Atherosclerosis 226 (2013) 269–274

Contents lists available at SciVerse ScienceDirect

Atherosclerosis

journal homepage: www.elsevier.com/locate/atherosclerosis

Association of coronary artery calcification and serum gamma-glutamyl transferase in Korean

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ARTICLE INFO

Article history:
Received 11 July 2012
Received in revised form
11 October 2012
Accepted 24 October 2012
Available online 2 November 2012

Keywords:
Gamma-glutamyl transferase
Coronary artery calcification
Cardiovascular disease
Coronary heart disease

ABSTRACT

Background and objective: Elevated serum gamma-glutamyl transferase (GGT) has been known to be associated with the cardiovascular disease. However, there is a lack of researches on direct examination of relevance between serum GGT and coronary artery calcification (CAC). Accordingly, the aim of this study was to investigate the association between serum GGT levels and the prevalence of CAC in Korean.
Methods: The study population consisted of 14,439 male and female adults without coronary artery disease, who were conducted health examination from January 2010 to December 2010. The prevalence of CAC in relation to the quartile groups of serum GGT levels and odds ratio and 95% CI of CAC were analyzed using multiple logistic regression model.
Results: The prevalence of CAC increased with increasing GGT quartile (4.6%, 8.7%, 11.8% and 14.7% in the lowest, second, third, highest GGT quartiles, respectively; $p < 0.001$). In the logistic regression analysis adjusted for multiple variables, odds ratio (95% CI) for the prevalence of CAC comparing the 1st GGT quartile to the 4th quartile were 2.43 (1.94–3.05) for all subjects, 1.49 (1.21–1.85) for men and 1.33 (0.62–2.87) for women.
Conclusion: Elevated serum GGT levels were independently associated with the prevalence of CAC. Physicians and health care providers should be observant regarding future development of coronary artery disease among people with increasing concentration of serum GGT.

1. Introduction

In terms of the order of causes of death in Korea, cerebrovascular disorders and cardiac disorders are ranked the 2nd and the 3rd, only after malignant neoplasm, and this ranking has not changed since 2000 up to 2010. While the rate of death arising from cerebrovascular disorders has been reduced from 73.1 persons per 100,000 people in 2000 to 53.2 persons per 100,000 in 2010, the rate for cardiac disorders increased from 38.2 persons per 100,000 in 2000 to 46.9 persons per 100,000 in 2009 [1].

Atherosclerosis of coronary artery is the most common cause of ischemic cardiac disorders, and acute coronary arterial syndrome that induces unstable angina and acute myocardial infarction, etc occurs mainly because of rapid closure of blood flow due to rupture of atherosclerotic plaque and thrombopoiesis [2]. Commonly, the screening test for ischemic cardiac disorders is made by means of exercise electrocardiogram and thallium myocardial scan, etc. which measures the blood flow and diagnoses stenosis of coronary artery indirectly. However, even if the stenosis of coronary artery is only slight, there are difficulties in early diagnosis with aforementioned method [3,4]. Coronary artery calcification (CAC) can be measured and quantified by using multiple detection computerized tomography (MDCT). Scoring system designed by Agatston et al. [5] is currently being used widely for measuring CAC, and strong correlation between the Agatston score and the atherosclerosis was confirmed [6].

Gamma-glutamyl transferase (GGT) is one of the enzymes in blood that are used frequently in assessment of liver function due to its relatively low cost and high level of sensitivity and accuracy of test. It is included as an essential item in the testing of liver function during health examination in Korea. Although serum GGT is known to be increased due to consumption of alcohol and damages to the liver tissues, interest on the role of GGT in the diseases of cardiovascular system has increased with the reports of epidemiological

Abbreviations: AST, aspartate aminotransferase; ALT, alanine aminotransferase; BMI, body mass index; BP, blood pressure; CAC, coronary artery calcification; GGT, gamma-glutamyl transferase; HDL-C, high-density lipoprotein cholesterol; hsCRP, high-sensitivity C-reactive protein; LDL-C, low-density lipoprotein cholesterol; MDCT, multiple detection computerized tomography.

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0021-9150/$ – see front matter © 2012 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.atherosclerosis.2012.10.059

and pathological reports that GGT is involved in the pathophysiologic process of atherosclerosis [7].

Although there have been numerous researches on the association between serum GGT and the diseases of cardiovascular system [7–11] in the past, there is lack of researches on direct examination of relevance between serum GGT and CAC. Although Atar et al. [12] reported that serum GGT, age, smoking and serum uric acid concentration are related to CAC in 112 subjects (97 males and 15 females), their research had limitation that the number of subjects was quite small. Therefore, the aim of this cross-sectional study was to investigate the association between serum GGT levels and the prevalence of CAC in Korean by analyzing the data from health examination, and, moreover, to examined the role of serum GGT as the index for forecasting of occurrence of coronary artery disease in the areas of health examination and clinical settings.

2. Methods

2.1. Study population

15,079 people who underwent coronary artery MDCT when they visited a university hospital for the purpose of health examination from January 2010 to December 2010 were chosen as the subjects. 14,439 people were chosen as the final subjects of the study by excluding those with past history including stroke, angina, myocardial infarction and chronic kidney disease, those for whom serum GGT test was omitted and high risk alcoholic consumer on the basis of self-report through questionnaire. High risk alcoholic consumption was defined as those who has more than 7 glasses on the average on a single sitting for male and more than 5 glasses for female, more than 2 times a week on the basis of Korea National Health & Nutrition Examination Survey (Fig. 1). This Study was approved by the Institutional Review Board of the Kangbuk Samsung Medical Center (KBC12007).

2.2. Clinical and laboratory measurements

Height (m) and weight (kg) was measured to the units of 0.1 cm and 0.1 kg, respectively, by using automatic height and weight measurement equipment while the subjects were wearing light clothing and on bare foot. Body mass index (BMI) was computed by using the measured height and weight (kg/m^2). Blood pressure (BP) was measured by experienced nurse by placing the arm at the height corresponding to the height of the heart after having taken rest for 5 min at the minimum on a chair with back support. Current smokers were defined as those who answered they are currently smoking in the questionnaire.

All blood samples were obtained in the morning after an overnight fast. Gamma-glutamyl transferase (GGT), alanine aminotransferase (ALT), aspartate aminotransferase (AST), fasting serum glucose, total cholesterol, triglyceride, low-density lipoprotein cholesterol (LDL-C), and high density lipoprotein-cholesterol (HDL-C) were measured using Bayer Reagent Packs on an automated chemistry analyzer (Advia 1650 Autoanalyzer; Bayer Diagnostics, Leverkusen, Germany). High sensitivity C-reactive protein (hsCRP) was analyzed by particle-enhanced immunonephelometry with the BNII System (Dade Behring, Marburg, Germany). The serum creatinine was measured with the alkaline picrate (Jaffe) method.

Hypertension was defined as those who are currently taking antihypertensive agents, or has measured systolic BP of more than 140 mmHg or diastolic BP of more than 90 mmHg. Diabetes was defined as those who are currently taking glucose-lowering agents or has measured fasting serum glucose of more than 126 mg/dL.

CT scans were performed with a 64-slice MDCT scanner (Lightspeed VCT XTe-64 slice, GE Healthcare), and a standard scanning protocol was 32 $\times$ 0.625-mm section collimation, 400-ms rotation time, 120-kV tube voltage, and 31-mAS (310mA30.1 s) tube current under electrocardiographic-gated dose modulation. In this study, the Agatston method was used to quantify the amount of CAC. CAC was defined to the situation in which the Agatston score is more than 0 [13].

2.3. Statistical analyses

Because there was statistically difference of all variables including serum GGT between male and female, sex-specific analyses were done. Concentration of serum GGT was divided into quartile groups in accordance with the distribution in presenting the distribution of different variables, and tendency analysis was made in accordance with the quartile groups.

The distributions of continuous variables were evaluated, and log transformations were used in the analysis as required. Logistic regression analysis was used to determine the odds ratio (OR) of presence of CAC associated with quartile groups of serum GGT levels (quartile 1 = reference). The correlation analysis and multiple linear regression analysis were also used to examine the quantitative association between serum GGT and CAC. The following variables, well-known risk factors of cardiovascular diseases, were entered into binary logistic and multiple linear regression model: age, BMI, systolic BP, ALT, fasting serum glucose, triglyceride, LDL-C, HDL-C, hsCRP, hypertension, diabetes and current status of smoking.

For statistical analysis, SPSS 18.0 for window (SPSS Inc.,Chicago, IL, USA) program was used. Statistical analysis was carried out by defining the level of statistical significance to be less than 0.05.

3. Results

Among the total of 14,439 subjects, there were 11,835 males and 2604 females, and their basic characteristics are given in Table 1. Median value (range of quartile) of serum GGT level was 32 (22–53) IU/L and 14 (11–20) IU/L, respectively in male and female. All the clinical variables except for HDL-C were higher in male than in female. Current smoking rate and prevalence of diabetes and hypertension were also higher in male than in female.

In both male and female, age, BMI, systolic and diastolic BP, AST, ALT, fasting serum glucose, total cholesterol, LDL-C, triglyceride, hsCRP and the prevalence of diabetes and hypertension increased as the serum GGT group increased, while the reverse was the case for HDL-C. However, the current smoking rate did not illustrate tendency of increasing or decreasing in either male or female (Table 2).

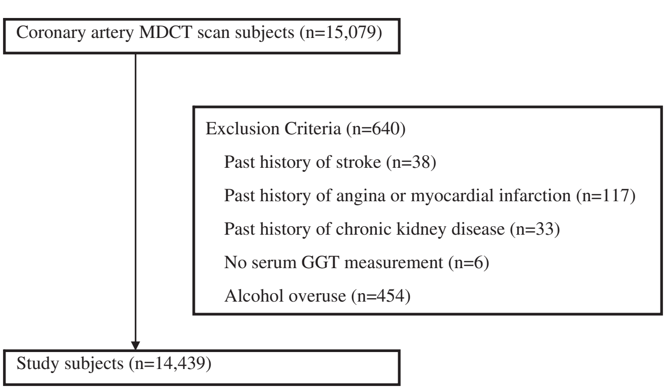

Fig. 1. Selection of study participants.

Table 1
Baseline characteristics of study participants by sex.

	Overall (n = 14,439)	Men (n = 11,835)	Women (n = 2604)
Age (years)[a]	42.2 (6.9)	42.0 (6.6)	43.0 (8.1)
BMI (kg/m^2)[a]	24.5 (3.1)	24.9 (2.9)	22.7 (3.3)
Systolic BP (mmHg)[a]	117.4 (12.5)	118.9 (11.7)	110.4 (13.1)
Diastolic BP (mmHg)[a]	74.9 (9.1)	76.2 (8.7)	69.2 (9.0)
AST (IU/l)[b]	22 (18–27)	23 (19–28)	19 (16–22)
ALT (IU/l)[b]	23 (16–34)	25 (18–36)	15 (11–20)
GGT (IU/l)[b]	29 (18–48)	32 (22–53)	14 (11–20)
Fasting serum glucose (mg/dl)[b]	94 (88–100)	95 (89–101)	91 (86–97)
Total cholesterol (mg/dl)[b]	202 (179–227)	204 (181–228)	193 (171–219)
LDL-C (mg/dl)[b]	124 (104–147)	127 (107–149)	112 (93–136)
HDL-C (mg/dl)[b]	51 (44–60)	49 (43–58)	60 (51–70)
Triglyceride (mg/dl)[b]	116 (81–168)	125 (89–179)	81 (60–112)
hsCRP (mg/dl)[b]	0.06 (0.03–0.11)	0.06 (0.04–0.11)	0.04 (0.03–0.08)
Smokers (%)	28.1	33.7	2.7
Diabetes (%)	4.6	4.9	3.0
Hypertension (%)	15.1	16.1	10.7

[a] Means (standard deviation).
[b] Medians (interquartile range).

By the quartile groups of serum GGT levels, the CAC prevalence and mean (standard deviation) in both male and female significantly increased as the serum GGT group increased (Table 3). Table 4 presents the OR and 95% CI for the existence of CAC by quartiles of GGT distribution. The multivariable-adjusted ORs and 95% CI of the top quartile in comparison to the lowest were 2.43 (1.94–3.05) in overall subjects, 1.49 (1.21–1.85) in male and 1.33 (0.62–2.87) in female. When quartile 1 set as a reference, in unadjusted analyses, the quartile 2, quartile 3, quartile 4 of GGT level had increased OR for the existence of CAC in overall subjects, male and female. After adjusting for age, a strong relationship between the quartiles of GGT level and the existence of CAC was showed in all groups still. After adjusting for age, BMI, systolic BP, ALT, fasting serum glucose, triglyceride, LDL-C, HDL-C hsCRP, current smoking status, hypertension and diabetes, multivariable-adjusted logistic regression analyses showed a strong relationship in overall and male, but not in female.

To examine the quantitative association between serum GGT and CAC, correlation analysis and multiple linear regression analysis were done. Positive correlations were found between ln(CAC score + 1) and ln(GGT), age, male gender, BMI, systolic BP, diastolic BP, ln(AST), ln(ALT), ln(fasting serum glucose), ln(total cholesterol), ln(LDL-C), ln(triglyceride), ln(hsCRP), current smoking, diabetes and hypertension. Negative correlations were found between ln(CAC score + 1) and ln(HDL-C) (Supplementary Table S1).

In the multiple linear regression analysis, after adjusting for multiple covariates, the parameter estimate of serum ln(GGT) was 0.042 (P-value = 0.013) (Supplementary Table S2).

4. Discussion

This study examined the existence of CAC in accordance with the concentration of serum GGT who underwent MDCT of coronary artery for the purpose of health examination as the subjects of the study. CAC is useful in measuring the atheromatous plaque and in

Table 2
Baseline characteristics by quartiles of GGT distribution.

	Men					Women				
	GGT (IU/L)				p-trend across quartiles	GGT (IU/L)				p-trend across quartiles
	≤21 (N = 2899)	22–32 (N = 3066)	33–52 (N = 2875)	≥53 (N = 2995)		≤10 (N = 608)	11–14 (N = 760)	15–20 (N = 608)	≥21 (N = 628)	
Age (years)[a]	40.8 (6.9)	41.8 (6.8)	42.5 (6.4)	42.8 (6.3)	<0.001	40.6 (6.7)	42.3 (8.0)	43.8 (8.0)	45.5 (8.6)	<0.001
BMI (kg/m^2)[a]	23.3 (2.4)	24.5 (2.6)	25.5 (2.8)	26.3 (3.0)	<0.001	21.8 (2.6)	22.0 (2.8)	22.7 (3.1)	24.5 (4.1)	<0.001
SBP (mmHg)[a]	116.2 (11.2)	118.1 (11.3)	119.8 (11.9)	121.6 (12.0)	<0.001	107.1 (11.9)	108.8 (12.4)	110.7 (13.1)	115.1 (13.8)	<0.001
DBP (mmHg)[a]	74.0 (8.2)	75.4 (8.3)	76.9 (8.7)	78.4 (9.0)	<0.001	67.3 (8.0)	68.1 (8.7)	69.3 (8.9)	72.4 (9.6)	<0.001
AST (IU/l)[b]	19 (17–23)	21 (18–25)	23 (20–28)	29 (23–38)	<0.001	17 (15–20)	18 (16–20)	19 (16–22)	22 (19–29)	<0.001
ALT (IU/l)[b]	17 (14–22)	22 (17–29)	28 (21–38)	38 (28–55)	<0.001	12 (10–15)	13 (11–16)	15 (12–19)	21 (16–31)	<0.001
FSG (mg/dl)[b]	93 (88–98)	94 (88–100)	96 (90–102)	98 (92–105)	<0.001	90 (85–96)	89 (84–94)	90 (86–97)	93 (88–100)	<0.001
TC (mg/dl)[b]	189 (170–212)	201 (180–224)	208 (186–232)	216 (192–242)	<0.001	183 (164–207)	189 (169–212)	196 (174–221)	208 (182–235)	<0.001
LDL-C (mg/dl)[b]	115 (97–135)	127 (108–148)	132 (111–154)	135 (113–158)	<0.001	103 (86–121)	109 (92–128)	116 (97–140)	126 (102–150)	<0.001
HDL-C (mg/dl)[b]	52 (45–60)	50 (43–58)	48 (42–56)	48 (42–56)	<0.001	61 (53–70)	61 (52–72)	61 (51–71)	56 (47–67)	<0.001
TG (mg/dl)[b]	93 (70–123)	115 (85–157)	137 (102–192)	169 (122–236)	<0.001	70 (55–92)	75 (57–98)	84 (63–114)	106 (75–162)	<0.001
hsCRP (mg/dl)[b]	0.04 (0.03–0.07)	0.05 (0.03–0.11)	0.07 (0.04–0.12)	0.08 (0.05–0.15)	<0.001	0.03 (0.03–0.05)	0.03 (0.03–0.06)	0.04 (0.03–0.08)	0.07 (0.04–0.15)	<0.001
Smokers (%)	32.0	33.6	35.4	33.8	0.063	2.2	2.8	3.0	2.9	0.801
Diabetes (%)	2.1	3.2	5.4	9.1	<0.001	1.0	2.0	2.4	6.9	<0.001
Hypertension (%)	8.9	13.4	18.6	23.5	<0.001	4.5	7.6	10.5	20.8	<0.001

DBP, diastolic blood pressure; FSG, fasting serum glucose; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride.
[a] Means (standard deviation).
[b] Medians (interquartile range).

Table 3
Prevalence of subjects with CAC and mean (standard deviation) of ln(CAC score + 1) by quartiles of GGT distribution.

	GGT				p-trend across quartiles
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Overall (N = 14,439)					
Total subjects	3747	3465	3598	3629	
CAC > 0, n(%)	173 (4.6)	301 (8.7)	423 (11.8)	532 (14.7)	<0.001
ln(CAC score + 1), mean (SD)	0.15 (0.76)	0.27 (0.98)	0.34 (1.06)	0.45 (1.23)	<0.001
Men (N = 11,835)					
Total subjects	2899	3066	2875	2995	
CAC > 0, n(%)	205 (7.1)	284 (9.3)	373 (13.0)	447 (14.9)	<0.001
ln(CAC score + 1), mean (SD)	0.22 (0.90)	0.28 (0.97)	0.38 (1.10)	0.46 (1.25)	<0.001
Women (N = 2604)					
Total subjects	608	760	608	628	
CAC > 0, n(%)	12 (2.0)	21 (2.9)	28 (4.8)	59 (9.1)	<0.001
ln(CAC score + 1), mean (SD)	0.07 (0.52)	0.09 (0.65)	0.15 (0.76)	0.33 (1.13)	<0.001

forecasting the level of risks prior to the manifestation of coronary artery disease. Larger quantities of calcification is found as the subject ages and for more progressed lesion [14]. Therefore, the extent of CAC can be used as a risk factor of cardiovascular diseases [15].

Regarding some of the mechanisms related to the role of oxidation stress on the pathophysiology of cardiovascular disease, GGT on the surface of cellular membrane is known to play important role in anti-oxidation mechanism by enabling the concentration of the glutathione to be maintained within the cell by the gamma-glutamyl cycle [8,16]. Therefore, it has been reported that increase in serum GGT could be a reaction against oxidation stress [17,18]. In particular, with the report of various researches on the correlation between serum GGT and hypertension [19,20], it is possible to confirm that serum GGT can be used as a new index to predict the manifestation of diseases of cardiovascular system [9]. As GGT has been observed in the atherosclerotic plaque of carotid and coronary artery, hypothesis that GGT is directly involved in the progress of atherosclerosis had been proposed [8,21,22].

Lee et al. on the relevance between serum GGT with already known risk factors of coronary artery diseases, reported that the manifestation of hypertension significantly increases 15 years later as the concentration of serum GGT increases even within the normal range after having multivariate adjustment, and explained the findings as the damage mechanism due to oxidation stress [20]. Such relevance has been consistently reported in Asians including Korea [23] and Hong Kong [24]. With regards to the relationship between the concentration of serum GGT and diabetes, the concentration of serum GGT has continuously been reported as useful clinical index in manifestation of diabetes if the subject of research was healthy [25] or diabetic patient [26], or is of young age [27] or of old age [26]. In addition, in the research on multi-racial population group, it was reported that the insulin resistance is associated with generation and progression of CAC [13]. As the GGT promotes the oxidation process of LDL-C in the progression of atherosclerosis and as biochemically activated GGT was discovered along with oxidized LDL and foam cell in the atheromatous plaque, the relevance between GGT and LDL-C was reported [18].

Several previous researches reported on the correlation between the increase in serum GGT and manifestation of diseases of cardiovascular system such as coronary artery disease. In particular, large scale cohort study that made follow-up observation on all the adults over the age of 19 in a region in Austria over a period of 17 years reported that more than moderate level of increase (>18 IU/L) in serum GGT is related to increase in death rate due to diseases of cardiovascular system [10]. Cohort study that made follow-up observation on subjects in the age range of 40–59 over 24 years in England, Wales and Scotland reported that serum GGT is related to the death rate due to diseases of cardiovascular system and cerebrovascular system, and can be used as index for prediction of the manifestation of diseases of cardiovascular system over prolonged period of time [28]. In a research that made follow-up observation over a mean period of 3.5 years on 10,746 subjects who have undergone MDCT of coronary artery, CAC displayed significant relevance with manifestation of coronary artery disease in both male and female even after the adjustment for age, smoking, hypercholesterolemia, hypertension and diabetes, etc. [15].

Table 4
Odds ratios (ORs) and 95% confidence intervals (CI) for the existence of CAC by quartiles of GGT distribution.

	GGT				p-trend across quartiles
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Overall					
Unadjusted	1	1.97 (1.62–2.38)	2.75 (2.29–3.31)	3.55 (2.97–4.24)	<0.001
Age-adjusted	1	2.00 (1.62–2.45)	2.84 (2.34–3.46)	3.73 (3.09–4.51)	<0.001
Age, sex-adjusted	1	1.44 (1.16–1.78)	1.91 (1.55–2.35)	2.44 (1.99–2.99)	<0.001
Multivariable-adjusted	1	1.61 (1.30–2.01)	2.06 (1.66–2.55)	2.43 (1.94–3.05)	<0.001
Men					
Unadjusted	1	1.34 (1.11–1.62)	1.96 (1.64–2.34)	2.31 (1.94–2.74)	<0.001
Age-adjusted	1	1.24 (1.02–1.51)	1.77 (1.47–2.14)	2.07 (1.72–2.49)	<0.001
Multivariable-adjusted	1	1.06 (0.86–1.30)	1.40 (1.15–1.72)	1.49 (1.21–1.85)	0.002
Women					
Unadjusted	1	1.41 (0.69–2.89)	2.40 (1.21–4.76)	5.15 (2.74–9.68)	<0.001
Age-adjusted	1	0.84 (0.39–1.84)	1.37 (0.65–2.87)	2.46 (1.25–4.87)	0.008
Multivariable-adjusted	1	0.71 (0.31–1.63)	1.10 (0.51–2.40)	1.33 (0.62–2.87)	0.384

Multivariate models are adjusted for age, sex (in overall group), BMI, systolic BP, ALT, fasting serum glucose, LDL-C, TG, HDL-C, hsCRP, current smoking status, hypertension and diabetes.

In this study, systolic and diastolic BP as well as prevalence of hypertension, fasting serum glucose and prevalence of diabetes, total cholesterol, LDL-C and triglyceride significantly increased in both male and female as the concentration of serum GGT increased. As the relevance between the concentration of serum GGT and CAC in all subjects and males has been continuously observed even after the adjustment of the already known risk factors of coronary artery, it was possible to confirm that serum GGT is an independent risk factor of diseases of coronary artery.

However, although the odds ratio of CAC increases significantly in male as the concentration of serum GGT increased in the multivariate logistic regression analysis in this study, the tendency of increase did not displays statistical significance in female. While the concentration of serum GGT for male had median value (range of quartile) of 32 (22–53) IU/L, female was substantially lower with value of 14 (11–20) IU/L, and the prevalence of CAC was also substantially lower in female at 4.6% in comparison to male at 11.1%. Therefore, there is possibility that the relevance between GGT concentration and CAC may not have been clearly visible. Even in previous research, the extent of CAC in female was approximately half of male [6]. In another research, although the hazard ratios of manifestation of CAC and coronary artery disease was observed significantly in both male and female, the hazard ratios displayed 1.5–10.0-fold differences between male and female even after having multivariate adjustment [15]. In meta-analysis of fully adjusted study results of the association of GGT with incident coronary heart disease, three studies showed significantly positive association in female. The HRs (95% CI) for the coronary heart disease were 8.34 (2.82–24.69), 1.14 (1.03–1.27) and 1.52 (1.03–2.25). However in another study, positive association was not statistically significant. The HR (95% CI) was 1.15 (0.33–1.50) [29]. Therefore, although the difference between the male and female of the relevance between concentration of serum GGT and CAC could be the effect of the gender, it may be also deemed to be the results of lower concentration of serum GGT in female in comparison to male.

This study has several limitations, despite being conducted on a large representative sample of the general population. Firstly, as a cross-sectional study, it is not possible to permit the determination of causality. Secondly, it is not possible to perfectly explain the effect of the current CAC on the manifestation of diseases of coronary artery in the future. However, Detrano et al. [30] proved that the extent of CAC is useful in forecasting of coronary artery disease. Therefore, MDCT examination can be utilized usefully as early stage screening test for diseases of coronary artery. Finally, this study was just confined to relatively racially homogeneous individuals of Korean ancestry who were recruited at a single urban hospital, which introduced the possibility of bias. Additionally, the participants were self-selected, so this study might show participant selection bias.

Although this study did not directly measure the manifestation of diseases of cardiovascular system and the death rate as the result, it was possible to confirm that there is relevance between the existence of CAC, which is an important pathological finding of occurrence of diseases of cardiovascular system, and serum GGT even after the multivariate adjustment, and measurement of CAC through MDCT, as a non-invasive method implemented within relatively short period of time, is useful in early diagnosis of diseases of coronary artery. Since serum GGT is being tested as an essential items in various types of health examination including those for laborers and in assessment of hepatic function of patients, it can be accessed easily with high level of accessibility of information, can be easily and quickly utilized along with existing well-known risk factors such as hypertension, fasting serum glucose and lipoprotein in prediction of coronary artery disease. Those with continual increase in serum GGT or CAC have high risk of manifestation of coronary artery disease. Therefore, more detailed medical examination by interview and more precise examinations need to be performed on such persons.

5. Conclusions

Elevated serum GGT levels were independently associated with the prevalence of CAC. Physicians and health care providers should be observant regarding future development of coronary artery disease among people with increasing concentration of serum GGT.

Financial support and disclosure statement

The authors have nothing to disclose.

Author contributions

J-H.R. coordinated the study, interpreted the data, contributed to discussion and wrote the manuscript.

W.L. interpreted and analyzed the data, reviewed, edited and wrote the manuscript.

B.S.S. reviewed, edited the manuscript.

J.L. collected the data, reviewed the manuscript.

J.K. collected the data, reviewed the manuscript.

J-H.R. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Acknowledgements

No potential conflicts of interest relevant to this article were reported.

Appendix A. Supplementary material

Supplementary material related to this article can be found at http://dx.doi.org/10.1016/j.atherosclerosis.2012.10.059.

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