# The interaction between serum uric acid and triglycerides level on blood pressure for middle-aged and elderly individuals in China

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# Abstract

Background The purpose of the research is to explore the extent of interaction between triglycerides (TG) and serum uric acid (SUA) level with blood pressure (BP) in middle-aged and elderly individuals in China.

Methods Data were selected from the CHARLS, a cross-sectional study. A total of 7119 individuals aged 45 to 96 in our study was included. Differences between gender, or between categories of blood pressure levels were evaluated by t-test or chi-square test. The adjusted associations between various characteristics and BP status were first compared using linear regression models, as appropriate. Then, general linear models adjusting for related potential confounders were used to examine the synergistic effect of SUA and TG level on blood pressure (BP) for middle-aged and elderly individuals in China.

Results Age-adjusted partial Pearson's correlation coefficient showed that SUA and TG level positively correlated with both SBP and DBP in men and women. Multiple linear regression analysis showedTG levels were significantly and positively associated with systolic blood pressure (SBP) and diastolic blood pressure (DBP) in both males (SBP: β =0.068, P =0.001; DBP: β =0.064, P =0.002) and females (SBP: β =0.061, P =0.002; DBP: β =0.084, P =0.000), but serum uric acid (SUA) were significantly and positively associated with systolic blood pressure (SBP) in both males (SBP: β =0.047, P =0.013) and females (SBP: β =0.040, P =0.028), regardless of other confounding factors. A general linear model adjusted for confounding factors was used to assessed the statistical significance of the synergistic relationship between serum uric acid (SUA) and triglycerides (TG) level. Evidence of interaction between serum uric acid (SUA) and triglycerides (TG) level on SBP (men: β =-1.090, P =0.726; women: β =-0.692, P =0.861) and DBP (men: β=-1.026, P =0.572; women: β =-0.794, P =0.842) was not observed.

Conclusion The interaction effect of serum uric acid (SUA) and triglycerides (TG) level on blood pressure (BP) was not observed in our study.


# Background

As well known, according to the relationship between prehypertension and cardiovascular disease[1–3] and the etiologies of cardiovascular disease (CVD)[4–6], the hypertension is defined with the standards as follows: diastolic blood pressure (BP) of >90 mmHg; and/or systolic blood pressure (BP) of >140 mmHg. Hypertension is a cluster of risk factors[7–14] associated with aging, central obesity, overweight, the household heredity factors, unhealthy behavior and life styles(cigarette smoking, alcohol consumption, and lack of physical activities), diabetes, dyslipidemia, low levels of high-density lipoprotein(HDL) cholesterol, high levels of low-density lipoprotein (LDL) cholesterol, elevated fasting glucose levels, and elevated triglycerides(TG). Because hypertension is more complex and patients suffer from physical, psychosocial, and economical burden, it has become a serious public health in the worldwide[15]. Recently, prevalence and incidence of hypertension remained higher up in China [16, 17]. For the aging population increases, it is disproportionately high among middle-aged and elderly individuals in China [18–20]. Hypertension is a multi-factor caused disease, and patients suffer a lot from

economic burden, psychological and physical distress. Recently, hypertension became most important public health challenges worldwide. In sum, hypertension prevention and treatment strategies, and its risks should be carefully studied. Exploring the its timely associated risks and their interaction of hypertension may provide the insight in public health implications for prevention and management of hypertension in future.

Serum uric acid (SUA) is an endogenous end product and is involved in the production of reactive-oxygen species. It is important to evaluate their status in advance of chronic disease development[21]. In recent years, as a key mark, systemic measured by serum uric acid (SUA) has become an important marker for chronic disease development. Studies have conduct that serum uric acid (SUA) is associated with various diseases, such as cardiovascular disease (CVD) [22–25], prehypertension [26–29], metabolic syndrome [30–32], and hypertension [33–35]. However, despite the association between SUA levels and these risk conditions, SUA levels may not be regarded as an independent risk factor. Since SUA level is highly associated with overweight, obesity and other risk factors [36–38], which is in turn associated with risk of hypertension, a causal condition may exist between triglycerides (TG) and risk of hypertension. Therefore, the association between SUA levels and risk of hypertension and the effects of triglycerides (TG) on this association are of considerable interest, and a modulating effect between triglycerides (TG) and serum uric acid (SUA) levels on blood pressure (BP) may also be fully considered.

To date, few studies on the association and interaction analysis between serum uric acid (SUA) and triglycerides (TG) level and blood pressure (BP) were conducted in individuals aged ≥45 years. The study has[39] explored the association and/or interaction analysis between serum uric acid (SUA) and triglycerides (TG) and blood pressure (BP), but the relationships lack of the related research in china culture background. Thus, this study aimed to determine the prevalence of normotension and hypertension and their association with serum uric acid (SUA), triglycerides (TG) level, and other confounding factors based on gender using the cross-sectional study data(CHARLS) from individuals aged ≥45 years in China.

## Methods

# Study design and setting

Data from the China Health and Retirement Longitudinal Study (CHARLS) were used in our study. The CHARLS was a nationally representative longitudinal study conducted by the China Centre for Economic Research at Peking University[40]. From the 2011 CHARLS Wave1, we included a total of 7119 individuals in our study.

# Participants

The participants of the study were from the CHARLS, Wave 1 (2011) [40]. The CHARLS involved 7119 individuals 45years old, out of whom 46.99% were 60.24 ± 9.24years and 53.01% women were 59.91 ±

9.95years.

# Self-reported factors

variables like age, educational levels (four categories, illiterate, less than elementary school, high school, and above vocational school), marital status (dichotomous variables, the single and married), residence (dichotomous variables, rural and urban), cigarette smoking (three categories, no, former smoke, and current smoke), alcohol consumption (three categories, no, less than once a month, and more than once a month), eating habit (three categories, ≤2 meals per day, 3 meals per day, and ≥4 meals per day), social events (dichotomous variables, no and yes), accidental injury (dichotomous variables, no and yes), physical exercise (three categories, no physical exercise, less than physical exercises, and regular physical exercises), history of liver disease (dichotomous variables, no and yes), history of cardiovascular disease (dichotomous variables, no and yes), antidiabetic medication (dichotomous variables, no and yes), antilipidemic medication (dichotomous variables, no and yes), and antihypertensive medication (dichotomous variables, no and yes) were obtained using a self-reported questionnaire, and most variables based on our study[41–43].

# Measurements

BMI was calculated based on the measured weight and height of the participants [44]. CRP was measured using immunoturbidimetric assay. Fasting plasma glucose (FPG), triglycerides (TG) levels, low density lipoprotein (LDL), high density lipoprotein (HDL), and HbA1c were analyzed using the enzymatic colorimetric tests, serum uric acid (SUA) levels were analyzed using the urinalysis (UA) plus method. The average value of BP was determined by mean of the 3 measurements. Estimated glomerular filtration rate (eGFR) was measured by the chronic kidney disease epidemiology collaboration (CKD-EPI) creatinine-cystatin equations[45]. Triglycerides (TG) was divided into two categories: 150mg/dL and 150mg/dL. Hyperuricemia (HUA) was defined as SUA concentration of >7mg/dL in men and >6 mg/dL in women[39]. Participants were divided into hypertension (defined as SBP of 140 mmHg and/or DBP of 90 mmHg), and normotension (defined as not being on antihypertensive therapies with an SBP of 140 mmHg and DBP of 90 mmHg) groups, the categorization has been widely used in previous studies.

# Statistical analysis

Data were analyzed by using SPSS17.0 software forWindows10 (IBM Corp., Armonk, NY, USA) and expressed as the mean SD or frequency, as appropriate. Differences between gender, or between categories of blood pressure levels were evaluated by t-test or chi-square test. The adjusted associations between various characteristics and BP status were first compared using linear regression models, as appropriate. Then, general linear models adjusting for related potential confounders were used to

examine the synergistic effect of serum uric acid and triglycerides level on blood pressure for middle-aged and elderly individuals in China. 2-tailed, and a value of P of 0.05 were considered significant.

# Results

In total, 7119 participants who effectively completed the questionnaires were included in our research. The baseline of demographic variables is shown in table 1, and most variables based on our previous studies [41–43]. Overall, 3345(46.99%) of the participants were male, and 3374 (53.01%) of the participants were female. The average ages of the male and female participants were 60.24 ± 9.24 and 59.91 ± 9.95years, respectively. In male, the mean and standard deviation of SUA levels were 4.87±1.24 mg/dl in normotension group, and 5.20±1.33 mg/dl in hypertension group, respectively. In male, the mean and standard deviation of TG levels were 120.58±100.65 mg/dl in normotension group, and 133.51±111.81 mg/dl, respectively. In female, the mean and standard deviation of SUA levels were 3.93±1.04 mg/dl in normotension group, and 4.24±1.16 mg/dl in hypertension group, respectively. In female, the mean and standard deviation of TG levels were 129.26±82.88 mg/dl in normotension group, and 154.49±112.79 mg/dl, respectively. Table1 show the relationship of various characteristics and CRP levels in the participants. Significant differences in distribution were observed between blood pressure status in male in all of the variables, except cigarette smoking, alcohol consumption, eating habit, social events, physical exercise, history of liver diseases, anti-diabetic medication, and HDL cholesterol. CRP, HbA1c, FPG, LDL-C, BMI, TG, and SBP and DBP were significantly higher in the hypertension than those in the normotension, whereas, eGFR levels was lower in the hypertension than that in the normotension. Significant differences in distribution were observed between blood pressure status in female in all of the variables, except residence, cigarette smoking, alcohol consumption, eating habit, social events, accidental injury, regular physical exercises, and history of liver diseases. CRP, HbA1c, FPG, LDL-C, TG, SBP, SUA level and DBP were significantly higher in in the hypertension than those in the normotension, but HDL-C and eGFR level were lower in the hypertension than that in the normotension.

Table 2 show age-adjusted relationship between baseline of demographic variables and BP status of participants categorized by gender. In male, firstly, age-adjusted partial Pearson's correlation coefficient showed that marital status, residence, accidental injury, history of CVD, antilipidemic medication, anti-hypertensive medication, HbA1c, FPG, LDL, HDL, eGFR, BMI, SUA and TG level positively correlated with both SBP and DBP. Secondly, anti-diabetic medication positively correlated with SBP. Thirdly, alcohol consumption, eating habit, and physical exericise positively correlated with DBP. In female, firstly, age-adjusted partial Pearson's correlation coefficient showed that alcohol consumption, history of CVD, antilipidemic medication, anti-hypertensive medication, anti-diabetic medication, antilipidemic medication, HbA1c, FPG, HDL, BMI, SUA and TG level positively correlated with both SBP and DBP. Secondly, marital status, CRP positively correlated with SBP. Thirdly, eating habit, history of liver diseases, LDL, and eGFR positively correlated with DBP.

Tables 3 show multivariate-adjusted relationship between baseline of demographic variables and BP in participants categorized by gender. The result showed that the TG levels were significantly and positively

associated with SBP and DBP in both males (SBP: β = 0.068, *P* = 0.001; DBP: β = 0.064, *P* = 0.002) and females (SBP: β = 0.061, *P* = 0.002; DBP: β = 0.084, *P* = 0.000), but SUA were significantly and positively associated with SBP in both males (SBP: β = 0.047, *P* = 0.013) and females (SBP: β = 0.040, *P* = 0.028), regardless of other confounding factors. We also take care of the direct associations between TG category and SUA levels on BP levels. Fig. 1. showed that the lines differenced from others in each figure.

A general linear model adjusted for the related confounding factors(socio-demographic characteristics [age, educational level, marital status, residence], health behaviors [smoking habit, alcohol consumption, eating habits, social events, accidental injury, physical activities], medical history [history of CVD, history of liver diseases, anti-diabetes, history of antilipidemic medication], metabolic measures [CRP, HbA1c, FPG, HDL-C, eGFR, LDL-C, BMI]) was used to explore the combined relationship between SUA levels and TG levels. Evidence of interaction between SUA and TG levels on SBP ( β = −1.090, *P* = 0.726 in men; β = −0.692, *P* = 0.861 in women) and DBP (β = −1.026, *P* = 0.572 in men; β = −0.794, *P* = 0.842 in women) was not observed (Tables 4).

# Discussion

At present, the association of serum uric acid (SUA) and triglycerides (TG) level and level with blood pressure (BP) varied in middle-aged and elderly individuals. In the research, we attempted to determine the hypertension prevalence and its association with triglycerides (TG) and serum uric acid (SUA) level. The results show that prevalence of hypertension was 32.23% (1078/3345) in men and 33.97% (1282/3774) in women, which is similar to those of the English individuals (men, 36.8%; women, 38.6%) [46]. Moreover, men who had hypertension took a higher prevalence on the risk factors, such as age, educational level, marital status, residence, accidental injury, history of cardiovascular disease (CVD), antidiabetic medication, fasting plasma glucose (FPG), low density lipoprotein (LDL), estimated glomerular filtration rate (eGFR), body mass index (BMI), serum uric acid (SUA) level, triglycerides (TG) levels, than those with normotension. Age, educational level, marital status, alcohol consumption, history of cardiovascular disease (CVD), history of liver diseases, antilipidemic medication, anti-diabetic medication, fasting plasma glucose (FPG), low density lipoprotein (LDL), high density lipoprotein (HDL), stimated glomerular filtration rate (eGFR), body mass index (BMI), serum uric acid (SUA) level, and triglycerides (TG) level were significantly associated with blood pressure (BP) among women.

Studies[47, 48] have explored the association and/or interaction analysis between BMI and SUA level and BP. Although previous studies [44, 47, 48] have explored the association and/or interaction analysis between BMI and SUA levels and BP, there are no consistent results pointing to such associations. Lee et al. [44], using data from 45,098 Koreans who underwent health examinations at Korea Association of Health Promotion with no history of taking drugs related with UA and/or BP, found that SUA levels were positively associated with SBP and DBP in males aged <40 years after adjustment for age, diabetes, dyslipidemia, BMI, and eGFR; however, no significant associations were found in males aged 60 years or older. Lyngdoh et al.[47], assessing 549 individuals aged 19–20 years, found that SUA levels tended to be positively associated with DBP and SBP in males, while the strength of the SUA-BP association was

similar in females. Kawamoto et al. [48] found that increased SUA levels were positively associated with SBP and DBP in participants with BMI <21.0 kg/$m^2$, while there was a negative association between SUA levels, SBP and DBP in those with BMI ≥ 21.0 kg/$m^2$, in whom the interaction between BMI and SUA levels was a significant and independent determinant of both SBP and DBP. However, since the sample size was relatively small, and individuals were not randomly selected, the analyses did not rely on gender. The mechanisms that lead to hypertension in participants with high TG or SUA level have not been completely understood. Choi et al. [49] reported that high SUA levels induced endothelial dysfunction through vascular resistance in insulin-induced NO production, potentially leading to hypertension. Maxwell et al. [50] suggested that the association of high SUA levels with CVD may be a consequence of impaired NO activity in the blood vessels. Papezikova et al. [51] demonstrated that high SUA levels lead to a decreased NO bioavailability through multiple mechanisms. These studies may provide insights on the pathogenic mechanism by which SUA induces hypertension. Moreover, SUA is strongly associated with [52–54], inflammation [55–57], oxidative stress [58–60] and other risk factors for CVD, such as BMI, T-C, HDL-C, BP, TG, and FPG [48]. Risk factors associated with hypertension may lead to decreased vasomotor reactivity, endothelial dysfunction, and arterial stiffness [48], ultimately causing hypertension. Our study suggests that SUA may play an important role in hypertension, and gender-specific factors may also be crucial. The SUA levels were higher in males than in females, which can partially explain the underlying mechanisms that possibly account for gender differences, such as alcohol consumption, whose prevalence is usually higher in males. Additionally, body fat and steroid hormones, and their interaction in middle-aged and older adults may also be associated with hypertension.

This study has three limitations. First, the association and interaction between serum uric acid (SUA) and triglycerides (TG) level and BP becomes seriously more complex. We only considered the identified confounders; however, some unknown factors still exist. Second, the relationship should be studied prospectively; however, our study investigated the interaction between serum uric acid (SUA) and triglycerides (TG) level and blood pressure (BP) in participants aged ≥45 years in a cross-sectional study. Follow-up study was relatively short to comprehensively observe changes in the next phase. Finally, more research is needed to confirm the results. However, this study has several strengths as well. First, this study was conducted based on a nationwide survey, and second, the analyses were conducted based on gender.

# Conclusion

An interaction between SUA and TG level and BP was not observed in both men and women in our study.

# Abbreviations

CHARLS, China Health and Retirement Longitudinal Study; CRP, C-reactive protein; FPG, fasting plasma glucose; TG, triglycerides; BMI, body mass index; DBP, diastolic blood pressure; SBP, systolic blood pressure; SUA, serum uric acid; CVD, cardiovascular disease; CKD-EPI, the chronic kidney disease epidemiology collaboration; eGFR, Estimated glomerular filtration rate; CDC, centers for disease control;

serum cystatin C; LDL, low density lipoprotein; HDL, high density lipoprotein; OR, Odd ratio; NSFC, National Natural Science Foundation of China; NIA, national intelligence agency.

## Declarations

# Ethics approval and consent to participate

The study is publicly available (http://charls.pku.edu.cn/zh-CN) with no direct contact with the individual participants.

# Consent for publication

Consent for publication was obtained from all participant.

# Availability of data and material

Data can be accessed via Http://charls.pku.edu.cn/zh-CN.

# Competing interests

The authors declare that they have no competing interests.

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# Authors' contributions

LZ conceived and draft the manuscript. L-lG, J-lL, and GX helped revise the manuscript.

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## References

1.Glynn RJ, L'Italien GJ, Sesso HD, Jackson EA, Buring JE: *Development of predictive models for long-term cardiovascular risk associated with systolic and diastolic blood pressure. Hypertension* 2002, *39(*1):105–110.

2.Yu D, Huang J, Hu D, Chen J, Cao J, Li J, Gu D: *Association between prehypertension and clustering of cardiovascular disease risk factors among Chinese adults. Journal of cardiovascular pharmacology* 2009, *53(*5):388–400.

3.Gu D, Chen J, Wu X, Duan X, Jones DW, Huang JF, Chen CS, Chen JC, Kelly TN, Whelton PK *et al: Prehypertension and risk of cardiovascular disease in Chinese adults. Journal of hypertension* 2009, *27(*4):721–729.

4.Fagard RH: *Predicting risk of fatal cardiovascular disease and sudden death in hypertension. Journal of hypertension* 2017, *35(*11):2165–2167.

5.James JE: *Hypertension control and cardiovascular disease. Lancet* 2017, *389(*10065):154.

6.Lackland DT, Weber MA: *Global burden of cardiovascular disease and stroke: hypertension at the core. The Canadian journal of cardiology* 2015, *31(*5):569–571.

7.Gui ZH, Zhu YN, Cai L, Sun FH, Ma YH, Jing J, Chen YJ: *Sugar-Sweetened Beverage Consumption and Risks of Obesity and Hypertension in Chinese Children and Adolescents: A National Cross-Sectional Analysis. Nutrients* 2017, *9(*12).

8.Lee MS, Chang CH, Lin RY, Lai MS: *Risks of hypertension associated with cyclosporine, nonsteroidal anti-inflammatory drugs, and systemic glucocorticoids in patients with psoriasis: a nationwide population-based nested case-control study in Taiwan. Pharmacoepidemiology and drug safety* 2016, *25(*2):133–140.

9.Kannel WB: *Hypertension: reflections on risks and prognostication. The Medical clinics of North America* 2009, *93(*3):541–558, Table of Contents.

10.Beilin L: *Alcohol and hypertension: balancing the risks and benefits. Journal of hypertension* 2005, *23(*11):1953–1955.

11.Cartier A, Malo JL, Gautrin D, Boulet LP, Boisjoly H: *Glucocorticoid use and risks of ocular hypertension and glaucoma. Jama* 1997, *277(*24):1929–1930.

12.Isezuo SA, Sabir AA, Ohwovorilole AE, Fasanmade OA: *Prevalence, associated factors and relationship between prehypertension and hypertension: a study of two ethnic African populations in Northern Nigeria. J Hum Hypertens* 2011, *25(*4):224–230.

13.Kawamoto R, Kohara K, Tabara Y, Abe M, Kusunoki T, Miki T: *Insulin resistance and prevalence of prehypertension and hypertension among community-dwelling persons. Journal of atherosclerosis and*

*thrombosis* 2010, *17(*2):148–155.

14.Kawamoto R, Tabara Y, Kohara K, Miki T, Abe M, Kusunoki T: *Increased high-density lipoprotein cholesterol is associated with a high prevalence of pre-hypertension and hypertension in community-dwelling persons. Endocrine* 2012, *42(*2):321–328.

15.Cloutier L, Morris D, Bruneau J, McLean D, Campbell N: *World Health Organization celebrates World Health Day, April 7,2013—focusing on hypertension. Canadian journal of cardiovascular nursing = Journal canadien en soins infirmiers cardio-vasculaires* 2013, *23(*2):9–11.

16.Zhao Y, Yan H, Marshall RJ, Dang S, Yang R, Li Q, Qin X: *Trends in population blood pressure and prevalence, awareness, treatment, and control of hypertension among middle-aged and older adults in a rural area of Northwest China from 1982 to 2010. PloS one* 2013, *8(*4):e61779.

17.Wu Y, Huxley R, Li L, Anna V, Xie G, Yao C, Woodward M, Li X, Chalmers J, Gao R *et al: Prevalence, awareness, treatment, and control of hypertension in China: data from the China National Nutrition and Health Survey 2002. Circulation* 2008, *118(*25):2679–2686.

18.Liu X, Gu W, Li Z, Lei H, Li G, Huang W: *Hypertension prevalence, awareness, treatment, control, and associated factors in Southwest China: an update. Journal of hypertension* 2017, *35(*3):637–644.

19.Wu L, He Y, Jiang B, Sun D, Wang J, Liu M, Yang S, Wang Y: *Trends in Prevalence, Awareness, Treatment and Control of Hypertension during 2001–2010 in an Urban Elderly Population of China. PloS one* 2015, *10(*8):e0132814.

20.Wang S, Chen R, Liu Q, Shu Z, Zhan S, Li L: *Prevalence, awareness and treatment of chronic kidney disease among middle-aged and elderly: The China Health and Retirement Longitudinal Study. Nephrology* 2015, *20(7*):474–484.

21.Kim Y, Kim YJ, Lim Y, Oh B, Kim JY, Bouwman J, Kwon O: *Combination of Diet Quality Score, Plasma Carotenoids, and Lipid Peroxidation to Monitor Oxidative Stress. Oxidative medicine and cellular longevity* 2018, *2018:*8601028.

22.Borghi C: *The role of uric acid in the development of cardiovascular disease. Current medical research and opinion* 2015, *31 Suppl 2:*1–2.

23.Wu AH, Gladden JD, Ahmed M, Ahmed A, Filippatos G: *Relation of serum uric acid to cardiovascular disease. International journal of cardiology* 2016, *213:*4–7.

24.Tian Y, Chen K, Xie Z, Fang Y, Wang H, Nie Y, Hu D, Mu Y: *The association between serum uric acid levels, metabolic syndrome and cardiovascular disease in middle aged and elderly Chinese: results from the DYSlipidemia International Study. BMC cardiovascular disorders* 2015, *15:*66.

25.Alderman M: *Uric acid in hypertension and cardiovascular disease. The Canadian journal of cardiology* 1999, *15 Suppl F:*20F–22F.

26.Kuwabara M, Hisatome I, Niwa K, Hara S, Roncal-Jimenez CA, Bjornstad P, Nakagawa T, Andres-Hernando A, Sato Y, Jensen T *et al: Uric Acid Is a Strong Risk Marker for Developing Hypertension From Prehypertension: A 5-Year Japanese Cohort Study. Hypertension* 2018, *71(*1):78–86.

27.Jiang M, Gong D, Fan Y: *Serum uric acid levels and risk of prehypertension: a meta-analysis. Clinical chemistry and laboratory medicine* 2017, *55(*3):314–321.

28.Soletsky B, Feig DI: *Uric acid reduction rectifies prehypertension in obese adolescents. Hypertension* 2012, *60(*5):1148–1156.

29.Syamala S, Li J, Shankar A: *Association between serum uric acid and prehypertension among US adults. Journal of hypertension* 2007, *25(*8):1583–1589.

30.Bouhenni H, Daoudi H, Djemai H, Rouabah A, Vitiello D, Rouabah L: *Metabolic syndrome, leptin-insulin resistance and uric acid: a trinomial foe for Algerian city-dweller adolescents' health. International journal of adolescent medicine and health* 2018.

31.King C, Lanaspa MA, Jensen T, Tolan DR, Sanchez-Lozada LG, Johnson RJ: *Uric Acid as a Cause of the Metabolic Syndrome. Contributions to nephrology* 2018, *192:*88–102.

32.Cibickova L, Langova K, Vaverkova H, Kubickova V, Karasek D: *Correlation of uric acid levels and parameters of metabolic syndrome. Physiological research* 2017, *66(*3):481–487.

33.Wu L, He Y, Jiang B, Liu M, Wang J, Zhang D, Wang Y, Zeng J: *Association between serum uric acid level and hypertension in a Chinese elderly rural population. Clinical and experimental hypertension* 2017, *39(*6):505–512.

34.Cui LF, Shi HJ, Wu SL, Shu R, Liu N, Wang GY, Zhou B, Sun K, Yu P, Wang J *et al: Association of serum uric acid and risk of hypertension in adults: a prospective study of Kailuan Corporation cohort. Clinical rheumatology* 2017, *36(*5):1103–1110.

35.Feig DI: *Uric acid and hypertension. Seminars in nephrology* 2011, *31(*5):441–446.

36.Kuwahara E, Murakami Y, Okamura T, Komatsu H, Nakazawa A, Ushiku H, Maejima F, Nishigaki Y, Nishiwaki Y: *Increased childhood body mass index is associated with young adult serum uric acid levels: a linkage study from Japan. Pediatric research* 2016.

37.Tanaka K, Ogata S, Tanaka H, Omura K, Honda C, Osaka Twin Research G, Hayakawa K: *The relationship between body mass index and uric acid: a study on Japanese adult twins. Environmental health and preventive medicine* 2015, *20(*5):347–353.

38.Yue JR, Huang CQ, Dong BR: *Association of serum uric acid with body mass index among long-lived Chinese. Experimental gerontology* 2012, *47(*8):595–600.

39.Teng F, Zhu R, Zou C, Xue Y, Yang M, Song H, Liang J: *Interaction between serum uric acid and triglycerides in relation to blood pressure. J Hum Hypertens* 2011, *25(*11):686–691.

40.Li C, Liu T, Sun W, Wu L, Zou ZY: *Prevalence and risk factors of arthritis in a middle-aged and older Chinese population: the China health and retirement longitudinal study. Rheumatology* 2015, *54(*4):697–706.

41.Zhang L, Liu K, Li H, Li D, Chen Z, Zhang LL, Guo LL: *Relationship between body mass index and depressive symptoms: the "fat and jolly" hypothesis for the middle-aged and elderly in China. BMC public health* 2016, *16(*1):1201.

42.Zhang L, Li JL, Zhang LL, Guo LL, Li H, Li D: *No association between C-reactive protein and depressive symptoms among the middle-aged and elderly in China Evidence from the China Health and Retirement Longitudinal Study. Medicine* 2018, *97(*38).

43.Zhang L, Li JL, Zhang LL, Guo LL, Li H, Li D: *Association and Interaction Analysis of Body Mass Index and Triglycerides Level with Blood Pressure in Elderly Individuals in China. BioMed research international* 2018, *2018:*8934534.

44.Zhou BF: *Effect of body mass index on all-cause mortality and incidence of cardiovascular diseases—report for meta-analysis of prospective studies open optimal cut-off points of body mass index in Chinese adults. Biomedical and environmental sciences: BES* 2002, *15(*3):245–252.

45.Zhu Y, Ye X, Zhu B, Pei X, Wei L, Wu J, Zhao W: *Comparisons between the 2012 new CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) equations and other four approved equations. PloS one* 2014, *9(*1):e84688.

46.Steptoe A, McMunn A: *Health behaviour patterns in relation to hypertension: the English Longitudinal Study of Ageing. Journal of hypertension* 2009, *27(*2):224–230.

47.Lyngdoh T, Viswanathan B, Myers GJ, Bochud M, Bovet P: *Impact of different adiposity measures on the relation between serum uric acid and blood pressure in young adults. J Hum Hypertens* 2012, *26(*11):677–683.

48.Kawamoto R, Ninomiya D, Senzaki K, Kumagi T: *Interaction between body mass index and serum uric acid in relation to blood pressure in community-dwelling Japanese men. Clinical hypertension* 2018, *24:*1.

49.Choi YJ, Yoon Y, Lee KY, Hien TT, Kang KW, Kim KC, Lee J, Lee MY, Lee SM, Kang DH *et al: Uric acid induces endothelial dysfunction by vascular insulin resistance associated with the impairment of nitric oxide synthesis. FASEB journal: official publication of the Federation of American Societies for Experimental Biology* 2014, *28(*7):3197–3204.

50.Maxwell AJ, Bruinsma KA: *Uric acid is closely linked to vascular nitric oxide activity. Evidence for mechanism of association with cardiovascular disease. Journal of the American College of Cardiology* 2001, *38(*7):1850–1858.

51.Papezikova I, Pekarova M, Kolarova H, Klinke A, Lau D, Baldus S, Lojek A, Kubala L: *Uric acid modulates vascular endothelial function through the down regulation of nitric oxide production. Free radical research* 2013, *47(*2):82–88.

52.Liu ZM, Ho SC: *The association of serum C-reactive protein, uric acid and magnesium with insulin resistance in Chinese postmenopausal women with prediabetes or early untreated diabetes. Maturitas* 2011, *70(*2):176–181.

53.Mangge H, Pilz S, Haj-Yahya S, Almer G: *Uric acid indicates a high cardiovascular risk profile but is not closely associated with insulin resistance in obese adolescents. Diabetes care* 2008, *31(*4):e21.

54.Chen LK, Lin MH, Lai HY, Hwang SJ, Chiou ST: *Uric acid: a surrogate of insulin resistance in older women. Maturitas* 2008, *59(*1):55–61.

55.Turak O, Ozcan F, Tok D, Isleyen A, Sokmen E, Tasoglu I, Aydogdu S, Sen N, McFann K, Johnson RJ *et al: Serum uric acid, inflammation, and nondipping circadian pattern in essential hypertension. Journal of clinical hypertension* 2013, *15(*1):7–13.

56.Zhou Y, Fang L, Jiang L, Wen P, Cao H, He W, Dai C, Yang J: *Uric acid induces renal inflammation via activating tubular NF-kappaB signaling pathway. PloS one* 2012, *7(*6):e39738.

57.Kalay N, Aytekin M, Kaya MG, Ozbek K, Karayakali M, Sogut E, Altunkas F, Ozturk A, Koc F: *The relationship between inflammation and slow coronary flow: increased red cell distribution width and serum uric acid levels. Turk Kardiyoloji Dernegi arsivi: Turk Kardiyoloji Derneginin yayin organidir* 2011, *39(*6):463–468.

58.Corry DB, Eslami P, Yamamoto K, Nyby MD, Makino H, Tuck ML: *Uric acid stimulates vascular smooth muscle cell proliferation and oxidative stress via the vascular renin-angiotensin system. Journal of hypertension* 2008, *26(*2):269–275.

59.Strazzullo P, Puig JG: *Uric acid and oxidative stress: relative impact on cardiovascular risk? Nutrition, metabolism, and cardiovascular diseases: NMCD* 2007, *17(*6):409–414.

60.Glantzounis GK, Tsimoyiannis EC, Kappas AM, Galaris DA: *Uric acid and oxidative stress. Current pharmaceutical design* 2005, *11(*32):4145–4151.

# Tables

**Table 1 baseline of demographic variables of participants categorized by gender and**

blood pressure status in male and female(N=7119)

| Variables | Male(n=3345) | | $t/c^2$ | *P* | Female (n=3774) | | $t/c^2$ | *P* |
|---|---|---|---|---|---|---|---|---|
| | Normotension | Hypertension | | | Normotension | Hypertension | | |
| | (n=2267) | (n=1078) | | | (n=2492) | (n=1282) | | |
| Age(years) | 60.5±9.55 | 63.41±9.53 | -8.231 | 0.000 | 58.07±9.19 | 63.5±10.39 | -16.433 | 0.000 |
| Educational levels | | | | | | | | |
| Illiterate | 311(65.2) | 166(34.8) | 8.758 | 0.033 | 1025(60.51) | 669(39.49) | 45.920 | 0.000 |
| Less than elementary school | 1661(67.91) | 785(32.09) | | | 1267(69.54) | 555(30.46) | | |
| High school | 197(74.34) | 68(25.66) | | | 142(79.78) | 36(20.22) | | |
| Above vocational school | 98(62.42) | 59(37.58) | | | 58(72.5) | 22(27.5) | | |
| Marital status | | | | | | | | |
| Single | 194(56.73) | 148(43.27) | 21.288 | 0.000 | 345(53.41) | 301(46.59) | 55.387 | 0.000 |
| Married | 2073(69.03) | 930(30.97) | | | 2147(68.64) | 981(31.36) | | |
| Residence | | | | | | | | |
| Rural | 1553(69.77) | 673(30.23) | 12.108 | 0.001 | 1591(66.6) | 798(33.40) | 0.930 | 0.335 |
| Urban | 714(63.81) | 405(36.19) | | | 901(65.05) | 484(34.95) | | |
| Cigarette smoking | | | | | | | | |
| No | 1320(68.18) | 616(31.82) | 0.395 | 0.821 | 2292(66.36) | 1162(33.64) | 2.105 | 0.349 |
| Former smoke | 384(66.9) | 190(33.1) | | | 51(60.71) | 33(39.29) | | |
| Current smoke | 563(67.43) | 272(32.57) | | | 149(63.14) | 87(36.86) | | |
| Alcohol consumption | | | | | | | | |
| No | 1026(67.37) | 497(32.63) | 0.686 | 0.710 | 2172(65.44) | 1147(34.56) | 6.263 | 0.044 |
| Less than once a month | 239(69.68) | 104(30.32) | | | 135(74.18) | 47(25.82) | | |
| More than once a month | 1002(67.75) | 477(32.25) | | | 185(67.77) | 88(32.23) | | |
| Eating habit | | | | | | | | |
| ≤2 meals per day | 32(66.67) | 16(33.33) | 3.447 | 0.178 | 35(67.31) | 17(32.69) | 0.676 | 0.713 |
| 3 meals per day | 1945(68.39) | 899(31.61) | | | 2125(66.26) | 1082(33.74) | | |
| ≥4 meals per day | 290(64.02) | 163(35.98) | | | 332(64.47) | 183(35.53) | | |
| Social events | | | | | | | | |
| No | 1106(67.27) | 538(32.73) | 0.367 | 0.545 | 1250(66.35) | 634(33.65) | 0.169 | 0.681 |
| Yes | 1161(68.25) | 540(31.75) | | | 1242(65.71) | 648(34.29) | | |
| Accidental injury | | | | | | | | |
| No | 314(73.02) | 116(26.98) | 6.228 | 0.013 | 181(70.7) | 75(29.30) | 2.673 | 0.102 |
| Yes | 1953(67.00) | 962(33.00) | | | 2311(65.69) | 1207(34.31) | | |
| Physical exercises | | | | | | | | |
| No physical exercise | 435(65.81) | 226(34.19) | 1.471 | 0.479 | 1492(64.73) | 813(35.27) | 4.543 | 0.103 |
| Less than regular physical exercises | 417(68.47) | 192(31.53) | | | 483(67.74) | 230(32.26) | | |
| Regular physical exercises | 1415(68.19) | 660(31.81) | | | 517(68.39) | 239(31.61) | | |
| History of cardiovascular disease | | | | | | | | |
| No | 2065(68.97) | 929(31.03) | 14.634 | 0.000 | 2187(67.46) | 1055(32.54) | 13.740 | 0.000 |
| Yes | 206(58.69) | 145(41.31) | | | 314(59.02) | 218(40.98) | | |
| History of liver diseases | | | | | | | | |
| No | 2170(67.77) | 1032(32.23) | 0.914 | 0.339 | 2413(66.18) | 1233(33.82) | 2.532 | 0.112 |
| Yes | 102(71.33) | 41(28.67) | | | 93(72.66) | 35(27.34) | | |
| Antilipidemic therapy | | | | | | | | |
| No | 2174(68.13) | 1017(31.87) | 4.029 | 0.045 | 2388(67.14) | 1169(32.86) | 33.645 | 0.000 |
| Yes | 93(60.39) | 61(39.61) | | | 104(47.93) | 113(52.07) | | |
| Antidiabetic therapy | | | | | | | | |
| No | 2195(67.96) | 1035(32.04) | 1.454 | 0.228 | 2395(66.51) | 1206(33.49) | 8.021 | 0.005 |
| Yes | 72(62.61) | 43(37.39) | | | 97(56.07) | 76(43.93) | | |
| Anti-hypertensive therapy | | | | | | | | |
| No | 2187(69.49) | 960(30.51) | 72.177 | 0.000 | 2386(67.31) | 1159(32.69) | 42.364 | 0.000 |
| Yes | 80(40.4) | 118(59.6) | | | 106(46.29) | 123(53.71) | | |
| C-reactive protein (mg/l) | 5.21±0.68 | 5.29±0.85 | -2.966 | 0.003 | 5.27±0.81 | 5.37±0.95 | -3.648 | 0.000 |
| HbA1c(%) | 2.85±7.4 | 3.46±8.74 | -2.110 | 0.035 | 2.12±4.98 | 3.10±7.17 | -4.922 | 0.000 |
| Fasting plasma glucose (mg/dl) | 108.35±32.73 | 113.93±39.51 | -4.304 | 0.000 | 108.43±34.39 | 115.26±44.62 | -5.209 | 0.000 |
| Low density lipoprotein (mg/dl) | 111.23±33.92 | 115.58±35.82 | -3.408 | 0.001 | 119.98±33.79 | 122.7±38.35 | -2.239 | 0.025 |
| High density lipoprotein (mg/dl) | 51.22±16.17 | 50.19±16.35 | 1.719 | 0.086 | 52.2±14.16 | 50.15±14.4 | 4.205 | 0.000 |
| eGFR(ml/min/1.73m$^2$) | 84.26±17.04 | 79.00±18.48 | 8.122 | 0.000 | 87.63±17.01 | 80.39±18.51 | 12.016 | 0.000 |
| Body mass index(kg/m$^2$) | 22.52±3.64 | 23.65±3.69 | -8.372 | 0.000 | 23.59±3.89 | 24.67±4.5 | -7.653 | 0.000 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Systolic blood pressure(mmHg) | 119.73±11.55 | 155.77±22.4 | -61.346 | 0.000 | 118.93±11.82 | 159.23±31.47 | -56.586 | 0.000 |
| Diastolic blood pressure(mmHg) | 71.23±9.30 | 88.88±12.55 | -45.640 | 0.000 | 71.27±9.05 | 86.79±11.9 | -44.687 | 0.000 |
| Serum uric acid(mg/dl) | 4.87±1.24 | 5.20±1.33 | -7.077 | 0.000 | 3.93±1.04 | 4.24±1.16 | -8.407 | 0.000 |
| Triglycerides (mg/dl) | 120.58±100.65 | 133.51±111.81 | -3.349 | 0.001 | 129.26±82.88 | 154.49±112.79 | -7.798 | 0.000 |

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**Table 2 Age-adjusted relationship between baseline of demographic variables**

**and blood pressure status of participants categorized by gender (N=7119)**

| **Variables** | Male (n=3345) | | Female (n=3774) | |
|---|---|---|---|---|
| | Systolic blood pressure | Diastolic blood pressure | Systolic blood pressure | Diastolic blood pressure |
| | partial r(*P*-value) | partial r(*P*-value) | partial r(*P*-value) | partial r(*P*-value) |
| Educational levels | 0.003(0.873) | 0.028(0.113) | -0.029(0.077) | -0.022(0.180) |
| Marital status | 0.064(0.000) | 0.050(0.004) | 0.045(0.007) | 0.010(0.529) |
| Residence | 0.080(0.000) | 0.083(0.000) | 0.024(0.138) | 0.014(0.394) |
| Cigarette smoking | 0.009(0.590) | -0.028(0.107) | -0.007(0.656) | 0.003(0.858) |
| Alcohol consumption | 0.017(0.334) | 0.044(0.011) | -0.052(0.002) | -0.045(0.007) |
| Eating habit | -0.028(0.107) | -0.047(0.008) | -0.011(0.521) | -0.052(0.002) |
| Social events | -0.009(0.589) | -0.002(0.928) | 0.014(0.380) | 0.009(0.585) |
| Accidental injury | -0.041(0.019) | -0.043(0.013) | -0.026(0.115) | -0.008(0.627) |
| Physical exercises | 0.020(0.245) | 0.001(0.942) | -0.010(0.546) | 0.006(0.735) |
| History of cardiovascular disease | 0.050(0.005) | 0.064(0.000) | 0.039(0.018) | 0.039(0.019) |
| History of liver diseases | -0.014(0.409) | -0.009(0.622) | -0.020(0.235) | -0.039(0.019) |
| Antilipidemic therapy | 0.036(0.039) | 0.046(0.009) | 0.063(0.000) | 0.076(0.000) |
| Antidiabetic therapy | 0.049(0.005) | 0.023(0.187) | 0.073(0.000) | 0.033(0.047) |
| Anti-hypertensive therapy | 0.152(0.000) | 0.147(0.000) | 0.106(0.000) | 0.084(0.000) |
| C-reactive protein (mg/l) | 0.024(0.177) | 0.007(0.704) | 0.030(0.070) | 0.022(0.172) |
| HbA1c(%) | 0.064(0.000) | 0.070(0.000) | 0.048(0.004) | 0.073(0.000) |
| Fasting plasma glucose(mg/dl) | 0.093(0.000) | 0.078(0.000) | 0.040(0.015) | 0.082(0.000) |
| Low density lipoprotein (mg/dl) | 0.083(0.000) | 0.065(0.000) | 0.022(0.182) | 0.034(0.039) |
| High density lipoprotein (mg/dl) | -0.054(0.002) | -0.048(0.006) | -0.085(0.000) | -0.111(0.000) |
| eGFR(ml/min/1.73m$^2$) | -0.090(0.000) | -0.045(0.009) | -0.023(0.156) | -0.042(0.010) |
| Body mass index(kg/m$^2$) | 0.218(0.000) | 0.221(0.000) | 0.165(0.000) | 0.221(0.000) |
| **Serum uric acid(mg/dl)** | **0.122(0.000)** | **0.096(0.000)** | **0.084(0.000)** | **0.102(0.000)** |
| **Triglycerides (mg/dl)** | **0.111(0.000)** | **0.109(0.000)** | **0.103(0.000)** | **0.143(0.000)** |

**Table 3 Multivariate-adjusted relationship between baseline of demographic variables**

**and blood pressure status of participants categorized by gender (N=7119)**

| Variables | Male (n=3345) | | Female (n=3774) | |
|---|---|---|---|---|
| | Systolic blood pressure b(*P*-value) | Diastolic blood pressure b (*P*-value) | Systolic blood pressure b (*P*-value) | Diastolic blood pressure b (*P*-value) |
| Age(years) | 0.144(0.000) | -0.119(0.000) | 0.224(0.000) | -0.057(0.011) |
| Educational levels | — | — | -0.043(0.014) | -0.036(0.042) |
| Marital status | 0.081(0.000) | 0.070(0.000) | 0.058(0.001) | — |
| Residence | 0.049(0.004) | 0.052(0.003) | — | — |
| Cigarette smoking | 0.048(0.005) | — | — | — |
| Alcohol consumption | — | 0.047(0.008) | -0.036(0.023) | — |
| Eating habit | — | -0.055(0.001) | — | -0.064(0.000) |
| Social events | -0.034(0.041) | — | — | — |
| Accidental injury | -0.034(0.036) | -0.039(0.019) | — | — |
| Physical exercises | — | — | — | — |
| History of CVD | — | 0.034(0.047) | — | — |
| History of liver diseases | — | — | — | -0.039(0.015) |
| Antilipidemic therapy | — | — | — | 0.036(0.034) |
| Antidiabetic therapy | — | -0.043(0.021) | 0.050(0.004) | — |
| Anti-hypertensive therapy | 0.126(0.000) | 0.124(0.000) | 0.097(0.000) | 0.075(0.000) |
| C-reactive protein (mg/l) | — | — | — | — |
| HbA1c(%) | — | — | — | — |
| Fasting plasma glucose(mg/dl) | 0.052(0.017) | — | — | — |
| Low density lipoprotein (mg/dl) | 0.068(0.000) | 0.050(0.004) | — | — |
| High density lipoprotein (mg/dl) | — | — | — | — |

| | | | | |
|---|---|---|---|---|
| eGFR(ml/min/1.73m$^2$) | -0.091(0.000) | -0.048(0.035) | — | -0.045(0.043) |
| Body mass index(kg/m$^2$) | 0.193(0.000) | 0.194(0.000) | 0.129(0.000) | 0.193(0.000) |
| Serum uric acid(mg/dl) | **0.047(0.013)** | — | **0.040(0.028)** | — |
| Triglycerides (mg/dl) | **0.068(0.001)** | **0.064(0.002)** | **0.061(0.002)** | **0.084(0.000)** |
| $R^2$ | 0.132(0.000) | 0.106(0.000) | 0.120(0.000) | 0.081(0.000) |

**Table 4 Interaction between Triglycerides**

**and uric acid on blood pressure status in male and female (N=7119)**

| Characteristics | Male (n=3345) | | Female (n=3774) | |
|---|---|---|---|---|
| | Systolic blood pressure | Diastolic blood pressure | Systolic blood pressure | Diastolic blood pressure |
| | b(*P*-value) | b(*P*-value) | b(*P*-value) | b(*P*-value) |
| Age(years) | 0.350(0.000) | -0.159(0.000) | 0.692(0.000) | 0.711(0.000) |
| Educational levels | — | — | -1.694(0.013) | -1.740(0.012) |
| Marital status | 6.149(0.000) | 2.975(0.000) | 4.244(0.001) | — |
| Residence | 2.141(0.009) | 1.444(0.002) | — | — |
| Cigarette smoking | 1.432(0.002) | — | — | — |
| Alcohol consumption | — | 0.753(0.001) | -1.911(0.016) | — |
| Eating habit | — | -1.917(0.001) | — | -1.53(0.196) |
| Social events | -1.681(0.027) | | — | — |
| Accidental injury | -2.445(0.030) | -1.737(0.008) | — | — |
| Physical exercises | — | — | — | — |
| History of CVD | — | 1.508(0.039) | — | -3.082(0.198) |
| History of liver diseases | — | — | — | 4.841(0.011) |
| Antilipidemic therapy | — | — | — | |
| Antidiabetic therapy | — | -1.691(0.169) | 6.722(0.001) | 11.466(0.000) |
| Anti-hypertensive therapy | 12.729(0.000) | 7.142(0.000) | 11.542(0.000) | — |
| C-reactive protein | — | — | — | — |
| HbA1c(%) | — | — | — | — |
| Fasting plasma glucose(mg/dl) | 0.034(0.002) | — | — | — |
| Low density lipoprotein (mg/dl) | 0.042(0.000) | 0.019(0.003) | — | — |
| High density lipoprotein (mg/dl) | — | — | — | — |
| eGFR(ml/min/1.73m$^2$) | -0.131(0.000) | -0.032(0.041) | — | -0.040(0.200) |
| Body mass index(kg/m$^2$) | 1.176(0.000) | 0.686(0.000) | 0.975(0.000) | 0.984(0.000) |
| Serum uric acid(0= £7mg/dL in men and £6 mg/dL in women, 1= >7mg/dL in men and >6 mg/dL in women) | -2.252(0.353) | -1.723(0.223) | -2.424(0.391) | -1.907(0.508) |
| Triglycerides(0= <150mg/dL 1= 150mg/dL) | -1.695(0.571) | -0.560(0.748) | -2.387(0.535) | -2.272(0.558) |
| **Serum uric acid * Triglycerides** | **-1.090(0.726)** | **-1.026(0.572)** | **-0.692(0.861)** | **-0.794(0.842)** |

# Figures

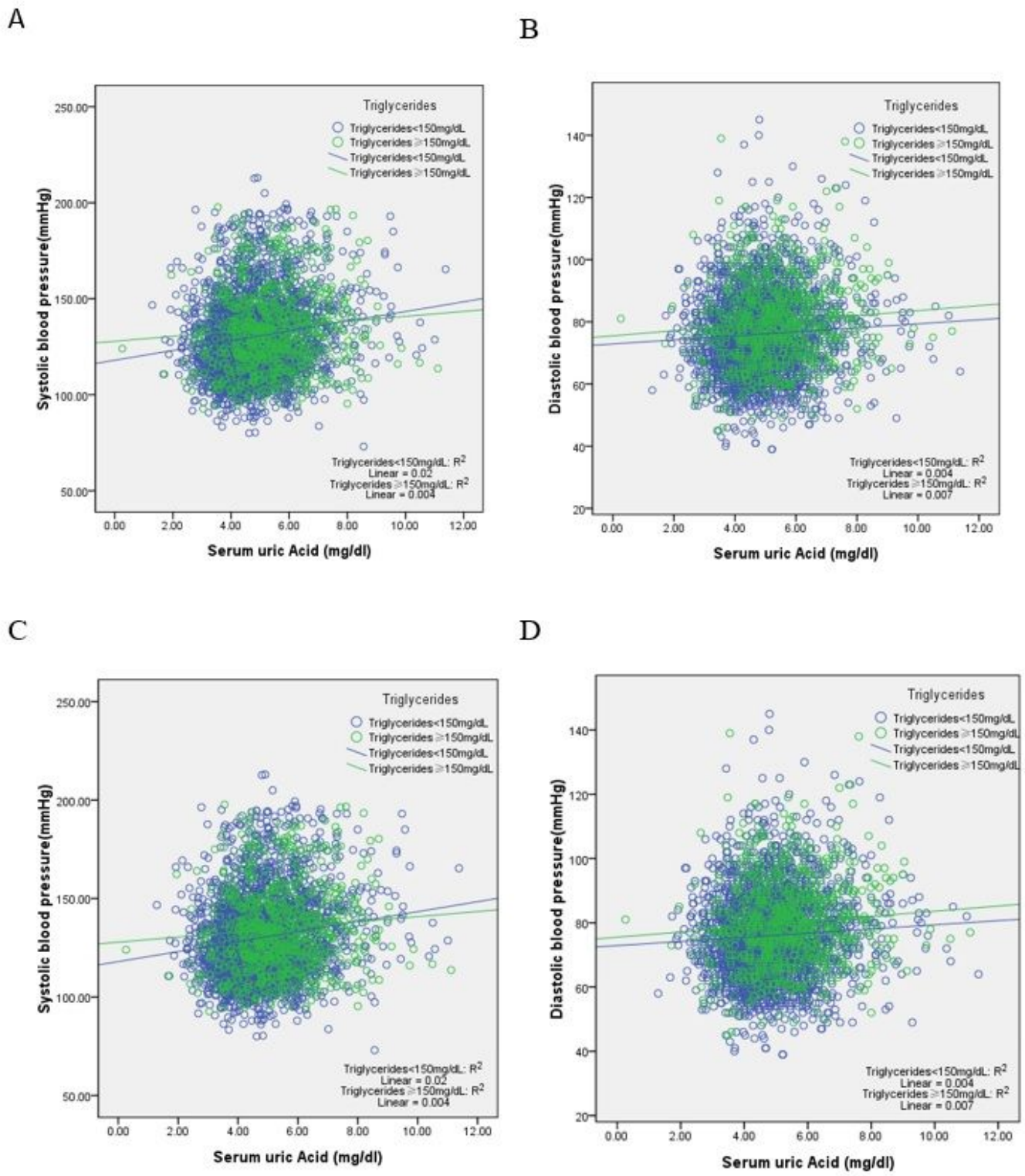


Figure 1

correlation between serum uric acid (SUA) and blood pressure (BP) of individuals categorized by triglycerides (TG) in male. C and D, correlation between serum uric acid (SUA) and blood pressure (BP) of individuals categorized by triglycerides(TG) in male.