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Original Article

Effects of smoking and aerobic exercise on male college students' metabolic syndrome risk factors

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Abstract. [Purpose] The aim was to investigate the effects of university students' smoking and aerobic exercise on metabolic syndrome risk factors. [Subjects and Methods] Twenty-three male students were randomly assigned to the following groups: exercise smoker (n=6), non-exercise smoker (n=6), exercise non-smoker (n=6), and non-exercise non-smoker (n=5). A basketball exercise program was conducted three times per week (70 minutes per session) for 8 weeks with exercise intensity set at 50–80% of heart rate reserve. After 8 weeks, the variables of risk factors for metabolic syndrome were obtained. [Results] Systolic blood pressure and diastolic blood pressure were significantly decreased in the exercise non-smoker group and significantly increased in the non-exercise smoker group. Waist circumference was significantly reduced in both exercise groups regardless of smoking and significantly increased in the non-exercise smoker group. Triglyceride, high-density lipoprotein-cholesterol, and fasting plasma glucose showed no differences between the groups. [Conclusion] Obesity and smoking management should be conducted together for students as well as for those with metabolic syndrome risk factors. It is recommended that more students participate in such programs, and exercise programs should be further developed and diversified to prevent metabolic syndrome and cardiovascular diseases.
Key words: Metabolic syndrome, Aerobic exercise, Smoking

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INTRODUCTION

Metabolic syndrome is defined as a combination of abnormal metabolic conditions such as central obesity, hypertension, hyperlipidemia, and impaired glucose tolerance. It refers to a clustered incidence observed in an individual and increases the risk of cardiovascular disease and type 2 diabetes[1, 2)].

The exact cause of metabolic syndrome is unknown, but it occurs due to various genetic and environmental factors[3)]. Smoking, drinking, and lack of physical activity are associated with the prevalence of metabolic syndrome[4)]. Smoking is a particular factor and it is understood that nicotine stimulates the sympathetic nervous system, increasing cortisol levels, which triggers the accumulation of visceral fat, which affects lipid metabolism. Nicotine is also known to increase insulin resistance and cause metabolic syndrome[5, 6)].

Smoking and obesity are globally the most common causes of death[7)]. Metabolic syndrome is typically caused by central obesity, and insulin resistance[8)] occurs more frequently in less active and fit individuals[9)].

Regular exercise not only has positive effects on body composition and body circumference but also offers various metabolic benefits that improve obesity and metabolic syndrome, such as increased metabolism when resting, through increased muscle mass[10)], improved blood lipids[11)], reduced blood pressure[12)], and improved insulin resistance[13, 14)]. Briefly, regular physical activity is an effective method to improve metabolic syndrome which can cause cardiovascular disease and type 2 diabetes.

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Table 1. Characteristics of subjects

Group	Age (yrs)	Height (cm)	Weight (kg)	Body fat (%)	Smoking history (yrs)
Ex smoker (n=6)	25.0 ± 1.3	178.7 ± 5.3	72.2 ± 13.6	15.3 ± 7.0	>5
Non Ex smoker (n=6)	24.2 ± 1.2	175.0 ± 5.7	67.7 ± 14.1	19.7 ± 4.6	>5
Ex Nonsmoker (n=6)	23.3 ± 6.8	178.8 ± 7.1	84.5 ± 9.5	21.4 ± 2.3	-
Non Ex Nonsmoker (n=5)	23.8 ± 3.0	171.4 ± 2.1	73.4 ± 14.6	21.9 ± 5.3	-

Results are shown as mean ± SD, Ex: exercise; Non Ex: non-exercise.

Table 2. Basketball exercise program

<table>
<tr><th></th><th>Week</th><th>Exercise content</th><th>Time (min)</th><th>Intensity (HRR)</th></tr>
<tr><td>Warm-up</td><td>1–8</td><td>- Stretching, jogging</td><td>10</td><td>20–40%</td></tr>
<tr><td rowspan="2">Main exercise</td><td>1–4</td><td>Basic skill
- Dribble, pass (chest, bound, side arm pass)
- Shoot (jump & lay-up shoot) & rebound
- Jump shoot after dribble, half-court game</td><td rowspan="2">50</td><td>50–65%</td></tr>
<tr><td>5–8</td><td>Repeat basic skill
Advanced skill
- Pivot, defense (man to man, zone), screen play
- Formation, full court game</td><td>65–80%</td></tr>
<tr><td>Cool-down</td><td>1–8</td><td>- Stretching, jogging</td><td>10</td><td>20–40%</td></tr>
</table>

HRR: hear rate reserve.

Metabolic syndrome is perceived as one of the most common health problems of today, and various research studies are in progress with multiple approaches to reduce it. In particular, the approach using physical activity and exercise is producing remarkable results. We compared and analyzed the changes in metabolic syndrome risk factors in male students in their 20s in relation to exercise and smoking. Our study offers an evaluation of the effects of these factors.

SUBJECTS AND METHODS

The study subjects were 23 male students at K University based in Gunsan City, Jeollabuk-do Province, who did not have any medical history, understood the explanation of our study's purpose, and voluntarily gave consent to participate. The study was approved by the Institutional Review Board of Kunsan National University. The participants were randomly assigned to one of the following groups: exercise smoker (n=6), non-exercise smoker (n=6), exercise non-smoker (n=6), and non-exercise non-smoker (n=5). Participants' characteristics are shown in Table 1.

Basketball is a representative aerobic exercise that is fun and induces interest in the players. It was chosen for the study program as it is easy to observe the effects of the exercise by varying the degree of exercise intensity. The exercise program was carried out 3 times a week for 8 weeks with each session lasting 70 minutes. The basketball exercise program took place at the outdoor basketball court of K University. The program focused on basic skills including dribbling, passing, and shooting. Warm-up exercises before the games and cool-down exercises were performed at every exercise session to prevent injuries and improve exercise functions. The target heart rate (THR) for this study was set at 50% to 80% of heart rate reserve (HRR), as suggested by the American College of Sports Medicine[15], and the exercise intensity was increased according to exercise skills and level (Table 2).

The subjects fasted from 10 pm on the night before the experiment, and a medical technologist at G Hospital in Gunsan City collected blood samples from the antebrachial vein. The samples were centrifuged and analyzed at the medical laboratory of G Hospital.

Metabolic syndrome in this study was defined according to the standards suggested by the National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) in 2001[16] and was categorized into 5 metabolic syndrome indicators including fasting plasma glucose, triglyceride (TG), high-density lipoprotein-cholesterol (HDL-C), blood pressure, and waist circumference (WC).

All data collected from the experiment were analyzed using SPSS version 22.0, and the average and mean ± standard deviation were calculated for each variable. Repeated-measures analysis of variance was performed to analyze differences in the metabolic syndrome indicators between groups, within groups, and before and after the exercise according to the aerobic exercise program participation of each group. The significance level for statistical testing was 0.05.

Table 3. Changes in systolic blood pressure according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
SBP (mmHg)	Ex smoker	119.5 ± 8.9	117.8 ± 10.3
	Non Ex smoker **	118.8 ± 10.9	124.8 ± 11.3
	Ex Nonsmoker *	125.2 ± 11.6	105.7 ± 8.0
	Non Ex Nonsmoker	121.3 ± 10.9	119.6 ± 7.1
$F_{group*time}$=10.61 (0.000)			

SBP: systolic blood pressure, *p<0.05, **p<0.01.

Table 4. Changes in diastolic blood pressure according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
DBP (mmHg)	Ex smoker	75.3 ± 7.2	77.5 ± 8.8
	Non Ex smoker **	71.5 ± 13.9	80.5 ± 11.1
	Ex Nonsmoker *	79.3 ± 14.0	71.3 ± 10.3
	Non Ex Nonsmoker	72.8 ± 16.2	75.4 ± 5.0
$F_{group*time}$=4.61 (0.014)			

DBP: diastolic blood pressure, *p<0.05, **p<0.01.

Table 5. Changes in waist circumference according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
WC (cm)	Ex smoker *	81.8 ± 10.1	80.7 ± 10.0
	Non Ex smoker *	82.2 ± 11.2	83.8 ± 10.8
	Ex Nonsmoker **	90.8 ± 8.4	89.0 ± 8.0
	Non Ex Nonsmoker	85.0 ± 11.3	84.6 ± 10.7
$F_{group*time}$=14.46 (0.000)			

WC: waist circumference, *p<0.05, **p<0.01.

RESULTS

The experiment results showed that there was an interaction between the groups and time points (p<0.001) for systolic blood pressure (SBP). The SBP of the non-exercise smoker group significantly increased from pretest to posttest (p<0.01), whereas that of the exercise non-smoker group significantly decreased from pretest to posttest (p<0.05). No significant change was observed in the exercise smoker and non-exercise non-smoker groups (Table 3).

There was an interaction between the groups and time points (p<0.05) for diastolic blood pressure (DBP). The DBP of the exercise non-smoker group significantly decreased from pretest to posttest (p<0.05), whereas that of the non-exercise smoker group significantly increased from pretest to posttest (p<0.01). On the other hand, no significant changes were observed in the exercise smoker and non-exercise non-smoker groups (Table 4).

An interaction between the groups and time points was observed (p<0.001) for waist circumference (WC). The WC of the exercise non-smoker group significantly decreased from pretest to posttest (p<0.01), and the exercise smoker group also showed a significant decrease from pretest to posttest (p<0.05). Conversely, WC in the non-exercise smoker group significantly increased from pretest to posttest (p<0.05), and no significant change was observed in the non-exercise non-smoker group (Table 5).

There was no interaction between the groups and time points for fasting plasma glucose (Table 6), triglyceride (Table 7), HDL-C (Table 8). Consequently, the results of the main effect demonstrated no significant difference between the time points and between the groups.

DISCUSSION

The dramatic rise of obesity is a worldwide phenomenon, suggesting that the prevalence of metabolic syndrome is extremely likely to grow higher[17, 18]. The possible causes of this problem include accumulation of fat in certain parts of the body as well as increased body weight and overall excess accumulation of body fat. In particular, the increase of visceral fat

Table 6. Changes in fasting plasma glucose levels according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
FPG (mg/dl)	Ex smoker	85.8 ± 3.8	90.7 ± 14.5
	Non Ex smoker	82.3 ± 6.1	84.2 ± 5.2
	Ex Nonsmoker	91.3 ± 4.2	87.8 ± 6.3
	Non Ex Nonsmoker	89.8 ± 5.2	86.2 ± 4.5
$F_{group*time}$=1.63 (0.216), F_{group}=41.28 (0.311), F_{time}=0.00 (0.948)			

FPG: fasting plasma glucose.

Table 7. Changes in triglyceride levels according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
TG (mg/dl)	Ex smoker	131.7 ± 98.9	119.7 ± 53.6
	Non Ex smoker	126.0 ± 67.3	187.0 ± 141.5
	Ex Nonsmoker	93.7 ± 33.7	97.2 ± 36.0
	Non Ex Nonsmoker	132.2 ± 114.9	195.4 ± 198.7
$F_{group*time}$=1.33 (0.293), F_{group}=0.61 (0.615), F_{time}=2.95(0.102)			

TG: triglyceride.

Table 8. Changes in HDL-C levels according to the pretest and posttest results of each group

	Group	Pre (mean ± SD)	Post (mean ± SD)
HDL-C (mg/dl)	Ex smoker	45.2 ± 9.2	48.5 ± 10.2
	Non Ex smoker	42.8 ± 7.0	44.0 ± 8.7
	Ex Nonsmoker	48.3 ± 7.2	52.0 ± 7.7
	Non Ex Nonsmoker	40.8 ± 8.0	40.8 ± 10.2
$F_{group*time}$=0.60 (0.622), F_{group}=1.38 (0.281), F_{time}=3.37 (0.082)			

HDL-C: high density lipoprotein-cholesterol.

raises the chance of insulin resistance, dyslipidemia, and hypertension. In general, smoking reduces body weight, but it is known to increase percent body fat and the waist to hip ratio. The mechanism of this has not been clearly proven, but studies report that high nicotine consumption increases cortisol concentrations, which leads to accumulation of visceral fat and increases the risk for diabetes[19]. In this study, the WC of the smoker group that did not participate in the 8-week basketball program significantly increased, whereas that of the groups that participated in the exercise program significantly decreased regardless of smoking. Ross and Janssen[20] studied the effect of physical activity on visceral fat reduction and reported that the volume of total body fat was reduced depending on the amount of physical activity, but exercise was associated with the reduction of visceral fat regardless of body weight reduction. Our study also demonstrated that the 8-week exercise program was effective in improving central obesity, which is closely associated with the prevalence of chronic diseases. Conversely, the non-exercise non-smoker group did not show any significant change in WC.

Physical activity through aerobic exercise and leisure activity reduce the risk factors for hypertension and are effective for improving SBP and DBP[21, 22]. On the other hand, the nicotine in cigarettes stimulates catecholamine secretion, which increases blood pressure[23]. In addition, nicotine enhances sympathetic activity, increasing heart rate and blood pressure[24], and it has been reported that SBP is more greatly affected[25].

In the present study, SBP and DBP significantly increased due to smoking in the non-exercise groups and decreased in the exercise non-smoking group. Conversely, no significant change was observed in the exercise smoker and non-exercise non-smoker groups.

Smoking is known to affect lipid metabolism and stimulate atherosclerosis. One of the mechanisms is the secretion of catecholamine by the sympathetic nervous system stimulated by nicotine, the stimulation of fat decomposition by its anti-estrogen effect, and increased plasma free fatty acids[26]. The other mechanism is that smoking reduces HDL-C, and particularly HDL_2-C and HDL_3-C, which have an anti-atherosclerosis effect[3]. In a study by Oh[27], the risk of abnormal TG and HDL-C and central obesity increased in accordance with the accumulation of smoking, and the risk of metabolic syndrome increased consequently. Existing studies also show corresponding results[28, 29].

In this study, no significant inter-group difference was observed in lipid changes of TG and HDL-C. Many previous studies have reported diverse findings on the effect of exercise in relation to HDL-C. Ready et al.[30] reported that exercise at a 60% intensity of maximal oxygen uptake (VO_2max) 3 to 5 times per week did not improve HDL-C. Gordon et al.[31] observed a significant increase of HDL-C when exercise was performed at 75% of VO_2max and claimed it is necessary to increase the exercise intensity or the period of exercise to raise HDL-C levels. With respect to changes of HDL-C according to the length of the exercise period, a study by Park[32] found that HDL-C in middle-aged women with obesity increased after a comprehensive 24-week exercise program. However, Heo et al.[33] reported that a 16-week exercise program did not improve HDL-C. Thus, the duration of exercise participation may require more than 6 months to increase the HDL-C level through exercise. A study by Lee et al.[34] found that abnormal TG and HDL-C levels were associated with the amount of daily smoking and reported that the daily smoking frequency is the factor that causes the most changes in lipid metabolism. Considering these previous study results, it is highly possible that the results of the present study concerning the difference in daily smoking frequency between smokers and non-smokers and participation in the exercise program for 8 weeks may not have been sufficient to cause changes in lipid metabolism.

Continued smoking causes insulin resistance and increases blood sugar levels[35] and enhances the risk of diabetes[36]. Most blood sugar is used for the synthesis of glycogen in the liver and muscles through exercise. Exercise also increases muscles' use of sugar and prevents exacerbating insulin sensitivity and further development of the metabolic syndrome[37]. In the present study, there was no significant difference in blood glucose levels between groups, and no significant increase or decrease of blood sugar levels was observed according to smoking and exercise. This is probably because the subjects of this study were young university students with normally functioning metabolism, free from the risk of insulin resistance or diabetes, and no abnormal blood sugar level was observed regardless of exercise and smoking.

Metabolic syndrome presents in conjunction with obesity and bad habits such as drinking, smoking, and lack of physical activity. In this study, the levels of metabolic syndrome risk factors changed according to smoking and exercise. The SBP and DBP of non-smoker students significantly decreased after the 8 weeks of the basketball exercise program. WC, in particular, was significantly reduced through exercise regardless of smoking. However, previous study results do not correspond to the results of the present study, and the differences may derive from differences in various factors including gender, age, study subjects, smoking accumulation, amount of daily smoking, and period of smoking. More diverse aspects should be investigated further in the future to determine the effects of smoking or exercise.

Conflict of interest

None.

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