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ORIGINAL ARTICLE

Relationship between body mass index and alanine aminotransferase concentration in non-diabetic Korean adults

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Background/Objectives: Obesity has been identified as an important factor of elevated alanine aminotransferase (ALT), a surrogate of non-alcoholic fatty liver disease. We investigated the relationship between obesity and elevated ALT in the general Korean population.
Subjects/Methods: The study sample was comprised of 3098 Korean adults who had participated in the 2005 Korean National Health and Nutrition Examination Survey. Obesity was assessed using body mass index (BMI). Overweight ($23 \leqslant \mathrm{BMI} < 25$) and obese ($\mathrm{BMI} \geqslant 25$) were defined by the International Obesity Task Force for Asian adults. ALT was measured by enzymatic methods. Elevated ALT was defined as an enzyme activity >40 IU/l for men and >31 IU/l for women.
Results: Among participants, 246 (12.7%) men and 86 (7.4%) women displayed elevated ALT. BMI was significantly higher in men and women with elevated ALT than those with normal ALT ($P < 0.0001$). The unadjusted odds ratio (OR) for elevated ALT increased according to the degree of BMI in men (OR: 1.9, 95% confidence interval (CI): 1.25–2.93 in overweight vs OR: 5.01, 95% CI: 3.49–7.21 in obese; $P < 0.0001$) and women (OR: 2.44, 95% CI: 1.24–4.82 vs OR: 3.94, 95% CI: 2.18–7.13; $P < 0.0001$). This trend did not differ after adjustment for putative risk factors including alcohol intake in men (OR: 1.56 vs OR: 3.47, $P < 0.0001$) and women (OR: 1.55 vs OR: 3.10, $P = 0.0015$).
Conclusion: BMI is implicated as a strong risk factor of elevated ALT in non-diabetic Korean adults.
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Keywords: obesity; alanine aminotransferase; non-alcoholic fatty liver disease; Korean adults

Introduction

Chronic liver disease is a worldwide health problem (Clark *et al*., 2003; Chen *et al*., 2007). The major causes of chronic liver disease include non-alcoholic fatty liver disease (NAFLD), hepatitis B or C, and excessive alcohol consumption (Pendino *et al*., 2005; Chen *et al*., 2006). NAFLD represents a spectrum of diseases that range from simple fatty liver (or steatosis), a generally benign accumulation of triglyceride (TG) in hepatocytes, to non-alcoholic steatohepatitis, which can progress to chronic liver disease, cirrhosis, and hepatocellular carcinoma (Teli *et al*., 1995; Clark *et al*., 2002; Saito *et al*., 2007). Currently, NAFLD is considered to be the most common cause of liver disease (Daniel *et al*., 1999).

Individuals with NAFLD are commonly characterized by elevated circulating concentrations of liver enzymes including alanine aminotransferase (ALT), aspartate aminotransferase, and γ-glutamyltransferase (Clark *et al*., 2003). Of these liver enzymes, ALT is most closely related to liver fat accumulation (Schindhelm *et al*., 2006), and, thus, it has been used as a surrogate marker of NAFLD in epidemiologic studies (Hanley *et al*., 2005; Wannamethee *et al*., 2005; Chang *et al*., 2007). Less well known, however, are the risk factors for elevated ALT concentration that influence the prevalence and etiology of NAFLD.

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Cross-sectional studies from Western countries have reported alcohol intake to be strongly associated with increased ALT levels (Ruhl and Everhart, 2005; Ioannou *et al*., 2006). However, other studies did not confirm such a relationship between alcohol intake and ALT level (Nakamura *et al*., 1998; Adams *et al*., 2008). Obesity has also been identified as a risk factor strongly associated with elevated ALT concentration (Ruhl and Everhart, 2003; Adams *et al*., 2008; Kim *et al*., 2008). It is perhaps not surprising that NAFLD is frequently observed in obese people. As obesity is dramatically increasing in both Asian and Western populations, it is likely that obesity will become an increasingly important risk factor for elevated ALT concentration (Flegal *et al*., 2002; Thorburn, 2005; Ko *et al*., 2007; Pan *et al*., 2008).

In Korea, three studies on the relationship between obesity and elevated ALT concentration have been reported (Lee *et al*., 2001; Sung *et al*., 2007; Song *et al*., 2008). However, these studies were limited to specific groups of Korean subjects; one study used only men (Lee *et al*., 2001), whereas the other involved only obese women who had visited the hospital for the management of their obesity (Song *et al*., 2008). Further limiting the value of these studies was their failure to consider alcohol intake, which is a potential risk factor of elevated ALT concentration (Lee *et al*., 2001; Sung *et al*., 2007).

In this study, we re-examined the relationship between obesity and elevated ALT concentration after adjusting for several putative risk factors including alcohol intake using the most recent survey data from the largest, nationally representative, general Korean population available.

Materials and methods

Subjects

The study was based on the third Korean National Health and Nutrition Examination Survey (KNHANES III), a cross-sectional and nationally representative survey carried out by the Korea Centers for Disease Control and Prevention from April to June 2005. The survey used a stratified multistage probability sampling design. KNHANES III consisted of surveys of health interview, health behavior, and nutrition, as well as a health examination study. Of the 7597 Koreans who participated in the health examination study, 5565 adults 20+ years of age were selected for this study. Pregnant or lactating women were excluded. Other exclusion criteria were diabetes (fasting plasma glucose (FPG) $\geqslant$126 mg per 100 ml or hypoglycemic agent or insulin administration) or history of diabetes, cancer, thyroid disease, another liver disease such as chronic hepatitis or positive serum hepatitis B surface antigen, and active intake of weight loss preparations. In particular, among 5565 adults (+20 years of age) who were selected for this study, 222 adults (4%) had positive serum hepatitis B surface antigen. From the remaining 3141 subjects, 43 were further excluded because they had insufficient information on anthropometric measurement or ALT concentration. A total of 3098 Korean adults (1931 men, 1167 women; mean age, 51.2 ± 15.8 years) were ultimately eligible for the analysis. Informed written consent for participation was obtained from each individual. The study was approved by the Korea Centers for Disease Control and Prevention Institutional Review Board.

Body composition measurements

Height, body weight, and waist circumference (WC) were measured as part of the health examination study. Height and body weight were measured while the subjects were wearing light clothes without shoes. WC was measured to the nearest 0.1 cm at the narrowest point between the lowest rib and the uppermost lateral border of the right iliac crest. Body mass index (BMI) was calculated from the measured height and weight of participants. The cutoff points of overweight and obesity were defined by the International Obesity Task Force for Asian adults in the Asian and Pacific regions (World Health Organization, 2000). We classified subjects into three categories: normal and underweight ($<$23 kg/m^2), overweight ($\geqslant$23 and $<$25 kg/m^2), and obese ($\geqslant$25 kg/m^2) based on the BMI. Abdominal obesity was defined by WC $\geqslant$90 cm for men or $\geqslant$80 cm for women (Alberti *et al*., 2005).

Alcohol consumption

Alcohol intake was assessed by questionnaires about drinking behavior during the month before the interview. The subjects were asked about their average frequency (days in month) and amount (in milliliters) of alcoholic beverages ingested on a typical occasion or during a typical day. The average amount of alcoholic beverage consumed was converted into the amount of pure alcohol (in g) consumed per day. Alcohol intake was used to categorized participants into three groups: non-drink, light, or moderate drinker (1–30 g alcohol/day), and heavy drinker ($\geqslant$30 g alcohol/day) (Song *et al*., 2008).

Metabolic variable measurements

Blood samples for measurements of TG, high-density lipoprotein cholesterol (HDL-C), and FPG and ALT were collected after an overnight fast. All biochemical analyses were carried out within 2 h of blood sampling. TG, HDL-C, FPG, and ALT were measured by enzymatic methods with an ADVIA 1650 autoanalyzer (Bayer, USA). Hepatitis B surface antigen was measured by an electrochemiluminescence immunoassay (Roche, Germany) (Van Helden *et al*., 2004). Elevated ALT was defined as an enzyme activity $>$40 IU/l for men and $>$31 for women (Clark *et al*., 2003; Ioannou *et al*., 2006). Blood pressure was measured with a Baumannomete mercury sphygmomanometer (WA Baum, NY, USA) after the subjects had rested for 5 min in a sitting position. Systolic (SBP) and diastolic blood pressures (DBP) were measured at phase I and V Korotkoff sound (The American Society of

Hypertension, 1992), respectively. Three readings of SBP and DBP were recorded, and the average of the last two readings was used for data analysis. The cutoff points for abnormal FPG, dyslipidemia and elevated blood pressure were defined by the criteria of the National Cholesterol Education Program Adult Treatment Panel III (NCEP, 2001): (1) FPG $\geqslant$ 6.11 mmol/l (110 mg per 100 ml), (2) TG $\geqslant$ 1.70 mmol/l (150 mg per 100 ml), (3) HDL-C < 1.03 mmol/l (40 mg per 100 ml) for men or $\geqslant$ 1.29 mmol/l (50 mg per 100 ml) for women, and (4) SBP $\geqslant$ 120 or DBP $\geqslant$ 80 mm Hg.

Statistical analyses
Data are expressed as number and percentage (categorical), or mean ± s.d. (continuous). Differences between normal subjects and those with elevated ALT were evaluated using Student's *t*-test or χ^2 test, as appropriate. Differences among the three BMI groups were determined using generalized linear model (Duncan's test of multiple comparisons). Multivariable-adjusted logistic regression analysis was conducted to examine the odds ratio (OR) and 95% confidence interval (CI) for the elevated ALT across a range of BMI or other potential risk factors. Statistical analyses were performed with SAS software version 9.1 (SAS Institute, Cary, NC, USA). Statistical significance was defined as $P<0.05$.

Results

Characteristics of study subjects
Of 3098 Korean adults assessed, 246 (12.7%) men and 86 (7.4%) women displayed elevated ALT (Table 1). Men with elevated ALT tended to be younger than those with normal ALT; this trend was not evident for women. BMI and WC were significantly higher in men and women with elevated ALT ($P<0.0001$). The prevalence of heavy alcohol consumption seemed to be higher in men with elevated ALT than in men with normal ALT ($P=0.0508$), but this trend was not seen in women. Men with elevated ALT displayed higher FPG, TG, SBP, and DBP, and lower HDL-C. In women, FPG, TG, and DBP were significantly higher in subjects with elevated ALT than in subjects with a normal ALT level.

Characteristics of subjects according to the degree of BMI
BMI and WC increased significantly at each category of BMI ($P<0.0001$) (Table 2). ALT concentration significantly increased according to the degree of BMI in both men and women ($P<0.0001$). As expected, the prevalence of subjects with elevated ALT was significantly higher in overweight and obese subjects than in normal weight adults of both genders ($P<0.0001$). The influence of alcohol intake was not appreciably different among the three BMI groups for both genders. Metabolic variables such as FPG, TG, and blood pressure were significantly increased on increasing BMI in both genders ($P<0.0001$). HDL-C was also significantly decreased by increased BMI.

Table 1 Characteristics of study subjects

	Normal ALT (n = *2766*)	*Elevated ALT* (n = *332*)	P
Men (*n* = 1931)	1685 (87.3)[a]	246 (12.7)	
Age (years)			
20–39	581 (34.48)	109 (44.31)	<0.0001
40–59	705 (41.84)	112 (45.53)	
⩾60	399 (23.68)	25 (10.16)	
BMI (kg/m^2)	23.60 ± 2.95[a]	26.00 ± 3.29	<0.0001
WC (cm)	82.95 ± 8.54	89.36 ± 8.10	<0.0001
Alcohol intake (g/day)			
None	1016 (69.64)	137 (66.5)	0.0508
Light/moderate	210 (14.39)	23 (11.17)	
Heavy	233 (15.97)	46 (22.33)	
ALT (IU/l)	21.71 ± 7.53	65.81 ± 41.02	<0.0001
FPG (mmol/l)	5.10 ± 0.55	5.26 ± 0.59	<0.0001
TG (mmol/l)	1.61 ± 1.17	2.56 ± 1.97	<0.0001
HDL-C(mmol/l)	1.11 ± 0.26	1.04 ± 0.27	<0.0001
SBP (mm Hg)	121.6 ± 15.64	124.19 ± 15.76	0.0155
DBP (mm Hg)	80.17 ± 10.20	83.20 ± 10.99	<0.0001
Women (n = 1167)	1081 (92.6)	86 (7.4)	
Age (years)			
20–39	116 (10.73)	8 (9.3)	0.7678
40–9	412 (38.11)	36 (41.86)	
⩾60	553 (51.16)	42 (48.84)	
BMI (kg/m^2)	23.87 ± 3.26	25.57 ± 3.13	<0.0001
WC (cm)	80.55 ± 9.41	85.45 ± 8.77	<0.0001
Alcohol intake (g/day)			
None	744 (91.18)	66 (97.06)	0.2108
Light/moderate	52 (6.37)	2 (2.94)	
Heavy	20 (2.45)	0 (0)	
ALT (IU/l)	16.93 ± 5.47	47.73 ± 23.45	<0.0001
FPG (mmol/l)	5.07 ± 0.52	5.22 ± 0.58	0.01
TG (mmol/l)	1.40 ± 0.78	1.96 ± 1.61	0.0019
HDL-C(mmol/l)	1.20 ± 0.29	1.16 ± 0.27	0.1353
SBP (mm Hg)	124.1 ± 19.67	126.37 ± 21.77	0.3517
DBP (mm Hg)	77.26 ± 10.59	81.53 ± 11.33	0.001

Abbreviations: ALT, alanine aminotransferase; BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.
[a]All values are *n* (%) or mean ± s.d.

ORs and CIs for elevated ALT concentration across the range of BMI
Table 3 shows the results of logistic regression analysis to determine ORs for elevated ALT level according to BMI. The unadjusted OR for elevated ALT significantly increased in overweight men (OR: 1.92, 95% CI: 1.25–2.93). The unadjusted OR for elevated ALT increased according to the increase of BMI (OR: 1.92, 95% CI: 1.25–2.93 vs OR: 5.01, 95% CI: 3.49–7.21; $P<0.0001$) in men. In women, the unadjusted OR for elevated ALT consistently was significantly increased according to degree of BMI

Table 2 Characteristics of subjects according to BMI

	Normal weight(BMI<23)	*Overweight (23⩽BMI<25)*	*Obese(BMI ⩾25)*	P
Men	739	524	668	
Age (years)	45.90±16.58[a]	45.88±14.16	44.99±13.19	0.4429
BMI (kg/m^2)	20.86±1.57[b]	23.99±0.58[c]	27.21±1.89[d]	<0.0001
WC (cm)	76.35±6.28[b]	84.25±4.52[c]	91.59±6.27[d]	<0.0001
Alcohol intake (g/day)				
None	457 (70.85)[a]	308 (67.25)	388 (69.04)	0.6080
Light/moderate	91 (14.11)	67 (14.63)	75 (13.35)	
Heavy	97 (15.04)	83 (18.12)	99 (17.62)	
ALT (IU/l)	22.23±20.16[b]	26.10±15.79[c]	33.94±25.85[d]	<0.0001
Elevated ALT(>40 IU/l)	41 (5.55)	53 (10.11)	152 (22.75)	<0.0001
FPG (mmol/l)	5.01±0.55[b]	5.09±0.53[c]	5.26±0.55[d]	<0.0001
TG (mmol/l)	1.35±1.05[b]	1.72±1.03[c]	2.15±1.68[d]	<0.0001
HDL-C (mmol/l)	1.19±0.29[b]	1.07±0.23[c]	1.03±0.22[d]	<0.0001
SBP (mm Hg)	118.84±16.01[b]	121.81±15.31[c]	125.44±14.84[d]	<0.0001
DBP (mm Hg)	77.36±9.74[b]	80.23±9.58[c]	84.33±10.36[d]	<0.0001
Women	462	277	428	
Age (years)	55.90±17.58[b]	58.09±13.26[c]	59.73±10.52[c]	0.0003
BMI (kg/m^2)	20.83±1.58[b]	24.03±0.57[c]	27.40±1.98[d]	<0.0001
WC (cm)	73.04±6.18[b]	81.33±5.74[c]	89.13±6.80[d]	<0.0001
Alcohol intake (g/day)				
None	298 (91.69)	205 (94.04)	307 (90.03)	0.4101
Light/moderate	18 (5.54)	11 (5.05)	25 (7.33)	
Heavy	9 (2.77)	2 (0.92)	9 (2.64)	
ALT (IU/l)	15.93±6.73[b]	19.75±13.66[c]	22.36±13.07[d]	<0.0001
Elevated ALT(>31 IU/l)	15 (3.25)	21 (7.58)	50 (11.68)	<0.0001
FPG (mmol/l)	4.95±0.49[b]	5.08±0.49[c]	5.23±0.54[d]	<0.0001
TG (mmol/l)	1.18±0.62[b]	1.44±0.87[c]	1.72±1.04[d]	<0.0001
HDL-C (mmol/l)	1.26±0.29[b]	1.18±0.30[c]	1.15±0.25[c]	<0.0001
SBP (mm Hg)	119.45±20.31[b]	122.78±18.35[c]	130.42±18.61[d]	<0.0001
DBP (mm Hg)	74.18±10.67[b]	77.16±9.66[c]	81.50±10.07[c]	<0.0001

Abbreviations: ALT, alanine aminotransferase; BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.
[a]All values are *n* (%) or mean±s.d.
[b,c,d]Values with unlike superscripts are significantly different ($P<0.05$).

Table 3 Odds ratios (95% confidence intervals) for elevated ALT concentrations across the range of BMIs

BMI category	*Men*		*Women*	
	Unadjusted	*Adjusted*[a]	*Unadjusted*	*Adjusted*[a]
<23	1.0	1.0	1.0	1.0
23–25	1.92 (1.25–2.93)	1.56 (0.97–2.51)	2.44 (1.24–4.82)	1.55 (0.65–3.68)
⩾25	5.01 (3.49–7.21)	3.47 (2.26–5.33)	3.94 (2.18–7.13)	3.10 (1.47–6.52)
P for trend	<0.0001	<0.0001	<0.0001	0.0015

Abbreviations: ALT, alanine aminotransferase; BMI, body mass index.
[a]Adjusted for age, alcohol intake, fasting plasma glucose, triglyceride, high-density lipoprotein cholesterol, and blood pressure using multiple logistic regression analysis.

(OR: 2.44, 95% CI: 1.24–4.82 vs OR: 3.94, 95% CI: 2.18–7.13; $P<0.0001$). This trend did not differ after adjustment for age, alcohol intake, and metabolic variables such as FPG, TG, HDL-C, and blood pressure in both men (OR: 1.56 vs OR: 3.47, $P<0.0001$) and women (OR: 1.55 vs OR: 3.10, $P=0.0015$).

Multiple logistic regression analysis of other potential risk factors and their association with elevated ALT concentration

Table 4 shows the OR and 95% CIs for the individual risk factors associated with elevated ALT among Korean adults. In the multiple logistic regression analysis, we found that the potential risk factors for the elevated ALT concentration were

Table 4 Multiple logistic analyses of other potential risk factors and their association with elevated ALT

Factors	OR[a]	95% CI (P) (Men)	OR[a]	95% CI (P) (Women)
Age (years)				
20–39	1.0		1.0	
40–59	0.54	0.38–0.76 (0.0005)	0.52	0.11–2.55 (0.4223)
⩾60	0.27	0.15–0.47 (<0.0001)	0.51	0.10–2.51 (0.4093)
WC (cm)				
<90 (M), <80 (W)	1.0		1.0	
⩾90 (M), ⩾80 (W)	2.44	1.73–3.43 (<0.0001)	1.83	0.97–3.46 (0.0629)
Alcohol intake (g/day)				
None	1.0		1.0	
Light/moderate	0.69	0.42–1.12 (0.1323)	0.35	0.08–1.58 (0.1724)
Heavy	1.27	0.87–1.86 (0.2241)	—	—
FPG (mmol/l)				
<6.11	1.0		1.0	
M⩾6.11	1.16	0.64–2.12 (0.6238)	2.20	0.78–6.22 (0.1375)
TG (mmol/l)				
<1.70	1.0		1.0	
⩾1.70	2.68	1.91–3.77 (<0.0001)	1.31	0.75–2.27 (0.3433)
HDL-C (mmol/l)				
<1.03(M), <1.29(W)	1.0		1.0	
⩾1.03(M), ⩾1.29(W)	0.85	0.61–1.19 (0.35)	0.93	0.50–1.75 (0.8275)
BP (mm Hg)				
SBP<120, DBP<80	1.0			
SBP⩾120 or DBP⩾80	1.08	0.75–1.57 (0.6662)	1.08	0.59–1.99 (0.7995)

Abbreviations: ALT, alanine aminotransferase; BP, blood pressure; CI, confidence interval; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; OR, odds ratio; M, men; W, women; SBP, systolic blood pressure; TG, triglyceride; WC, waist circumference.
[a]Adjusted for age, BMI, alcohol intake, TG, FPG, HDL-C, and blood pressure.

age, WC (⩾90 cm for men and ⩾80 cm for women), and TG⩾1.70 mmol/l (150 mg per 100 ml) after adjusted for age, BMI, alcohol intake, FPG, TG, and HDL-C in men. In women, however, none of these factors were significant.

Discussion

Obesity has been reported as a risk factor associated with elevation of ALT, which is a surrogate marker of NAFLD (Robinson and Whitehead, 1989; Salvaggio *et al*., 1991; Bizzaro *et al*., 1992; Chen *et al*., 2007). We evaluated the relationship between obesity and an elevated ALT concentration among general Korean population based on the data from the 2005 KNHANES survey. In this large, nationally representative, population-based study, we found that BMI had a strong relationship with an elevated ALT concentration in non-diabetic Korean adults. The prevalence of the elevated ALT significantly increased in overweight (23⩽BMI<25) and obese (BMI⩾25) subjects compared with subjects with normal weight. The risk of elevated ALT levels was over threefold higher in obese Korean adults than Korean adults with normal weight after adjustment for other risk factors such as age, alcohol intake, and several metabolic variables in both genders. The risk for elevated ALT concentration tended to increase according to the severity of obesity. These results suggest that overall obesity measured by BMI is an independent indicator of elevated ALT concentration among non-diabetic Korean population.

An earlier study showed that among Australians aged 20–80 years, overweight (25⩽BMI<30) and obese (BMI⩾30) subjects had a two–threefold and sevenfold increased risk for the elevation of ALT, respectively, after adjusting for age and alcohol consumption compared with subjects with normal weight (Adams *et al*., 2008). Similarly, NHANES III data has revealed that the risk of elevated ALT activity is also two–threefold higher in overweight (25⩽BMI<30) and obese (BMI⩾30) American adults compared with adults with normal weight after adjustment for age, sex, ethnicity, alcohol, smoking, caffeine consumption, and HgbA1c (Ruhl and Everhart, 2005). The results from these two studies substantially agree with our study. However, a direct comparison of these studies is not possible because of different conditions used, principally the differing BMI definitions for Asians and Caucasians.

Although BMI, WC, and abdominal height were all highly correlated with ALT levels among subjects aged 35–80 years from a study conducted in Western New York (Stranges *et al*., 2004), central obesity assessed by abdominal height was reported to be a better correlate of ALT levels than BMI after adjusting for several covariates in the analysis of multiple linear regression in both sexes. A cross-sectional study using non-diabetic overweight Korean women documented that visceral fat was the strongest predictor of elevated ALT concentration among the anthropometric variables including BMI (Song *et al*., 2008). This earlier study showed that the adjusted OR for elevation of ALT increased by threefold in third quartile (102.7–135 cm^2) of visceral adipose tissue and up to 15-fold in the highest quartile (135.1–382.7 cm^2) after adjustment for age, alcohol consumption, and several metabolic variables. From this result, we also tested whether abdominal obesity as measured by WC was a better correlate of ALT levels than BMI. We found that WC tended to significantly increase the risk of elevated ALT in men (OR: 2.44, 95% CI: 1.73–3.43), but not in women (OR: 1.83, 95% CI: 0.97–3.46) suggesting that BMI may be a stronger indicator of elevated ALT concentration than WC in the general Korean population.

The data from NHANES conducted between 1998 and 2002 showed that alcohol consumption is a strong predictor of elevated ALT activity (Ioannou *et al*., 2006). However, in our study, alcohol intake was not significantly associated with the risk for elevated ALT in both Korean men and women. Similarly, the Western New York Health Study indicated that obesity and body fat distribution may be more important than alcohol consumption for high ALT concentration (Stranges *et al*., 2004). Among Australian adults, obesity accounted for half of the abnormal ALT levels in the study subjects, whereas excessive alcohol intake was responsible for $<10\%$ suggesting that excess weight is a greater risk factor of ALT levels than excessive alcohol consumption (Adams *et al*., 2008). In a 4-year follow-up study using Korean male workers aged 25–50 years, being overweight increased the risk of elevated ALT by 5–14-fold, but alcohol consumption was not related to ALT levels when adjusted for age, smoking, and exercise (Lee *et al*., 2001), which is consistent with the present finding. Studies conducted with Japanese adults have also reported that alcohol consumption was not significantly related to ALT (Nakamura, 1980; Nakamura *et al*., 1998).

Our study has several limitations. As our results are based on a cross-sectional design, we could not define the causal relationship between obesity and an elevated ALT concentration. Secondly, we did not measure hepatitis C antibody, which is known to be related to an elevated ALT. However, the prevalence of hepatitis C virus-related chronic liver disease is low among Korean adults (Kwon and Bae, 2008). Third, we used an elevated ALT concentration as a surrogate marker of liver damage instead of liver biopsy, which is the standard way to diagnose NAFLD (Hultcrantz *et al*., 1986; Ratziu *et al*., 2000; Skelly *et al*., 2001). Thus, our findings cannot, with confidence, be used to claim a direct relationship between obesity and NAFLD in the general Korean population. The definitive means to establish a direct relationship, liver biopsy, cannot ethically be used in a large population study.

Conclusions

Obesity defined by BMI is presently strongly associated with an elevation of ALT concentration, as a surrogate of NAFLD, in non-diabetic Korean adults. However, in an attempt to evaluate the causal relationship between obesity and an elevated ALT concentration, large-scale follow-up studies should be conducted.

Conflict of interest

The authors declare no conflict of interest.

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