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Original Article

Prevalence and determinants of elevated gamma-glutamyl transferase in Chinese hypertensive adults

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Abstract: *Objectives:* This study aims to examine the prevalence and determinants of elevated gamma-glutamyl transferase (GGT) in Chinese hypertensive adults aged 45-75 years. *Methods:* A cross-sectional investigation was carried out in the rural area of Lianyungang, Jiangsu provinces, China. A total of 14206 adults with hypertension (5602 men, age 59.5 ± 7.6 years) from two counties were analyzed. Elevated GGT was defined as a GGT level ≥50 IU/L. *Results:* The prevalence of elevated GGT was 8.59% (2.8% in women and 17.6% in men). Median GGT level was 20.2 IU/L (17.6 IU/L in women and 26.4 IU/L in men). In multiple logistic-regression analyses, women had lower risk for elevated GGT than men (OR, 0.29; 95% CI, 0.24-0.36), abdominal obesity (waist circumference ≥90 cm; OR, 1.42; 95% CI, 1.20-1.67), obesity (body mass index ≥25 kg/m^2; OR, 1.69; 95% CI, 1.44-1.98), current drinking (OR, 3.57; 95% CI, 3.04-4.21) were important independent risk factors for elevated GGT in both genders. Age and physical activity levels were inversely associated with elevated GGT. In sex-subgroup analyses, antihypertensive treatment (OR, 0.84; 95% CI, 0.72-0.98) and inland (OR, 0.79; 95% CI, 0.68-0.93) had lower risk and red meat consumption ≥3 times (OR, 1.47; 95% CI, 1.19-1.83) and elementary or higher levels (OR, 1.28; 95% CI, 1.06-1.55) had high risk for elevated GGT in men but not in women. *Conclusions:* There was a high prevalence of elevated GGT in Chinese hypertensive adults, a high prevalence of elevated GGT in male participants from coastal (vs. inland) areas. Physical activity is necessary to decrease GGT level. A detrimentally effect of current drinking, obesity or waist circumference on the GGT levels was also observed in both gender and a detrimentally effect of greater red meat consumption only in male was observed.

Keywords: Prevalence, elevated gamma-glutamyl transferase, determinants, chinese hypertensive adults

Introduction

Gamma-glutamyl transferase (GGT) is an enzymatic liver function test that has been available for several decades, and has been initially used as a sensitive indicator of alcohol ingestion, hepatic inflammation, fatty liver disease and hepatitis [1]. However, at present, growing evidences suggest that GGT is not only a marker of oxidative stress [2], but also a proatherogenic marker [3]. Furthermore, several prospective epidemiological studies have shown a robust association between higher GGT levels within the normal range [4-7] or changes in GGT [8] and the incidence of cardiovascular diseases (CVD). By contrast, current data suggest that alanine aminotransferase (ALT) levels are not significantly associated with CVD risk. In addition, in prospective studies, baseline serum GGT levels within the normal range predicted future diabetes and hypertension [9-11].

Increased GGT level is also a strong predictor for existing hypertension in Hong Kong Chinese [12]. However, to our knowledge, no previous publication has studied the prevalence of elevated serum GGT in Chinese hypertensive adults, particularly in coastal areas. For this reason, the present study was performed to examine the prevalence and determinants of elevated serum GGT and GGT levels in Chinese hypertensive adults aged 45-75 years in Lianyungang, Jiangsu province, China.

Subjects and methods

Study population

Study subjects were participants of the China Stroke Primary Prevention Trial (CSPPT). CSPPT is a multi-center randomized double-blind controlled trial conducted from May, 2008 to August, 2013 in two study centers in China (Jiangsu and Anhui provinces). It was designed to confirm that enalapril maleate and folic acid tablets combined is more effective in preventing stroke among patients with hypertension when compared with enalapril maleate alone. Details regarding inclusion/exclusion criteria, treatment assignment and outcome measures of the trial have been described elsewhere (http://clinicaltrials.gov/ct2/show/NCT00794885). In the current study, we included subjects from Lianyungang who participated in the screening phase of the CSPPT.

Briefly, we conducted a community-based screening in 20 townships within two counties (Ganyu, which is coastal, and Donghai, which is inland) in Lianyungang of Jiangsu province, East China, from October 2008 to September 2009. Inclusion criteria were as follows: (1) aged 45-75 years, and (2) seated systolic blood pressure (SBP) ≥140 mmHg and/or seated diastolic blood pressure (DBP) ≥90 mmHg in both of the two screening visits (with at least 24 hours between visits) or currently under anti-hypertension treatment. Participants were excluded if they reported a history of myocardial infarction, stroke, heart failure, cancer, serious mental disorders; or if they were unwilling to participate in the survey. This study was approved by the Ethics Committee of the Institute of Biomedicine, Anhui Medical University, Hefei, China. Written informed consent was obtained from each participant before data collection.

Data collection procedures

Baseline data collection was conducted by trained research staff according to standard operating procedures. Each participant was interviewed using a standardized questionnaire designed specifically for this study. The question on standard of living was phrased as, "How does your standard of living compare to others"?, and a choice of three responses (bad, medium and good) was provided. The question on physical activity was phrased as, "How do you describe your daily physical activity level"?, and a choice of three responses (low, moderate and high) was provided. The question on meat consumption was phrased as, "Do you eat meat (red meat) frequently (count the yearly averaged weekly intake times of meat consumption)"?, and a choice of four responses regarding weekly intake was provided: <1 time, 1-2 times, 3-5 times, and ≥5 times. The question on fruit and green vegetable consumption was phrased as, "How much fruit and green vegetables do you eat (count the yearly averaged weekly intake of fruits and green vegetables)"?, and a choice of three responses regarding weekly intake was provided: <1 jin (<500 g), 1-3 jin (500-1,500 g) and ≥3 jin (≥1,500 g). Finally, the question regarding family history was phrased as, "Has any of your immediate family (mother, father and/or siblings) had any of the following conditions"?, and choices of hypertension, diabetes, coronary heart disease (CHD) and stroke were given.

Anthropometric measurements including height, weight and waist circumference were taken using standard operating procedures. Height was measured without shoes to the nearest 0.1 cm on a portable stadiometer. Weight was measured in light indoor clothing without shoes to the nearest 0.1 kg. Body mass index (BMI) was calculated as weight (kilograms)/height (meters) squared. Waist circumference (WC) measurements were taken at the level of the maximum extension of the buttocks.

Seated blood pressure (BP) measurements were obtained by a trained research staff after subjects had been seated for 10 minutes using a mercury manometer with the standard method of calibration and appropriately sized cuffs, according to standard operating procedures. Triplicate measurements on the same arm were taken, with at least two minutes between readings. Each patient's systolic and diastolic blood pressures were calculated as the mean of three independent measures. BP measured at the second visit was used for analysis.

Table 1. Characteristics of study participants

	Total	Men	Women	*P* value
N	14206	5602	8604	
Age, yrs$	59.5 ± 7.6	60.3 ± 7.7	59.0 ± 7.5	<0.001
Age group (y)				<0.001
45-54	4342 (30.6)	1517 (27.1)	2825 (32.8)	
55-64	6144 (43.2)	2372 (42.3)	3772 (43.8)	
65-75	3720 (26.2)	1713 (30.6)	2007 (23.3)	
GGT, IU/L$$	20.2 (15.3-29.1)	26.4 (19.2-40.5)	17.6 (14.0-23.2)	<0.001
Antihypertensive Treatment, Treated$$$	6671 (47.0)	2430 (43.4)	4241 (49.3)	<0.001
SBP, mmHg$	168.5 ± 20.9	167.2 ± 20.8	169.4 ± 20.9	<0.001
DBP, mmHg$	95.5 ± 12.0	97.3 ± 12.4	94.3 ± 11.5	<0.001
HTN Grades$$$				0.425
Normal BP or Grade 1#	7833 (55.1)	3079 (55.0)	4754 (55.3)	
Grade 2	4705 (33.1)	1841 (32.9)	2864 (33.3)	
Grade 3	1668 (11.7)	682 (12.2)	986 (11.5)	
BMI (kg/m^2)				
Mean$	25.6 ± 3.6	24.9 ± 3.2	26.0 ± 3.7	<0.001
Obesity##,$$$	7630 (53.7)	2569 (45.9)	5061 (58.8)	<0.001
Waist Circumference				
Mean, cm$	85.4 ± 9.6	85.5 ± 9.7	85.3 ± 9.6	0.223
Abdominal Obesity###,$$$	4749 (33.4)	1952 (34.9)	2797 (32.5)	0.004
Current Smoking$$$	3272 (23.0)	2953 (52.7)	319 (3.7)	<0.001
Current Drinking$$$	3332 (23.5)	3039 (54.3)	293 (3.4)	<0.001
Family history of HTN$$$	5418 (38.2)	2079 (37.2)	3339 (38.9)	0.042
Family history of diabetes$$$	615 (4.3)	230 (4.1)	385 (4.5)	0.291
Family history of CHD$$$	569 (4.0)	215 (3.8)	354 (4.1)	0.412
Family history of stroke$$$	1931 (13.6)	771 (13.8)	1160 (13.5)	0.629
Counties$$$				<0.001
Ganyu (coastal)	5688 (40.0)	2356 (42.1)	3332 (38.7)	
Donghai (inland)	8518 (60.0)	3246 (57.9)	5272 (61.3)	
Living Standards$$$				<0.001
Bad	1619 (11.4)	755 (13.5)	864 (10.0)	
Medium	11022 (77.6)	4322 (77.2)	6700 (77.9)	
Good	1560 (11.0)	524 (9.4)	1036 (12.0)	
Red Meat Consumption$$$				<0.001
<1 time/week	9026 (63.6)	2932 (52.3)	6094 (70.9)	
1-2 times/week	3877 (27.3)	1947 (34.8)	1930 (22.4)	
≥3 times/week	1295 (9.1)	722 (12.9)	573 (6.7)	
Fruits and vegetables Consumption$$$				0.108
<500 g/week	265 (1.9)	113 (2.0)	152 (1.8)	
500-1500 g/week	2686 (18.9)	1099 (19.6)	1587 (18.5)	
≥1500 g/week	11245 (79.2)	4387 (78.4)	6858 (79.8)	
Education$$$				<0.001
Illiterate	9141 (64.4)	2075 (37.1)	7066 (82.2)	
Primary level	2142 (15.1)	1325 (23.7)	817 (9.5)	
Elementary or higher levels	2915 (20.5)	2200 (39.3)	715 (8.3)	
Physical Activity$$$				0.232
Low	5609 (39.5)	2164 (38.7)	3445 (40.1)	

Moderate	5594 (39.4)	2242 (40.1)	3352 (39.0)
High	2987 (21.1)	1191 (21.3)	1796 (20.9)

BMI = body mass index, CHD = coronary heart disease, DBP = diastolic blood pressure, GGT = Gamma-glutamyl transferase, HTN = hypertension, SBP = systolic blood pressure. $Means (SD); $$Median (25th-75th); $$$N (%), #429 subjects with antihypertensive treatment and normal blood pressure were included; ##Obesity was defined as a BMI of ≥25 kg/m²; ###Abdominal obesity was defined as a waist circumference ≥90 cm.

Blood sample collection and laboratory methods

After 12-15 hours of fasting, venous blood sample was obtained from each subject. Serum or plasma samples were separated within 30 minutes of collection and stored at -70°C, which were used for measurement of GGT concentrations using a Dade Dimension Chemistry Analyzer (Siemens, Germany).

Statistical analysis

Hypertension (HTN) was categorized into three grades: grade 1, SBP 140-159 and/or DBP 90-99 mmHg; grade 2, SBP 160-179 and/or DBP 100-109 mmHg; grade 3, SBP ≥180 and/or DBP ≥110 mmHg [9]. Treated hypertension was defined as receiving antihypertensive medication within the past two weeks. Current smoking was defined as having smoked at least one cigarette per day or ≥18 packs in the previous year. Current drinking was defined as drinking alcohol at least two times per week in the previous year. Obesity was defined as a BMI of ≥25 kg/m² [13]. Abdominal obesity was defined as having a waist circumference ≥90 cm. Elevated GGT was defined as a GGT level ≥50 IU/L [13].

Means and proportions were calculated for population characteristics by gender. The difference in population characteristics were compared using Student's *t*-test or chi-square test. The adjusted odds ratios and 95% confidence interval (CI) of having elevated serum GGT levels was determined from multivariable logistic-regression models that included age group, gender, obesity, abdominal obesity, cigarette smoking, alcohol drinking, antihypertensive treatment status, HTN grades, geographic region (coastal and inland), standard of living, meat consumption, fruit and green vegetable consumption, education level, physical activity levels and family history of HTN, diabetes, CHD or stroke. All statistical analyses were performed in empower software (www.empowerstats.com, X&Y solutions, Inc., Boston, MA) and R software (http://www.R-project.org/).

Results

Overall, 15486 participants aged 45-75 years with hypertension was in the study. 15460 participants had valid measurements of serum GGT levels. In this report, study participants self-reported liver disease (n = 213), diabetes or undertaken antidiabetic therapy (n = 595), self-reported hyperlipidemia or undertaken antihyperlipidemia therapy (n = 552), without GGT (n = 26) or with any missing data on antihypertensive treatment status, age, gender, height, weight, WC, smoking status, drinking status, standard of living, meat consumption, fruit and green vegetable consumption, education and physical activity levels, and family history of hypertension, coronary heart disease, diabetes and stroke were excluded. Our final analysis included 14206 participants.

Population characteristics stratified by gender are listed in **Table 1**. Men had significantly higher age, DBP, abdominal obesity cigarette smoking, alcohol drinking, meat consumption and education levels, and lower SBP, BMI, standard of living antihypertensive treatment and family history of HTN, compared with women.

The prevalence of elevated GGT was 8.59% (2.8% in women and 17.6% in men). Median GGT level was 20.2 IU/L (17.6 IU/L in women and 26.4 IU/L in men). The average age of the study subjects was 59.5 years.

In multivariable logistic-regression models, abdominal obesity, obesity, current drinking, were important independent risk factors for elevated GGT in both genders. Older age and high physical activity was inversely associated with elevated GGT both in men and women. For other risk factors, gender-related differences were observed. Some were important independent risk factors for elevated GGT only in men, 0.79 (0.68-0.93) for inland vs. coastal residents, 1.47 (1.19-1.83) for participants with

Table 2. Adjusted& odds ratios (95% Confidence Intervals) of having elevated serum gamma-glutamyl transferase (GGT) in Different Subgroups

	Total		Men		Women	
	N (%)	OR& (95 CI)	N (%)	OR& (95 CI)	N (%)	OR& (95 CI)
Total	1221 (8.59)		984 (17.6)		237 (2.8)	
Sex						
Men	984 (17.6)	1.0				
Women	237 (2.8)	0.29 (0.24, 0.36)**				
Age (y)						
45-55	489 (11.3)	1.0	414 (27.3)	1.0	75 (2.7)	1.0
55-65	514 (8.4)	0.72 (0.62, 0.84)**	398 (16.8)	0.63 (0.53, 0.75)**	116 (3.1)	0.72 (0.62, 0.84)**
65-75	218 (5.9)	0.44 (0.36, 0.54)**	172 (10.0)	0.38 (0.30, 0.48)**	46 (2.3)	0.44 (0.36, 0.54)**
Antihypertensive Treatment						
Untreated	726 (9.7)	1.0	619 (19.5)	1.0	107 (2.5)	1.0
Treated	493 (7.4)	0.92 (0.81, 1.05)	363 (14.9)	0.84 (0.72, 0.98)*	130 (3.1)	1.21 (0.93, 1.58)
HTN Grades						
Controlled BP or Grade 1#	649 (8.3)	1.0	511 (16.6)	1.0	138 (2.9)	1.0
Grade 2	406 (8.6)	1.00 (0.87, 1.15)	335 (18.2)	1.05 (0.90, 1.24)	71 (2.5)	0.81 (0.60, 1.09)
Grade 3	166 (10.0)	1.12 (0.92, 1.36)	138 (20.2)	1.18 (0.94, 1.48)	28 (2.8)	0.92 (0.61, 1.40)
Obesity##						
No	459 (7.0)	1.0	395 (13.0)	1.0	64 (1.8)	1.0
Yes	762 (10.0)	1.42 (1.20, 1.67)**	589 (22.9)	1.40 (1.16, 1.69)*	173 (3.4)	1.53 (1.09, 2.14)*
Abdominal Obesity###						
No	616 (6.5)	1.0	490 (13.4)	1.0	126 (2.2)	1.0
Yes	604 (12.7)	1.69 (1.44, 1.98)**	493 (25.3)	1.74 (1.44, 2.10)**	111 (4.0)	1.49 (1.10, 2.02)*
Current smoking						
No	604 (12.7)	1.0	419 (15.8)	1.0	226 (2.7)	1.0
Yes	575 (17.6)	1.03 (0.89, 1.20)	564 (19.1)	1.01 (0.87, 1.19)	11 (3.4)	1.01 (0.87, 1.19)
Current drinking						
No	427 (3.9)	1.0	204 (8.0)	1.0	223 (2.7)	1.0
Yes	793 (23.8)	3.57 (3.04, 4.21)**	779 (25.6)	3.76 (3.15, 4.50)**	14 (4.8)	1.97 (1.09, 3.56)*
FHH						
No	746 (8.5)	1.0	603 (17.1)	1.0	143 (2.7)	1.0
Yes	473 (8.7)	0.89 (0.77, 1.03)	379 (18.2)	0.86 (0.73, 1.02)	94 (2.8)	0.94 (0.70, 1.26)
FHD						
No	1166 (8.6)	1.0	945 (17.6)	1.0	221 (2.7)	1.0
Yes	53 (8.6)	0.95 (0.69, 1.30)	37 (16.1)	0.80 (0.54, 1.17)	16 (4.2)	1.48 (0.87, 2.51)
FHC						
No	1174 (8.6)	1.0	952 (17.7)	1.0	222 (2.7)	1.0
Yes	45 (7.9)	0.82 (0.59, 1.15)	30 (14.0)	0.64 (0.42, 0.97)*	15 (4.2)	1.55 (0.89, 2.69)
FHS						
No	1042 (8.5)	1.0	840 (17.4)	1.0	202 (2.7)	1.0
Yes	176 (9.1)	1.00 (0.83, 1.22)	141 (18.3)	0.98 (0.78, 1.23)	35 (3.0)	1.09 (0.73, 1.61)
Counties						
Ganyu (coastal)	563 (9.9)	1.0	478 (20.3)	1.0	85 (2.6)	1.0
Donghai (inland)	658 (7.7)	0.87 (0.76, 1.00)*	506 (15.6)	0.79 (0.68, 0.93)*	152 (2.9)	1.17 (0.88, 1.56)
Living Standards						
Bad	205 (12.7)	1.0	179 (23.7)	1.0	26 (3.0)	1.0
Medium	936 (8.5)	0.96 (0.80, 1.16)	748 (17.3)	0.96 (0.78, 1.18)	188 (2.8)	1.00 (0.65, 1.53)
Good	79 (5.1)	0.79 (0.59, 1.07)	56 (10.7)	0.76 (0.53, 1.09)	23 (2.2)	0.85 (0.47, 1.54)
Red Meat Consumption						
<1 time/week	555 (6.1)	1.0	390 (13.3)	1.0	165 (2.7)	1.0
1-2 times/week	431 (11.1)	1.10 (0.95, 1.27)	377 (19.4)	1.16 (0.98, 1.37)	54 (2.8)	0.96 (0.69, 1.32)
≥3 times/week	234 (18.1)	1.39 (1.15, 1.69)*	216 (29.9)	1.47 (1.19, 1.83)*	18 (3.1)	1.02 (0.61, 1.71)
Fruit and vegetable consumption						
<500 g/week	31 (11.7)	1.0	25 (22.1)	1.0	6 (3.9)	1.0

500-1500 g/week	244 (9.1)	0.74 (0.48, 1.14)	201 (18.3)	0.80 (0.48, 1.33)	43 (2.7)	0.63 (0.26, 1.52)
≥1500 g/week	944 (8.4)	0.75 (0.49, 1.14)	756 (17.2)	0.81 (0.50, 1.33)	188 (2.7)	0.67 (0.29, 1.55)
Education						
Illiterate	466 (5.1)	1.0	270 (13.0)	1.0	196 (2.8)	1.0
Primary level	235 (11.0)	1.08 (0.90, 1.30)	210 (15.8)	1.13 (0.92, 1.39)	25 (3.1)	1.06 (0.69, 1.63)
Elementary or higher levels	519 (17.8)	1.22 (1.03, 1.44)*	503 (22.9)	1.28 (1.06, 1.55)*	16 (2.2)	0.74 (0.43, 1.28)
Physical Activity						
Low	520 (9.3)	1.0	413 (19.1)	1.0	107 (3.1)	1.0
Moderate	480 (8.6)	0.83 (0.72, 0.96)*	384 (17.1)	0.82 (0.69, 0.97)*	96 (2.9)	0.92 (0.69, 1.23)
High	218 (7.3)	0.72 (0.60, 0.87)*	186 (15.6)	0.77 (0.62, 0.96)*	32 (1.8)	0.56 (0.37, 0.84)*

BMI = body mass index, FHC = family history of coronary heart disease; FHD = family history of diabetes; FHH = family history of hypertension; FHS = family history of stroke; HTN = hypertension. *P<0.05, **P<0.0001. & All variables were included in the same models; # 429 subjects with antihypertensive treatment and normal blood pressure were included; ## Obesity was defined as a BMI of ≥25 kg/m^2; ### Abdominal obesity was defined as a waist circumference ≥90 cm.

red meat consumption ≥3 times/week vs. <1 time/week, 0.84 (0.72-0.98) for participants with vs. without antihypertensive treatment, 1.28 (1.06-1.55) for participants with elementary or higher levels vs. illiterate, 0.82 (0.69-0.97) for participants with moderate physical activity (vs low physical activity) in men (**Table 2**).

Consistently, odds ratios (95% CIs) that have elevated GGT for men and women were 1.74 (1.44-2.10) and 1.49 (1.10-2.02) for abdominal obesity, 1.40 (1.16-1.69) and 1.53 (1.09-2.14) for obesity, 3.76 (3.15-4.5) and 1.97 (1.09-3.56) for current alcohol drinkers (*vs.* non-current drinkers), 0.38 (0.30-0.48) and 0.63 (0.53-0.75) for participants aged 65-75 years vs. 45-55 years in men, 0.44 (0.36-0.54) and 0.72 (0.62-0.84) for participants aged 65-75 years vs. 45-55 years in women, 0.77 (0.62-0.96) and 0.56 (0.37-0.84) for participants with high physical activity (vs. low physical activity) (**Table 2**).

Discussion

This is the first study to examine the prevalence of elevated GGT and simultaneously explore the effect of socioeconomic status, lifestyle, diet and family history on the prevalence of elevated GGT and GGT levels in Chinese hypertensive adults. In our present study, median GGT level was 23.0 IU/L (29.0 IU/L in men and 20.0 IU/L in women). Consistently, median GGT level (*n* = 5,385) [14] was 29 IU/L for men and 18 IU/L for women in an ethnic She Chinese population. In addition, median GGT level (*n* = 5404) [15] was 27 IU/L for men and 21 IU/L for women in two urban communities in Shanghai, China.

Consistent with previous studies [13, 16], men and low physical activity levels were important determinants for higher GGT levels. At the same time, our study was the first to prove that even in fully adjusted models, abdominal obesity, obesity and current drinking were independent risk factors for elevated GGT and higher GGT levels, which suggests that both obesity and abdominal obesity control and drinking restriction are necessary to decrease GGT levels. Furthermore, though the positive association between age and GGT levels in previous studies [13], older age was inversely associated with elevated GGT in our study, which was consistent with a report [17] in Germany.

Breitling LP *et al.* reported [18] that there was a positive interaction effect between smoking and alcohol, and a negative interaction effect between smoking and BMI with regards to GGT levels in men, without adjustment for waist circumference, socioeconomic status and diet. However, there was a detrimentally effect of current drinking (3.76 P<0.0001 in male and 1.97 P<0.05 in female) or waist circumference (≥90 cm vs. <90 cm, P<0.0001 in male and P<0.05 in female) in GGT levels in men and women in our study, even in fully adjusted models. Considering the high prevalence of these avoidable risk factors, our findings have important clinical and public health implications, which suggest the importance of taking effective measures to reduce the above combinations in Chinese population, and decrease GGT levels and related diseases.

Most interestingly, inland (*vs.* coastal) residents had a lower prevalence of elevated GGT and GGT levels. Some evidence has shown that altered methionine/folate metabolism may contribute to the development of hepatic injury [19]. Higher betaine [20] and vitamin B-12 [21] (high in seafood) intake in coastal areas may protect the liver and induce lower GGT level.

Our previous study [22] also revealed that folic acid treatment may be beneficial in lowering serum ALT concentration. However, this time our discovery is contradictory with these results. And we did not collect detailed information on seafood intake in this study. Maybe there are other important effect factors. Further researches are needed and further understanding of these regional differences would provide us with some new strategies for the control of elevated GGT levels.

In the current study, male participants with greater red meat consumption or without antihypertensive treatment had significantly higher GGT levels. These results revealed that blood pressure lowering and red meat consumption reducing would solve the problem of high GGT levels in men not in women. Concomitant lifestyle changes including cigarette smoking and alcohol drinking cessation, as well as obesity and abdominal obesity control, may be necessary to decrease GGT levels in Chinese hypertensive adults.

Family history is a surrogate marker not only for genetic susceptibility to the corresponding disease, but also environmental factors that cluster in families. Through the robust association between higher GGT levels within the normal range and incident of CVD or diabetes, we found no significant relationship between family history of diabetes, CHD or stroke with the GGT levels. Furthermore, participants with a family history of HTN had significantly lower GGT levels in both genders. Future prospective studies are needed to further confirm our results.

We excluded participants with known hepatic diseases, diabetes and dyslipidemia from our analyses to permit us to exclude the possibility of confounding our results due to concomitant diseases or medications. However, our study population was not a representative sample. Caution is needed in generalizing our findings from this hypertensive Chinese population to other populations. Furthermore, we did not have direct liver fat measurements.

In conclusion, there was a high prevalence of elevated GGT in Chinese hypertensive adults, a high prevalence of elevated GGT in male participants from coastal (vs. inland) areas. Physical activity is necessary to decrease GGT level. A detrimentally effect of current drinking, obesity or waist circumference on the GGT levels was also observed in both gender and a detrimentally effect of greater red meat consumption only in male was observed.

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Disclosure of conflict of interest

None.

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