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Original Article

The Compound Relationship of Smoking and Alcohol Consumption with Obesity

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The purpose of this study was to examine 1) whether the relationship between smoking and obesity was linear or non-linear (specifically U-shaped), and 2) if this relationship was proved to U-shaped, whether it was due to the interaction of the effects of smoking and alcohol consumption on obesity. The present study was performed using cross sectional data taken from the medical records of 400 male patients. Data was analyzed using linear and curvilinear estimation, Fisher's exact test, and two-way ANCOVA.

The relationship between smoking intensity and BMI was able to be explained significantly by a quadratic model, rather than by linear model. As has been shown in other studies, this relationship was parabolic (or U-shaped), though it was not particularly remarkable. This U-shaped relationship appeared to be due to the interaction of the effects of smoking intensity and alcohol consumption on BMI.

On the other hand, the relationship between smoking intensity and the percentage of body fat was able to be explained significantly by a linear as well as a quadratic model. Additionally, the interaction effect between smoking intensity and alcohol consumption did not influence the percentage of body fat significantly.

In conclusion, there is no doubt that smoking and obesity are both serious health hazards. Based on the results of this and other studies, it can be confirmed that heavy smoking has a positive relationship with obesity. Therefore, the health benefits of smoking cessation, as well as the correction of unhealthy habits such as alcohol consumption should be clearly emphasized.

Key Words: Smoking intensity, obesity, alcohol consumption, quadratic estimation

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INTRODUCTION

Numerous epidemiological studies have shown that the mortality rate of lean, underweight individuals is higher than that of average weight.[1-3] This finding is paradoxical, since many other studies have shown that mortality and morbidity rates are positively related to body weight and amount of fat, and are therefore higher in the obese person.[4] Investigators have demonstrated that lean persons were more likely to be cigarette smokers than are overweight persons.[5-7] Therefore, it is likely that the increased mortality and morbidity in underweight persons is due to smoking habits and not to leanness itself.[4]

It has been suggested that some people may adopt the habit of smoking to control body weight and that many people sustain to smoking habit because they are afraid of weight gain.[8] Indeed, the facts that smokers are leaner than non- smokers and that smokers who give up the smoking habit put on weight, can be obstacles in the attempt to stop smoking.

The fact that smokers weigh less than non-smokers can be explained by the effect of smoking on the metabolic rate. Smoking increases energy expenditure by releasing adrenaline and other metabolic hormones. This effect of nicotine is particularly strong during light activity.[9-11] It has been also suggested that smoking induces caloric loss by increasing bowel motility and suppressing the appetite.[12,13] Thus it seems that there is an inverse linear relationship between smoking and body weight, i.e. smokers are leaner than non-smokers.

However, a curvilinear relationship between

smoking intensity and relative body weight has been found in several studies.[5-7,12,14-18] These studies showed that light smokers, those who smoked 5 to 20 cigarettes per day, were the leanest group, while heavy smokers, those who smoked more than 20 cigarettes per day, were the heaviest group. This result seems paradoxical, given the metabolic effects of smoking. However, Salonen et al.[19] postulated that heavy smokers weighed more due to a clustering of other unhealthy habits, such as heavy consumption of alcohol, less exercise, and a high fat diet.

Few attempts have been made to clarify the relationship between smoking and body weight in light of the interaction with other unhealthy habits, such as heavy alcohol consumption. Therefore, we first attempted to determine whether the relationship between smoking intensity and obesity (using two indices: BMI and percentage of body fat) exhibited a linear or curvilinear relationship. Next, we investigated whether there was a significant interaction between smoking and alcohol consumption, and if this interaction effect influenced obesity significantly.

MATERIALS AND METHODS

Subjects

Data was collected from the medical records of 400 male patients who visited a university hospital located in Inchon, Korea for physical examination. The mean age of the subjects was 48 (S.D.: 10.5, range: 20-76). Twenty-six percent of subjects were between the ages of 20 and 39, 35% were between the ages of 40 and 50, 27% were between the ages of 51 and 60, and 12% were over the age of 61. Forty percent (n=162) of the subjects were college/university graduates and 27.3% (n=107) were high school graduates. The majority of subjects enjoyed a relatively high economic status, since most of them had a high level of education. Forty-one percent (n=164) of the subjects earned more than $2,200 a month (in U.S. dollars), and 20.8% (n=83) earned between $1,300 and $1,800 a month.

Measurements

Smoking intensity

Smoking intensity was measured by the average number of cigarettes smoked daily during the last six months. The patients were classified into 4 groups according to smoking intensity: group 1, non-smokers; groups 2, ex-smokers; group 3, less than 20 cigarettes a day; and group 4, more than 20 cigarettes a day. Such a classification has generally been used in other studies.[5,20,21]

Alcohol consumption

Alcohol consumption was measured by the product of the usual frequency of alcohol use per week during the last six months and the average volume (expressed by gram) of alcohol consumed at one time. The patients were classified into 4 groups according to the amount of alcohol consumption: group 1, non-drinkers; group 2, 1-10 g of alcohol a day; group 3, 11-20 g of alcohol a day; and group 4, over 20 g of alcohol a day. Such a classification has generally been used in other studies.[5,21]

Obesity

Body mass index (BMI) and percentage of body fat was used as indices of obesity. BMI was a measure for relative weight and calculated as the weight in kilograms divided by the square of the height in meters. Percentage of body fat signifies the proportion of fat in the body and was measured in this study using a body composition analyzer (BCA, Gilwoo Trading, Seoul, Korea: GIF-891DX).

Data analysis

In order to determine whether the relationship between smoking and obesity was a linear or curvilinear, linear and curvilinear (particularly quadratic) estimation was conducted using the SPSS/win 7.5. The significance of the cross relationship between smoking intensity and alcohol consumption was examined using Fisher's Exact test. In addition, two-way ANCOVA was also used to test the significance of the interactive effects between smoking and alcohol on BMI and percentage of body fat, while adjusting for age.

RESULTS

Descriptive statistics for the major variables

Fifty-one percent of subjects were smokers, 27% were non-smokers, and 22% were ex-smokers. The smoking duration of smokers and ex-smokers averaged 9 years (S.D.=12.21), and the smoking amount of smokers averaged 21.7 cigarettes (S.D.=11.25) a day. Twenty-seven percent of subjects were non-alcohol consumers and 73% were alcohol consumers. The mean frequency of alcohol consumption a week was 2.7 (S.D.=1.75), and the mean amount of alcohol consumption a week was 165.82 g (S.D.=270.30), equivalent to 1.8 bottles of Korean spirits (So-Joo) or 6.5 bottles of beer.

The mean percentage of body fat in subjects was 20.95 (S.D.=4.60), and the mean BMI was 24.23 (S.D.=2.94). Forty-eight percent of subjects were obese and 52% was normal weight, when obesity was defined as more than a score of 25 on the BMI index.

The relationship between smoking intensity and obesity

We performed the linear and curvilinear (especially, quadratic) estimation simultaneously (Table 1) in order to examine which of these two models was offered a statistically significant explanation of the relationship between smoking intensity and obesity. We also plotted the pattern of the relationship between smoking intensity and obesity for further visual inspection.

The relationship between smoking intensity and BMI

Our results showed that the quadratic model established to explain the relationship between smoking intensity and BMI was statistically significant (F=3.92, p=0.02, Table 1), however, the linear model was not (F=1.12, p=0.29). Ten percent (R^2=0.10) of BMI was explained by this quadratic model (coefficients; B1=-0.03, B2=0.01). As shown in Fig. 1, BMI was slightly decreased with an increasing intensity of smoking up to approximately medium-intensity, after which it increased progressively with further increasing smoking intensity. This pattern appeared to be slightly parabolic (U-shaped) according to visual inspection.

In order to determine whether this U-shaped relationship was produced by significant interactive effects between smoking intensity and other unhealthy habits such as alcohol consumption, we examined the significance of the cross relationship between smoking intensity and alcohol consumption using Fisher Exact test. The results showed that smoking intensity was significantly related to

Table 1. Linear and Quadratic Estimations of the Relationships between Smoking Intensity and Obesity (BMI and Percentage of Body Fat)

< Smoking Intensity and BMI >

Linear Model			Quadratic Model		
Variable	Coefficient (S.E.)	p-value	Variable	Coefficient(S.E.)	p-value
Intercept	24.04 (0.15)	0.00*	Intercept	24.29 (0.15)	0.00*
BMI	0.01 (0.01)	0.29	BMI	-0.03 (0.02)	0.13
			BMI^2	0.01 (0.001)	0.01*
R^2 = 0.003, F = 1.12, p = 0.29			R^2 = 0.10, F = 3.92, p = 0.02*		

< Smoking Intensity and Percent of Body Fat >

Linear Model			Quadratic Model		
Variable	Coefficient (S.E.)	p-value	Variable	Coefficient (S.E.)	p-value
Intercept	25.69 (0.30)	0.00*	Intercept	25.98 (0.31)	0.00*
BMI	-0.16 (0.02)	0.00*	BMI	-0.39 (0.04)	0.00*
			BMI^2	0.01 (0.001)	0.01*
R^2 = 0.07, F = 54.44, p = 0.00*			R^2 = 0.10, F = 37.59, p = 0.00*		

*$p \leq 0.05$.

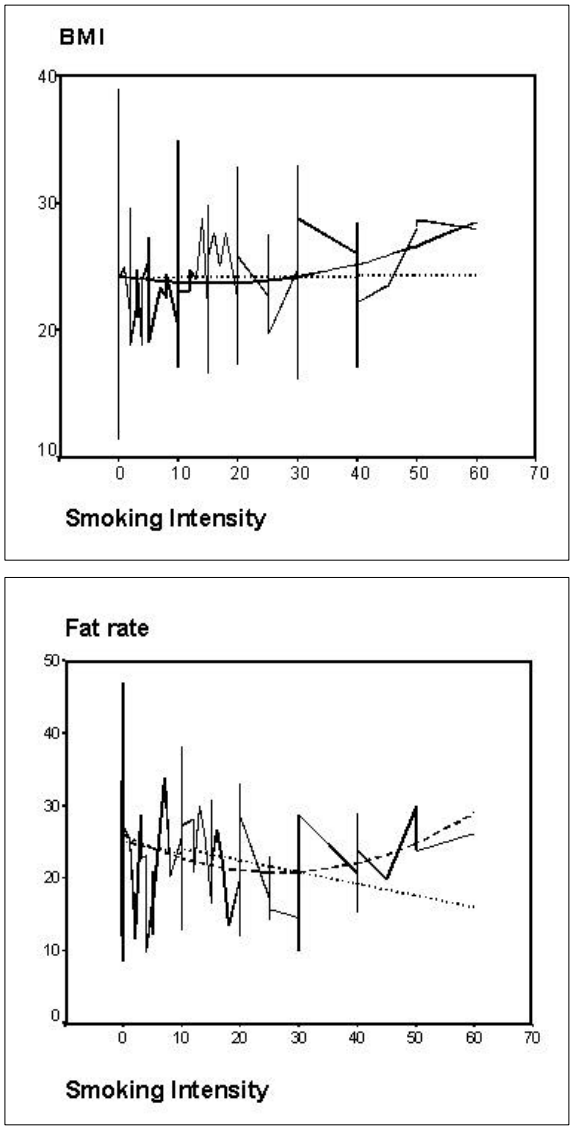

Fig. 1. Linear and quadratic estimations of the relationship between smoking and obesity.

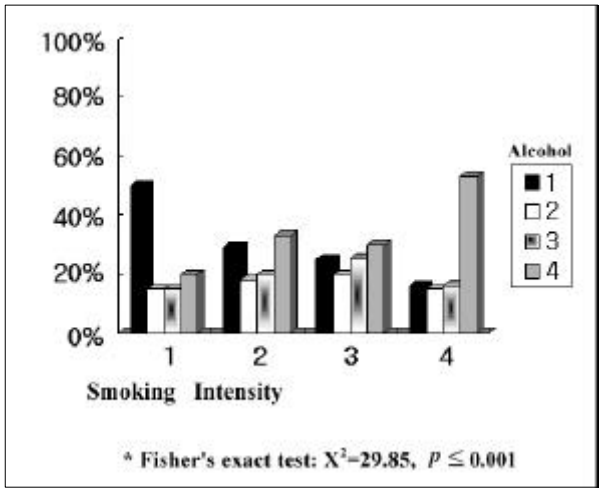

Fig. 2. Cross relationships between smoking intensity and alcohol consumption. Significant test for cross relationship was performed using Fisher's exact test ($\chi^2 = 29.85$, $p < 0.001$). The patients were classified into 4 groups according to smoking intensity: group 1, non-smokers; group 2, ex-smoker; group 3, smoking group (> 20 cigarettes/day); and group 4, smoking group (< 20 cigarettes/day). The patients were also classified into 4 groups according to alcohol intensity: group 1, non-drinker; group 2, alcohol consuming group (1 - 10 g of alcohol/day); group 3, alcohol consuming group (11 - 20 g of alcohol/day); group 4, alcohol consuming group (over 20 g of alcohol/day).

alcohol consumption ($p \leq 0.001$) (Fig. 2). Indeed, the prevalence of alcohol consumption of $\geq$ 20 g/day was greatest in subjects who smoked more than 20 cigarettes daily.

Next, we examined the significance of the interactive effects of smoking intensity and alcohol consumption on BMI. Since various studies have shown that age has a compounding effect on obesity,[4,5,14,15] two-way ANCOVA was used with BMI as the dependent variable and age as the covariate variable. The independent variables were smoking intensity and alcohol consumption. The result of ANCOVA (Table 2) indicated that the independent effects of smoking intensity and alcohol consumption on BMI were not significant (p=0.22, p=0.16, respectively), however, the interactive effect of smoking intensity with alcohol consumption on BMI was significant (p=0.04).

In heavy smokers (smoking intensity group 4), the lowest BMI was found in the non-alcohol consumers (alcohol consuming group 1), and BMI increased incrementally with alcohol consumption in heavy smokers (Fig. 3). This result indicated that these two unhealthy habits, smoking and alcohol consumption, simultaneously contribute to an increased BMI.

Taken together, heavy smokers had a tendency to be heavy alcohol consumers, and the negative effect of smoking on BMI was cancelled by the effects of alcohol consumption when these two unhealthy habits co-existed.

The relationship between smoking intensity and percentage of body fat

The results of the linear and curvilinear estimation showed that the relationship between smoking intensity and percentage of body fat was

Table 2. Interaction of the Effects of Smoking Intensity and Alcohol Consumption on BMI

Variables	Mean (S.D.)	*p*-value from ANCOVA
Smoking Intensity		
Group 1	24.03 (3.26)	
Group 2	24.89 (2.83)	0.22
Group 3	23.76 (3.36)	
Group 4	24.00 (2.98)	
Alcohol Consumption		
Group 1	24.09 (3.37)	
Group 2	23.18 (3.20)	0.16
Group 3	24.23 (3.12)	
Group 4	24.75 (2.86)	
Smoking · Alcohol		0.04*

ANCOVA, Analysis of covariance (age is a covariate variable).

*$p \leq 0.05$.

Smoking intensity group: 1: non-smoker, 2: ex-smoker, 3: smoking group (> 20 cigarettes/day), 4: smoking group (< 20 cigarettes/day).

Alcohol consumption group: 1: non-drinker, 2: alcohol consuming group (1 - 10 g of alcohol/day), 3: alcohol consuming group (11 - 20 g of alcohol/day), 4: alcohol consuming group (over 20 g of alcohol/day).

explained by the linear model (F=54.44, p=0.000) as well as a quadratic model (F=37.59, p=0.000) (Table 1). Seven percent (R^2=0.07) of percentage of body fat was explained by linear model (coefficients; B1=-0.16), and 10% (R^2=0.10) of percentage of body fat was explained by quadratic model (coefficients; B1=-0.39; B2=0.01). As shown in Fig. 1, the relationship between smoking intensity and percentage of body fat was inversely linear and appeared to be slightly U-shaped. Considering the simplicity of the model, the linear model was concluded to be more reliable for explaining this relationship, as opposed to the quadratic model.

As previously mentioned, the heavy smoking group had a tendency to consume excessive amounts of alcohol (χ^2=29.85, $p \leq 0.01$) (Fig. 2). However, the results of two-way ANCOVA demonstrated that the interactive effects of smoking intensity and alcohol consumption (p=0.66) on the percentage of body fat were not significant when adjusted for age (Table 3). The result of our analysis of the independent effects of smoking intensity and alcohol consumption on percentage of body fat (Table 3) showed that alcohol consumption had a significant effect on percentage of body fat (p=0.04) although smoking intensity did not (p=0.71). In particular, the percentage of body fat was significantly different (p=0.02) between alcohol consumption group 2 (consuming 1 - 10 g of alcohol/day) and group 4 (consuming over 20 g of alcohol/day).

DISCUSSION

The relationship between smoking intensity and BMI

Our main finding was that there was a significant quadratic relationship between smoking intensity and BMI. In addition, the plot of this relationship was visually assessed as being a slightly U-shaped. However, the degree of explanation was relatively low at only 10%. Therefore, it seemed that there were more important variables to be considered in explaining BMI.

In this study, heavy smokers who were also heavy alcohol consumers exhibited the highest BMI of the other smoking groups (Fig. 3). This finding was consistent with other studies, suggesting a positive relationship between body weight and smoking intensity in heavy smokers.[5-7,12-18]

The reason that heavy smokers weigh more has

Table 3. Interaction of Effects of Smoking Intensity and Alcohol Consumption on the Percentage of Body Fat

Variables	Mean (S.D.)	*p*-value (ANCOVA)	
Smoking Intensity			
Group 1	26.59 (6.71)		
Group 2	21.49 (5.12)	0.71	
Group 3	22.34 (6.27)		
Group 4	21.17 (4.63)		
Alcohol Consumption			Post-hoc Analysis†
			Groups / *p*-value
Group 1	26.50 (7.02)		Group 1 · 2 / 0.52
			Group 1 · 3 / 0.90
Group 2	21.57 (5.22)	0.04*	Group 1 · 4 / 0.20
Group 3	21.49 (5.49)		Group 2 · 3 / 0.54
			Group 2 · 4 / 0.02*
Group 4	22.27 (5.14)		Group 3 · 4 / 0.36
Smoking · Alcohol		0.66	

ANCOVA, Analysis of covariance (age is a covariate variable).

*$p \leq 0.05$.

†Duncan test.

Smoking intensity group: 1: non-smoker, 2: ex-smoker, 3: smoking group (> 20 cigarettes/day), 4: smoking group (< 20 cigarettes /day).

Alcohol consumption group: 1: non-drinker, 2: alcohol consuming group (1 - 10 g of alcohol/day), 3: alcohol consuming group (11 - 20 g of alcohol/day), 4: alcohol consuming group (over 20 g of alcohol/day).

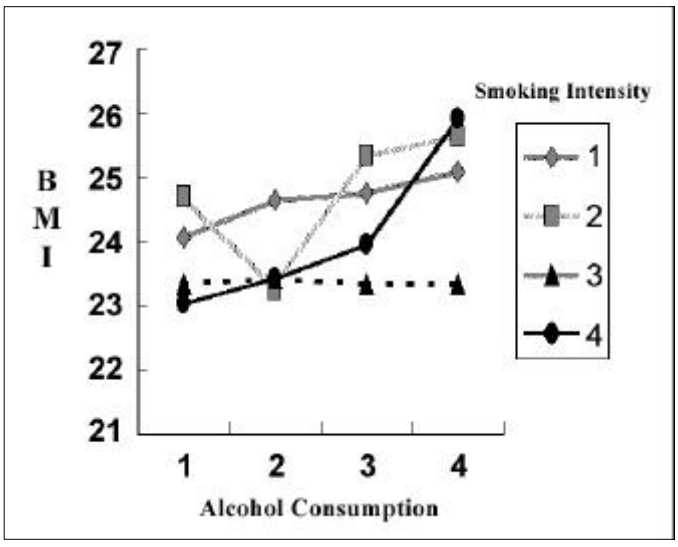

Fig. 3. Interaction of the effects of smoking intensity and alcohol consumption on BMI. The patients were classified into 4 groups according to smoking intensity: group 1, non-smokers; group 2, ex-smoker; group 3, smoking group (> 20 cigarettes/day); and group 4, smoking group (< 20 cigarettes/day). The patients were also classified into 4 groups according to alcohol intensity: group 1, non-drinker; group 2, alcohol consuming group (1 - 10 g of alcohol/day); group 3, alcohol consuming group (11 - 20 g of alcohol/day); group 4, alcohol consuming group (over 20 g of alcohol/day).

been proposed as a clustering of other unhealthy habits.[21] Therefore, we examined the significance of the interaction of the effects of smoking intensity and another unhealthy habit, alcohol consumption, on BMI. Our study showed that the prevalence of excessive alcohol consumption (≥ 20 g of alcohol/day) was greatest in heavy smokers (≥ 20 cigarettes/day). Gordon and Kannel[22] demonstrated similar results. They concluded that the smoking habit was strongly and positively associated with alcohol consumption.

Heavy smokers in the heavy alcohol consump-

tion group showed the highest BMI (Fig. 3). However, heavy smokers in the non-alcohol consumption group showed the lowest BMI. This result illustrated that alcohol consumption may be a major factor in the increased BMI of heavy smokers. The general notion that heavy smokers are the leanest group due to increased caloric utilization[9] or a suppressed appetite due to smoking[13,23] was true only for non-alcohol consumers. The BMI of heavy smokers was increased by alcohol consumption, and this phenomenon has been consistently supported by reports that have shown a positive relationship between alcohol and obesity.[12,22,24-26]

The highest BMI was found in both the heavy smokers and ex-smokers with heavy alcohol consumption (Fig. 3). That is, when alcohol consumption was heavy, the smoking habit did not affect BMI significantly. It is likely that alcohol consumption has a stronger independent effect than smoking intensity on BMI. Williamson et al.[27] also reported that the negative relationship between smoking and weight in men was diminished by alcohol consumption.

Within the non-smoker, ex-smoker, and heavy smoker groups, heavy alcohol consumers displayed the highest BMI. In the moderate smoker group, however, the level of alcohol consumption did not affect BMI. This suggests that the modifying effect of alcohol consumption on BMI may differ in accordance with various levels of smoking intensity.

The relationship between smoking intensity and Percentage of body fat

There were both significant linear and quadratic relationships seen between smoking intensity and the percentage of body fat. From the visual inspection for Fig. 1, it was noted that both the inverse linear and U-shape relationship existed together. Considering to the simplicity of the model, the linear model appeared to be more reliable for explaining the relationship between these two variables. Additionally, the interaction of the effects of smoking intensity with alcohol consumption on the percentage of body fat was not observed to be significant. The result suggested that alcohol consumption affects the percentage of body fat independently, not because of interactions with smoking intensity. In other words, the percentage of body fat was affected by alcohol consumption itself rather than any interaction of alcohol consumption and smoking.

In conclusion, heavy smokers had a tendency to be heavy alcohol consumers. When these two unhealthy habits existed together, the negative effect of smoking on BMI was cancelled by the effect of alcohol consumption. Ordinarily, BMI can be decreased by smoking possibly due to the effects of smoking on metabolism. In the case of heavy smokers, however, BMI was somewhat increased due to the interaction of the effects of smoking and alcohol consumption.

There is no doubt that both smoking and obesity are serious health hazards. However, the effects of smoking and alcohol consumption on obesity should not be interpreted independently. Rather these relationships should be considered with respect to the compounding effect or interaction of effects between these two unhealthy habits, smoking and alcohol consumption.

Additionally, it should be emphasized that the effects of smoking and alcohol consumption can be altered according to the type obesity index. In our result, the BMI (body weight divided by the square of the height) was significantly affected by the compounding effect of smoking and alcohol consumption. On the contrary, the percentage of body fat did not appeared to be significantly affected.

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