Association between serum alanine and aspartate aminotransferase and blood pressure: a cross-sectional study of Chinese freshmen

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Abstract

**Background:** High blood pressure is a well-recognized risk factor for cardiovascular events, and the incidence of hypertension is increasing among young people. This study investigated the relationship between ALT and AST levels and hypertension among freshmen in China.

**Methods:** This cross-sectional study was conducted in the Anhui Province from September to November 2018. A total of 3114 freshmen underwent a physical examination including testing of biochemical indicators and a standardized questionnaire.

**Results:** The overall prevalence of elevated ALT and AST were 6.8% and 2.3% among freshmen. The mean ALT and AST levels were higher in males (22.59 ± 21.98 vs. 12.62 ± 10.30 U/L; 23.55 ± 12.24 vs. 20.02 ± 5.75 U/L, respectively). The prevalence of hypertension was significantly higher in men (16.1%) than in women (1.9%). The mean values of BMI, SBP, DBP, TC, TG, and LDL-C were found to be increased with elevated levels of serum ALT and AST in the quartiles (P for trend < 0.05). After adjusting for covariates, the risk of hypertension was significantly higher in the highest ALT quartile than in the lowest quartile (OR (95% CI) of 1.681 (1.028, 2.751) in males; 2.802 (1.102, 7.124) in females). A strong linear relationship was found between serum ALT levels and the odds of hypertension after adjustment for potential confounders only in total population and females (P for trend < 0.05).

**Conclusions:** These findings suggest that ALT level is significantly associated with hypertension both in male and female freshmen.

**Keywords:** Alanine aminotransferase, Aspartate aminotransferase, Freshmen, Hypertension, Association, Cross-sectional

Background

Cardiovascular diseases are responsible for more than 18 million deaths each year, accounting for approximately one-third of all global deaths [1]. High blood pressure is a well-recognized risk factor for cardiovascular events. Although hypertension is traditionally more prevalent in older people, recent epidemiological studies have shown an increased prevalence of risk...
factors in the young, including obesity, diabetes mel-
itus, and renal disease, and the incidence of hyper-
tension is progressively rising among the young [2].
Moreover, the younger the onset of hypertension, the
higher the risk of cardiovascular disease and all-cause
mortality [3]. Recently, some epidemiological studies
suggest liver enzymes such as alanine and aspartate
aminotransferase (ALT, AST) are associated with the
presence of hypertension [4, 5]. ALT and AST are sen-
sitive indicators of liver cell injury and have been used
to identify patients with liver disease. A case–control
study in China has showing ALT is a potential indicator
for patients with hypertension in senior adults [6]. A
12-year Korean Cohort Study reported that progression
to hypertension was associated with frequent drinking
and high ALT levels among men [7]. Moreover, previous
work from the Framingham Heart Study found that
increased ALT levels were associated with elevated
blood pressure, and higher AST levels were correlated
with higher DBP [8]. Inconsistent with previous stud-
ies, Gupta et al. [9] reported no significant relationship
in the ALT and AST levels of normal, prehypertensive,
and hypertensive individuals. However, most of the
previous studies assessed the relationship that included
only in adults and their findings were inconsistent.
There are scarce earlier studies of this association
among young people.

Freshmen generally experience substantial changes
including the transition from high school to univer-
sity, changes in living environment, lifestyle, and life
content. A survey in Lebanon found that the students
gained approximately 1.90 kg when transitioning from
high school to university and significant increases in
waist circumference, blood glucose, and triglyceride
levels were detected [10]. An entry health examina-
tion of college students in North Taiwan shows that
the prevalence of abnormal liver function tests was
6.2% among freshmen [11]. A meta-analysis on the
prevalence of hypertension among college students in
China shows that 3.62% of college students suffer from
hypertension [12]. Another study of university students
aged 15–19 in Nigeria showed that the prevalence of
hypertension was 25.1% [13]. The epidemiological data
concerning the association between elevated ALT and
AST and hypertension in the Chinese freshmen are
not available yet. In view of the relationship between
liver enzymes and blood pressure in adults, the study
of liver enzymes in adolescents may have guiding sig-
nificance for mitigating the risk of hypertension among
adolescents.

This study aimed to investigate whether there is a rela-
tionship between ALT and AST and the occurrence of
hypertension among freshmen in China.

Methods

Study population

A population-based cross-sectional survey was con-
ducted at a medical college in Anhui, China between
September and November 2018. A total of 3450 freshmen
were investigated. Another 101 individuals with missing
height or weight and 235 individuals with missed ques-
tionnaires and associated information were excluded.
Ultimately, 3114 freshmen were included in the final
analysis. The study was approved by the Ethics Com-
mittee of Wannan Medical College, Yijishan Hospital
(Approval No. 32 (2018)). Written informed consent was
obtained from all participants or, if subjects are under 18,
from a parent and/or legal guardian.

Data collection and measurements

Each participant completed a standard questionnaire and
underwent a detailed physical examination by a trained
doctor or nurse. Physical examination included the fol-
lowing procedures. Blood pressure was measured twice
with an interval of no less than 2 min with a mercury
sphygmomanometer (Omron U30, China), with the par-
ticipants in a sitting position and after at least 5 min of
rest. The average value of the two measurements was
taken as the final BP. The height and weight of the sub-
jects were measured using an ultrasound height and
weight measuring instrument (Shengyuan, China), with
the participants in light clothing and without shoes, in
an upright position. Waist circumference was measured
1 cm above the umbilicus in a horizontal plane. Body
mass index (BMI) was calculated by dividing weight (kg)
by height (m) squared (kg/m²).

Venous blood samples were collected in the morning
after at least 10 h of overnight fasting. The serum sam-
ple were separated for biochemical assays without freez-
ing. Biochemical variables, including serum ALT, AST,
triglyceride (TG), total cholesterol (TC), high-density
lipoprotein cholesterol (HDL-C), low-density lipoprotein
cholesterol (LDL-C), and glucose (GLU) were measured
using an auto-analyzer.

Definitions

Hypertension in Chinese adult was defined accord-
ing to the “2018 Chinese guidelines for the manage-
ment of hypertension [14]” as systolic blood pressure
(SBP) ≥ 140 mm Hg and /or diastolic blood pressure
(DBP) ≥ 90 mm Hg, and/or use of antihypertensive medi-
cations. For adolescents ≥ 13 years of age, “hypertension”
was defined as SBP ≥ 130 mmHg and /or DBP ≥ 80 mmHg
[15]. Obesity was diagnosed according to the “Screening
for Overweight and Obesity Among School-age Chil-
dren and Adolescents” criteria: BMI ≥ 27.1, BMI ≥ 27.6,
BMI ≥ 28.0 were the obesity criteria for adolescents aged
16, 17, 18 years and older, respectively. Criteria for abnormal liver enzymes for adolescents < 18 years of age were ALT > 30 U/L for boys and > 21 U/L for girls, AST > 38 U/L for boys and > 33 U/L for girls [16]. The upper limit of normal serum ALT level and AST levels both were set at 40 U/L in adults, and an elevated ALT level was defined as > 40 U/L, and elevated AST was defined as > 40 U/L [17]. Serum ALT levels were categorized by quartiles as ≤ 9, 10–12, 13–18, and > 19 U/L. Serum AST levels were categorized by quartiles as ≤ 17, 18–20, 21–23, and ≥ 24 U/L.

Statistical analysis
We calculated the mean ± standard deviation (SD) for continuous data and frequency (percentage) for categorical variables. The independent-samples t-test was performed to compare the differences in continuous variables. The categorical variable distributions were compared using Chi-square tests. Pearson correlation was used to evaluate the relationship between ALT and AST levels and other variables. Multivariate logistic regression models adjusted for age and sex (Model 1) or age, sex, BMI, smoking, and drinking (Model 2) or Model 2 plus, TC, TG, HDL-C, LDL-C, and GLU were used to estimate the odds ratios (ORs) of the associations between ALT and AST and hypertension. All statistical analyses were conducted using SPSS software (version 18.0; SPSS Inc., Chicago, IL, USA). Statistical significance was defined as a two-tailed P < 0.05.

Results
Baseline characteristics of this study
The baseline characteristics of the study population according to sex are presented in Table 1. A total of 3114 freshmen (1264 men and 1850 women) participated in the study. The mean age was 18.52 ± 1.01 years (range 15—27 years). The overall prevalence of elevated ALT and AST were 6.8% (n = 211), 2.3% (n = 71) among freshmen. The mean ALT and AST levels were higher in males (22.59 ± 21.98 vs. 12.62 ± 10.30 U/L; 23.55 ± 12.24 vs. 20.02 ± 5.75 U/L, respectively). Male freshmen had a significantly higher prevalence of hypertension (16.1%) than female freshmen (1.9%). Additionally, male participants had higher levels of BMI, SBP, DBP, TG, and LDL-C, but lower GLU, TC, and HDL-C levels than the females (P < 0.05).

Prevalence of hypertension
The overall prevalence of hypertension was 8.4% (n = 262). Participants with hypertension had higher BMI, TC, TG, LDL-C, ALT, and AST, and had lower HDL-C levels. The prevalence abnormal liver enzymes rate was significantly higher in the hypertensive group (ALT 21.0% vs. 5.5%; AST 6.5% vs. 1.9%; obesity 30.9% vs. 10.5%, P < 0.05) than in the normotensive group. In males, the mean ALT and AST concentration were higher in those with hypertension. In contrast, no differences were observed among the female participants (Table 2).

| Characteristic                  | Total (n = 3114) | Males (n = 1264) | Females (n = 1850) | t/χ²   | P   |
|--------------------------------|-----------------|-----------------|--------------------|--------|-----|
| Age (year)                     | 18.52 ± 1.01    | 18.57 ± 1.01    | 18.48 ± 1.01       | 2.417  | 0.016 |
| BMI (kg/m²)                    | 22.33 ± 3.53    | 23.11 ± 3.97    | 21.8 ± 3.09        | 9.868  | 0.000 |
| SBP (mmHg)                     | 114.05 ± 13.73  | 121.71 ± 13.57  | 108.81 ± 11.14     | 27.966 | 0.000 |
| DBP (mmHg)                     | 70.94 ± 10.56   | 73.21 ± 11.04   | 69.38 ± 9.92       | 9.904  | 0.000 |
| GLU (mmol/L)                   | 4.57 ± 0.4      | 4.51 ± 0.38     | 4.6 ± 0.41         | −6.271 | 0.000 |
| TC (mmol/L)                    | 4.05 ± 0.68     | 4.01 ± 0.74     | 4.08 ± 0.63        | −2.95  | 0.001 |
| TG (mmol/L)                    | 0.83 ± 0.4      | 0.87 ± 0.47     | 0.81 ± 0.35        | 3.826  | 0.000 |
| HDL-C (mmol/L)                 | 1.42 ± 0.28     | 1.31 ± 0.25     | 1.49 ± 0.27        | −18.915| 0.000 |
| LDL-C (mmol/L)                 | 2.09 ± 0.56     | 2.15 ± 0.63     | 2.05 ± 0.05        | 4.846  | 0.000 |
| ALT (U/L)                      | 16.67 ± 16.82   | 22.59 ± 21.98   | 12.62 ± 10.30      | 15.035 | 0.000 |
| AST (U/L)                      | 21.45 ± 9.13    | 23.55 ± 12.24   | 20.02 ± 5.75       | 9.566  | 0.000 |
| Prevalence of elevated ALT (%) | 211 (6.8)       | 154 (12.2)      | 57 (3.1)           | 98.498 | 0.000 |
| Prevalence of elevated AST (%) | 71 (2.3)        | 52 (4.1)        | 19 (1.0)           | 32.116 | 0.000 |
| Current smoking status (%)     | 76 (2.4)        | 68 (5.4)        | 8 (0.4)            | 77.192 | 0.000 |
| Current drinking status (%)    | 428 (13.7)      | 329 (26.0)      | 99 (5.4)           | 270.812| 0.000 |
| Prevalence of hypertension (%) | 262 (8.4)       | 203 (16.1)      | 59 (1.9)           | 161.438| 0.000 |

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; GLU, glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ALT, alanine aminotransferase; AST, aspartate aminotransferase

Table 1 Characteristics of the study participants
Table 2  Anthropometric and metabolic characteristics categorized by hypertension and sex

| Characteristic | Total (n = 3114) | Hypertension (n = 262) | Males (n = 1264) | Females (n = 1850) | | | |
|----------------|------------------|------------------------|-----------------|-------------------|--|--|
| Age (year)     | 18.52 ± 1.01     | 18.42 ± 1.03           | 1.594           | 0.111             | 18.58 ± 1.01       | 18.51 ± 1.02         | 0.935          | 0.350             | 18.49 ± 1.01       | 18.12 ± 1.04         | 2.786          | 0.005             |
| BMI (kg/m²)    | 22.09 ± 3.27     | 25.04 ± 4.90           | −9.575          | 0.000             | 22.68 ± 3.61       | 25.37 ± 4.91         | −7.444          | 0.000             | 21.73 ± 2.99       | 23.91 ± 4.75         | −3.492          | 0.001             |
| GLU (mmol/L)   | 4.57 ± 0.40      | 4.55 ± 0.42            | 0.563           | 0.573             | 4.51 ± 0.38        | 4.54 ± 0.41          | −0.867          | 0.386             | 4.6 ± 0.41         | 4.62 ± 0.45          | −0.22           | 0.826             |
| TC (mmol/L)    | 4.04 ± 0.67      | 4.17 ± 0.82            | −2.374          | 0.018             | 3.97 ± 0.71        | 4.2 ± 0.86           | −4.045          | 0.000             | 4.08 ± 0.63        | 4.05 ± 0.65          | 0.437           | 0.662             |
| TG (mmol/L)    | 0.82 ± 0.38      | 0.98 ± 0.55            | −4.731          | 0.000             | 0.84 ± 0.45        | 1 ± 0.56            | −3.717          | 0.000             | 0.81 ± 0.34        | 0.93 ± 0.49          | −1.915          | 0.060             |
| HDL-C (mmol/L) | 1.43 ± 0.27      | 1.27 ± 0.24            | 9.897           | 0.000             | 1.33 ± 0.25        | 1.24 ± 0.21          | 5.273           | 0.000             | 1.49 ± 0.27        | 1.39 ± 0.32          | 2.865           | 0.004             |
| LDL-C (mmol/L) | 2.07 ± 0.54      | 2.30 ± 0.72            | −5.000          | 0.000             | 2.11 ± 0.6         | 2.35 ± 0.75          | −5.017          | 0.000             | 2.05 ± 0.5         | 2.11 ± 0.55          | −0.979          | 0.328             |
| ALT (U/L)      | 15.63 ± 14.89    | 27.96 ± 28.51          | −6.917          | 0.000             | 20.96 ± 19.64      | 31.10 ± 30.18        | −4.606          | 0.000             | 12.47 ± 9.90       | 17.15 ± 18.20        | −1.967          | 0.054             |
| AST (U/L)      | 21.06 ± 7.99     | 25.74 ± 19.71          | −3.822          | 0.000             | 22.92 ± 9.26       | 26.86 ± 21.75        | −2.539          | 0.012             | 19.95 ± 5.60       | 21.90 ± 9.07         | −1.635          | 0.107             |
| Prevalence of elevated ALT (%) | 54 (1.9) | 17 (6.5) | 22.741 | 0.000 | 37 (3.5) | 15 (7.4) | 6.577 | 0.010 | 17 (0.9) | 2 (3.4) | 1.377 | 0.241 |
| Prevalence of elevated AST (%) | 299 (10.5) | 81 (30.9) | 93.501 | 0.000 | 137 (12.9) | 67 (33.0) | 50.827 | 0.000 | 162 (9.0) | 14 (23.7) | 14.306 | 0.000 |
| Prevalence of obesity (%) | 65 (2.3) | 11 (4.2) | 3.713 | 0.054 | 57 (5.4) | 11 (5.4) | 0.001 | 0.979 | 8 (0.4) | 0 (0) | — | 0.771 |
| Current smoking status (%) | 373 (13.1) | 55 (21.0) | 12.676 | 0.000 | 277 (26.1) | 52 (25.6) | 0.021 | 0.884 | 96 (5.4) | 3 (5.1) | 0.001 | 0.999 |

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; GLU, glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ALT, alanine aminotransferase; AST, aspartate aminotransferase.
Table 3  Baseline characteristics of the study participants according to ALT and AST quartiles

| Characteristic     | ALT (U/L) |     |     |     | P-values for trend | AST (U/L) |     |     |     |     | P-values for trend |
|-------------------|-----------|-----|-----|-----|-------------------|-----------|-----|-----|-----|-----|-------------------|
|                   | Q1 (≤ 9) | Q2 (10–12) | Q3 (13–18) | Q4 (≥ 19) |       | Q1 (≤ 17) | Q2 (18–20) | Q3 (21–23) | Q4 (≥ 24) |       |
| Age (year)        | 18.50±1.05 | 18.49±1.01 | 18.53±0.98 | 18.56±0.98 | 0.162 | 18.50±1.04 | 18.54±1.05 | 18.54±0.98 | 18.48±0.94 | 0.651 |
| BMI (kg/m²)       | 20.89±2.38 | 21.56±2.86 | 22.29±3.03 | 25.15±4.21 | 0.000 | 21.68±2.81 | 21.69±2.96 | 22.22±3.32 | 24.11±4.5 | 0.000 |
| SBP (mmHg)        | 110.01±11.82 | 111.42±12.6 | 115.97±13.35 | 120.49±14.89 | 0.000 | 112.39±12.58 | 112.20±13.08 | 114.41±13.54 | 118.25±15.13 | 0.000 |
| DBP (mmHg)        | 69.18±9.85 | 69.96±10.22 | 71.06±10.38 | 74.21±11.24 | 0.000 | 70.27±10.11 | 69.99±10.19 | 70.91±10.36 | 73.07±11.44 | 0.000 |
| GLU (mmol/L)      | 4.56±0.40 | 4.57±0.38 | 4.56±0.39 | 4.58±0.44 | 0.560 | 4.58±0.41 | 4.57±0.40 | 4.57±0.38 | 4.54±0.42 | 0.077 |
| TC (mmol/L)       | 3.97±0.60 | 4.02±0.65 | 4.00±0.66 | 4.25±0.79 | 0.000 | 3.96±0.60 | 4.00±0.65 | 4.08±0.69 | 4.21±0.78 | 0.000 |
| TG (mmol/L)       | 0.75±0.26 | 0.78±0.34 | 0.82±0.39 | 1.01±0.55 | 0.000 | 0.77±0.28 | 0.80±0.35 | 0.85±0.43 | 0.95±0.53 | 0.000 |
| HDL-C (mmol/L)    | 1.47±0.25 | 1.47±0.27 | 1.40±0.28 | 1.30±0.28 | 0.000 | 1.44±0.26 | 1.43±0.27 | 1.43±0.27 | 1.36±0.29 | 0.000 |
| LDL-C (mmol/L)    | 1.98±0.45 | 2.00±0.50 | 2.06±0.53 | 2.36±0.66 | 0.000 | 2.01±0.47 | 2.03±0.51 | 2.10±0.56 | 2.27±0.66 | 0.000 |

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; GLU, glucose; TC, total cholesterol; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ALT, alanine aminotransferase; AST, aspartate aminotransferase
Levels of demographic and clinical variables in the serum ALT and AST quartiles
Baseline information of the subjects in each serum ALT and AST quartile is presented in Table 3. The mean values of BMI, SBP, DBP, TC, TG, and LDL-C were found to be increased with elevated levels of serum ALT and AST in the quartiles. (P < 0.05 for trend).

Correlation between ALT and AST levels and hypertensive risk factors
Serum ALT levels were positively correlated with BMI, SBP and DBP in both genders (r = 0.511, 0.207, 0.172, respectively; P < 0.05). Serum AST levels were positively correlated with BMI, SBP and DBP in males, but only with BMI and DBP in females (P < 0.05) (Table 4).

Association of ALT and AST with hypertension
After adjusting for age and sex, the odd ratios (ORs) (95% CI) were 1.774 (1.139, 2.762), and 3.047 (2.028, 4.578), respectively in Q3 and Q4 compared to Q1 of the ALT. After additionally adjusting obesity, smoking, and drinking, TC, TG, LDL-C, HDL-C, compared with those in the lowest quartile, individuals in the highest quartile of serum ALT levels had associated with hypertension in males and females, with an OR (95% CI) of 1.681 (1.028, 2.751), and 2.802 (1.102, 7.124), respectively. However, there was no significant association of serum AST levels with hypertension in the full adjustment model (Table 5).

Discussion
In this study, we evaluated the relationship between ALT and AST levels and hypertension in a large, representative sample of 3114 freshmen. We demonstrated that only serum ALT, but not AST, was associated with hypertension both in males and females after adjusting for potential confounders.

In recent years, the incidence of abnormal ALT and AST has increased worldwide, making it a health issue [18, 19]. The overall prevalence of elevated ALT and AST were 6.8% and 2.3% in our study. A school-based cross-sectional study in China reported a prevalence of 6.76% for ALT levels greater than 30 U/L for boys and 9 U/L for girls, compared with 2.43% at a cut-off level of greater than 40 U/L for girls, compared with 2.43% at a cut-off level of greater than 40 U/L [20]. Asymptomatic elevation in ALT levels is common in primary care, and the prevalences of elevated ALT and AST in the United States were 8.9%, 4.9% respectively [21]. Freshmen are a special group and some biomarker levels are quite different from those of healthy adults [22]. This study shows that the prevalence of elevated ALT and AST levels differed in gender among freshman of China. Male freshmen had a significantly higher prevalence of elevated ALT and AST than female freshmen. We should take the prevalence as a predictor and continue to play a warning and preventive role.

ALT refers to an enzyme that is largely found in the liver. When the liver is damaged, ALT will be sent to the bloodstream, signalling liver disease, and ALT level in blood is used as an indication of the liver status, giving information about the seriousness of liver damage. Although AST is a marker of hepatocellular health, it is a less specific marker of liver function than ALT [23]. Our results revealed the SBP and DBP were increasing along with serum ALT and AST elevating whether in females or males populations. However, in regression analysis, only ALT was significantly associated with hypertension even after adjustment of potential confounders. A similar finding was observed in a previous study that only serum ALT was associated with hypertension [24].
ALT showed an independent relationship with hypertension [24]. More and more studies have shown that ALT play a considerable role in the development of cardiovascular diseases [18, 25]. Besides, ALT is associated with endothelial dysfunction and coronary heart disease [26]. A Korea Medical Insurance Corporation study showed that an elevated ALT is a predictor of intracerebral hemorrhage [27]. A longitudinal increase in ALT activity increases the incidence of metabolic syndrome [28]. Elevated plasma ALT levels were associated with hypertension at baseline in the Hong Kong Cardiovascular Risk Factor Prevalence Study. For participants who were not on antihypertensive medications, the plasma ALT level correlated with high blood pressure [29].

Although the mechanism underlying the associations between ALT and hypertension remains unclear, some

| Table 5 Association of ALT and AST with hypertension |
|-----------------------------------------------------|
| Group     | Characteristic | Model 1   | Model 2   | Model 3   |
|-----------|----------------|-----------|-----------|-----------|
| Total     | ALT            |           |           |           |
| Q1 (≤ 9)  | 1              | 1         | 1         |
| Q2 (10–12)| 1.575 (0.992, 2.500) | 1.517 (0.955, 2.409) | 1.511 (0.950, 2.402) |
| Q3 (13–18)| 1.774 (1.139, 2.762)* | 1.614 (1.033, 2.523)* | 1.545 (0.986, 2.420) |
| Q4 (≥ 19)| 3.047 (2.028, 4.578)* | 2.111 (1.365, 3.266)* | 1.815 (1.157, 2.846)* |
| P for trend | 0.000          | 0.001     | 0.014     |

ALT

| Group     | Characteristic | Model 1   | Model 2   | Model 3   |
|-----------|----------------|-----------|-----------|-----------|
| Q1 (≤ 17)| 1              | 1         | 1         |
| Q2 (18–20)| 1.446 (0.964, 2.167) | 1.471 (0.979, 2.212) | 1.435 (0.953, 2.162) |
| Q3 (21–23)| 1.479 (0.966, 2.264) | 1.354 (0.879, 2.085) | 1.329 (0.860, 2.054) |
| Q4 (≥ 24)| 2.000 (1.355, 2.953)* | 1.502 (1.001, 2.254)* | 1.388 (0.917, 2.099) |
| P for trend | 0.001          | 0.102     | 0.219     |

AST

| Group     | Characteristic | Model 1   | Model 2   | Model 3   |
|-----------|----------------|-----------|-----------|-----------|
| Males     | ALT            |           |           |           |
| Q1 (≤ 11)| 1              | 1         | 1         |
| Q2 (12–16)| 1.409 (0.884, 2.243) | 1.319 (0.826, 2.107) | 1.245 (0.776, 1.966) |
| Q3 (17–25)| 1.401 (0.874, 2.245) | 1.166 (0.718, 1.893) | 1.031 (0.630, 1.688) |
| Q4 (≥ 26)| 3.139 (2.076, 4.746)* | 2.033 (1.274, 3.245)* | 1.681 (1.028, 2.751)* |
| P for trend | 0.000          | 0.006     | 0.076     |

AST

| Group     | Characteristic | Model 1   | Model 2   | Model 3   |
|-----------|----------------|-----------|-----------|-----------|
| Females   | ALT            |           |           |           |
| Q1 (≤ 7)  | 1              | 1         | 1         |
| Q2 (8–9)  | 1.442 (0.508, 4.094) | 1.421 (0.499, 4.040) | 1.430 (0.502, 4.071) |
| Q3 (10–13)| 2.660 (1.062, 6.662)* | 2.453 (0.976, 6.170) | 2.516 (0.996, 6.356) |
| Q4 (≥ 14)| 3.444 (1.386, 8.557)* | 2.916 (1.157, 7.351)* | 2.802 (1.102, 7.124)* |
| P for trend | 0.002          | 0.008     | 0.012     |

AST

| Group     | Characteristic | Model 1   | Model 2   | Model 3   |
|-----------|----------------|-----------|-----------|-----------|
| Q1 (≤ 16)| 1              | 1         | 1         |
| Q2 (17–19)| 1.721 (0.724, 4.093) | 1.794 (0.751, 4.283) | 1.784 (0.747, 4.263) |
| Q3 (20–21)| 1.398 (0.514, 3.802) | 1.409 (0.516, 3.846) | 1.409 (0.514, 3.865) |
| Q4 (≥ 22)| 2.554 (1.077, 6.055)* | 2.395 (1.005, 5.711)* | 2.398 (0.998, 5.763) |
| P for trend | 0.042          | 0.076     | 0.078     |

Model 1: Adjusted for age, gender
Model 2: Adjusted for model 1 plus, obesity (based on BMI), smoking and drinking
Model 3: Adjusted for model 2 plus, TC, TG, HDL, LDL

*Compared to Q1, P < 0.05
mechanisms can be considered, and one of the most plausible is non-alcoholic fatty liver disease (NAFLD). Elevated serum ALT levels reflect an excess deposit of fat in the liver and are commonly used as a surrogate marker for NAFLD in epidemiological studies [30]. NAFLD represents the hepatic manifestation of the metabolic syndrome, which refers to a variably defined aggregate of disorders related to obesity, hypertension, type 2 diabetes, and hyperlipidemia [31]. Lopez-Suarez A et al. [32] indicated that NAFLD is associated with an independent risk of identifying hypertension and high-normal SBP. Detection of NAFLD, even with normal ALT levels, should serve as an opportunity to identify metabolic and BP abnormalities. Overweight and obesity are associated with elevated biochemical markers of liver damage, and obesity is well-known major predisposing conditions to NAFLD [33]. Children and adolescents who are overweight or obese have shown higher ALT concentrations in all age groups [34]. Our results also showed that ALT had the strongest correlation with BMI than other hypertension risk factors. A study of Poland middle and high school students aged 15–17 found that BMI is one of the strongest predictors of hypertension in teenagers [35]. A previous study revealed that an increase in BMI is linked to hypertension in university students [36]. Obesity may lead to hypertension in multiple ways by different percents [37]. It is speculated that high ALT levels will lead to an increase in BMI, which in turn leads to hypertension. Other possibility is that elevated serum ALT is a marker of inflammation and oxidative stress, and oxidative stress may play an important role in the initiation and progression of hypertension [38]. Finally, insulin resistance is the most common abnormality associated with the pathogenesis of both ALT and hypertension. ALT is associated with insulin resistance [39], and insulin resistance is commonly detected in individuals with hypertension [40].

We present the gender-specific analysis for the association between increasing liver enzymes levels and hypertension. In our logistic regression analysis, after adjusting for hypertensive risk factors, the risk of hypertension was significantly higher in the highest ALT quartile than in the lowest quartile in both sexes. However, a clear linear association between ALT and hypertension was present only among females. We did not observe an association between elevated serum AST levels and hypertension. One reason for the lack of linear association between ALT and hypertension in males may be related to sex differences in the absolute risk of hypertension. Research has reported that the gender difference of blood pressure began to appear in adolescence, and pubertal growth spurt occurs earlier for females than for males [41]. Thus, the relationship between ALT levels and hypertension in males needs to be further investigated.

The limitations of this study are as follows. First, this was a cross-sectional study, and causality could not be determined. Thus, further prospective studies are needed to verify the causal relationship between ALT and the prevalence of hypertension. Second, the study participants were all freshmen, so the results may not be generalizable to students of other age groups.

Conclusions

Results of this study suggest that serum ALT but not AST levels were positively associated with the prevalence of hypertension in both sexes. A linear association between elevated serum ALT and hypertension only in total population and females. To understand the complex interaction between ALT and hypertension, a large, well-constructed prospective study to elucidate the association between these factors is indicated.

Abbreviations

ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; BMI: Body mass index; BP: Blood pressure; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; GLU: Glucose; TC: Total cholesterol; TG: Triglycerides; HDL-C: High-density lipoprotein cholesterol; LDL-C: Low-density lipoprotein cholesterol; UA: Uric acid.

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Authors’ contributions

LZ and ZF conducted the experiments. LZ managed and analyzed the data and wrote the manuscript. MH and YJ were one of the principal investigators of the study. WC and LH revised the manuscript. YC was a contributor in organizing the database. YC and YY reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets during and/or analyzed during the current study will be available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the First Affiliated Yijishan Hospital of Wannan Medical College (Approval No. 32 (2018)). All procedures performed in studies involving human participants were in accordance with the ethics standards of the institutional and national research committee and with the Declaration of Helsinki. Written informed consent was obtained from all participants or, if subjects are under 18, from a parent and/or legal guardian.
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