DBP, fasting blood glucose, and triglycerides levels were significantly different according to different categories of resting heart rate. In addition, the present study also found that as resting heart rate increased, the relative risk of developing metabolic syndrome also increased. A study by Coonet et al.<sup>29</sup> found that the risk of developing cardiovascular disease was 2 times higher in men with a resting heart rate of  $\geq 90$  bpm, and 3 times higher in women with a resting heart rate  $\geq 90$  bpm, in comparison with men and women with resting heart rate of  $< 60$  bpm. A study by Oda et al.<sup>30</sup> also found that there was an association between resting heart rate and risk factors for metabolic syndrome; the prevalence of metabolic syndrome was 2.13 higher in a group with elevated resting heart rate compared with a group with low resting heart rate, similar to the results of the present study. Therefore, it can be concluded that as resting heart rate increases, the risk of developing metabolic syndrome also increases. Previous studies have suggested that obesity and insulin resistance which is central to the development of metabolic syndrome activates sympathetic nerves.<sup>31,32</sup> In this respect, it is thought that high baseline heart rate which is an excitatory indicator of sympathetic nervous system may be a direct cause of metabolic syndrome. Thus resting heart rate can thus be utilized as a meaningful predictor that of the risk of developing metabolic syndrome. For instance, exercise, known to lower resting heart rate and manage metabolic syndrome, is equally important as a means to lower the risk of developing atherosclerotic cardiovascular disease.

Cardiorespiratory fitness has also been suggested as an independent predictor of metabolic syndrome,<sup>33</sup> whereby a low cardiorespiratory fitness was found to increase the risk of developing metabolic syndrome.<sup>34,35</sup> Furthermore, the resting heart rate has a negative correlation with cardiorespiratory fitness.<sup>25</sup> According to the results of the present study,  $VO_2\max$  was higher when resting heart rate was lower, indicating that there is an association between resting heart rate and  $VO_2\max$  ( $r = -0.196$ ,  $p < 0.001$ ). Improvement of cardiorespiratory fitness will affect resting heart rate. According to a 16-year follow-up of a prospective study by Jessen et al.<sup>25</sup> there was an inverse correlation between the  $VO_2\max$  measured in 1970–1971 and resting heart rate measured in 1985–1986; elevated resting heart rate was found to be associated with an increased risk of mortality. Nauman et al.<sup>36</sup> also found that healthy subjects with resting heart rates of  $< 60$  bpm in 1984–1986 (i.e., at baseline) had higher  $VO_2\max$  23 years later compared with those with resting heart rates of  $\geq 80$  bpm at baseline. From these findings, it can postulated that high cardiorespiratory fitness is important for lowering the resting heart rate. In particular, exercise serves to promote cardiorespiratory fitness, inhibit sympathetic activity, and enhance parasympathetic activity, resulting in a decrease in resting heart rate.<sup>37,38</sup> Therefore, the present study supports that exercise, which serves to increase cardiorespiratory fitness, is an important factor for lowering resting heart rate.

The present study confirmed that resting heart rate is indicative of autonomic nervous system activity, and is associated with metabolic syndrome parameters. However, medications and sympathetic-stimulating psychological states affecting resting heart rate measurements were not considered in this study. In addition, because this study was cross-sectional in nature, the causal relationship between resting heart rate, metabolic syndrome risk factors, and cardiorespiratory fitness cannot be inferred.

## 5. Conclusion

The present study showed that there was an association between resting heart rate and metabolic syndrome parameters in male adults; as resting heart rate increased, the relative risk of

developing metabolic syndrome also increased. We also showed that there was an association between resting heart rate and cardiorespiratory fitness. Based on these findings, this study suggests that high resting heart rate may be an important factor in predicting the risk of metabolic syndrome.

## Conflicts of interest

The authors have no conflicts of interest relevant to this study.

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