Published in final edited form as:

J Hypertens. 2015 February ; 33(2): 275–278. doi:10.1097/HJH.0000000000000396.

Neck circumference and prehypertension: the cardiometabolic risk in Chinese study

Jun Liang^{a,*}, Yu Wang^{a,*}, Lianjun Dou^a, Hongyan Li^a, Xuekui Liu^a, Qinqin Qiu^b, and Lu Qi^{c,d}

^aDepartment of Endocrinology, Xuzhou Central Hospital, Xuzhou Clinical School of Xuzhou Medical College, Xuzhou Institute of Medical Sciences, Xuzhou Institute of Diabetes, Affiliated Hospital of Southeast University, Xuzhou, Jiangsu, China

^bXuzhou Medical College, Xuzhou, Jiangsu, China

^cDepartment of Nutrition, Harvard School of Public Health, Boston, Massachusetts, USA

^dChanning Laboratory, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts, USA

Abstract

Background—We have previously found that neck circumference was related to insulin resistance, a risk factor for hypertension in Chinese. Little is known about whether high neck circumference is associated with elevated blood pressure.

Method—The study samples were from a community-based health examination survey in central China. In total, 1709 men and women with neck circumference measurement were included. We analysed the associations between neck circumference and the risk of prehypertension.

Results—Although neck circumference was strongly associated with SBP/DBP in a univariate analysis, it was no longer associated with SBP and the association was much weaker with DBP when the association was adjusted for BMI or waist circumference. Similarly, high neck circumference was significantly related to an increased risk of prehypertension [odds ratio 1.254; 95% confidence interval (95% CI) 1.171–1.343] in a univariate analysis, and the association became marginal in models further adjusting for BMI or waist.

Conclusion—Our data suggest that neck circumference as predictor for prehypertension is not obvious given the moderate improvement of disease prediction.

Keywords

blood pressure; China; neck circumference; prehypertension

Correspondence to Dr Lu Qi, MD, PhD, Department of Nutrition, Harvard School of Public Health, 665 Huntington Ave, Boston, MA 02115, USA. Tel: +1 617 432 4116; fax: +1 617 432 2435; luqi@hsph.harvard.edu.

*Both Jun Liang and Yu Wang contributed equally to this work.

Conflicts of interest

There are no conflicts of interest.

INTRODUCTION

Several previous studies have shown that upper-body subcutaneous adipose tissue may confer additional risk for metabolic risk factors beyond overall and central adiposity [1]. Neck circumference as an index for upper-body subcutaneous adipose tissue distribution has been associated with cardiometabolic risk across various ethnicities in the general population [2–7]. In the Framingham Heart Study, including 2732 individuals, Preis *et al.* [6,8] found that neck circumference was positively associated with risks of type 2 diabetes, hypertension. Zhou *et al.* [3] found that neck circumference was significantly correlated with cardiometabolic risk factors including hypertension in adults of China.

In our previous analysis, we found that high neck circumference was related to insulin resistance, a risk factor for hypertension, in Chinese adults from the Cardiometabolic Risk in Chinese (CRC) Study. However, data on the association between neck circumference and prehypertension are limited, especially in Chinese adults.

In this study, we examined the associations between neck circumference and the risk of prehypertension in a large sample of Chinese population with normal range of blood pressure.

MATERIALS AND METHODS

Study population

In the CRC Study, we performed a community-based health examination survey for 6431 individuals (18–93 years) who were randomly selected from residents living in the urban area of Xuzhou, China, in 2009. The details of this study have been presented elsewhere [9–14]. For the present study, we included adult men and women (≥ 18 years) who were successfully measured for neck circumference, blood pressure and other metabolic markers (fasting glucose and lipids). We excluded the potential patients of hypertension (SBP ≥ 140 mmHg and DBP ≥ 90 mmHg), and individuals with goitre and other neck masses and deformity. In total, 1709 individuals were included in the final analyses. There was no significant difference in age and anthropometrics between individuals who were included and those who were not included in the analyses. The protocol and informed consent document were approved by the ethics committee of the Central Hospital of Xuzhou, China. Written consents were obtained from all the participants.

Assessment of blood pressure and prehypertension

Blood pressure was measured after the participant had rested for at least 5 min with a mercury manometer by doctors. The participant's arm was placed at heart level. Three measurements, 60 s apart, were taken. SBP was defined as the average of the three SBP readings. DBP was defined as the average of the three DBP readings. We defined prehypertension as SBP between 120 and 139 mmHg or DBP between 80 and 89 mmHg according to The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC-7) [15].

Anthropometric measures

Neck circumference (cm) was measured with head erect and eyes facing forward, horizontally at the upper margin of the laryngeal prominence with a flexible tape. Height and body weight were measured with participants standing without shoes and heavy outer garments. BMI was calculated as weight (in kilograms) divided by height (in metres) squared. Waist circumference (cm) was measured at the minimum abdominal girth to the nearest 0.1 cm. Hip circumference (cm) was measured at the level of maximal protrusion of the gluteal muscles.

Assessment of biomarkers

Venous blood sample was drawn from all individuals after an overnight fast (10 h). The blood was transferred into glass tubes and allowed to clot at room temperature. Immediately following clotting, serum was separated by centrifugation for 15 min at 3000 rpm. Fasting blood specimens were collected for measurement of glucose, total cholesterol (TC), triglyceride, high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C). All biochemical assays were determined by enzymatically on an autoanalyser (Type 7600; Hitachi Ltd, Tokyo, Japan).

Statistical analyses

General linear models were used to compare mean values of quantitative traits. Pearson correlations between neck circumference levels were calculated with cardiometabolic risk factors. Multivariable linear and logistic regression models were used to assess the significance of covariate-adjusted associations between neck circumference levels and blood pressure. The SAS statistical package was used for the analyses (SAS, Version 9.0; SAS Institute Inc., Cary, North Carolina, USA). Statistical significance was set at the 0.05 level. All *P* values are two-sided.

RESULTS

The average age of study population was 45.4 years and was represented by 59.0% of men. The average neck circumference were 36.2 ± 3.5 cm in the total sample, 37.9 ± 3.1 cm in men and 32.7 ± 2.3 cm in women. The prevalence of prehypertension in this study population was 18.6%. Compared with women, men had a higher BMI, waist circumference, neck circumference, SBP, DBP, fasting plasma glucose and triglyceride ($P < 0.001$), whereas women had a higher mean HDL-C level than men (Table 1). Table 2 summarizes the characteristics of the study participants according to neck circumference levels (in quintiles). Age, BMI, waist circumference, hip circumference, glucose, TC, triglyceride and LDL-C showed statistically significant differences between neck circumference groups, with an increasing trend as the level of neck circumference increased, except for HDL-C that showed a decreasing trend. Neck circumference was correlated with BMI, waist circumference, blood pressure, fasting glucose level, triglyceride level, but not with TC in the study samples (Table 3). Table 4 summarizes the multivariate linear regression analysis of neck circumference and blood pressure. Neck circumference was strongly associated with SBP/DBP in a univariate analysis. Neck circumference is not associated with SBP and the

association is much weaker with DBP when the association is adjusted for body BMI or waist circumference.

In addition, we analysed the associations between Neck circumference and the risk of prehypertension (Table 5). In a univariate analysis, the odds ratio (OR) (95% confidence interval, 95% CI) of prehypertension was 1.254 (1.171–1.343). Further adjusting for age, sex, waist circumference, OR was 1.095 (1.003–1.202). Further adjusting for age, sex, BMI, OR was 1.102 (1.007–1.201).

Discussion and perspectives

In a large cohort of apparently healthy Chinese adults, we found that high neck circumference levels were related to the risk of prehypertension, independent of sex, age, BMI or waist circumference. But neck circumference does not add much incremental information when BMI or waist circumference is known. Neck circumference as a predictor for prehypertension is not obvious given the moderate improvement of disease prediction.

Neck circumference is an index for upper body subcutaneous fat distribution. Several potential mechanisms underlying the association between neck circumference and blood pressure have been proposed. It has been shown that an elevated concentration of free fatty acid increases oxidative stress markers [16] and provokes vascular endothelial injury [17], and might play a role in the development of hypertension [18]. Upper-body subcutaneous fat has been demonstrated to be responsible for the majority of systemic free fatty acid release, particularly in obese individuals [19]. On the contrary, neck circumference is an important predictor of obstructive sleep apnoea (OSA) [20]. Fluid accumulated in the legs may suffer overnight rostral displacement to the peripharyngeal region. Increase in neck circumference has been associated with the severity of sleep-disordered breathing [21]. OSA is associated with hypertension with potential for fluid retention [22]. However, we failed to find any association between neck circumference and prehypertension in obese participants, indicating that some other mechanisms must exist in this complicated process.

Our findings are in line with several recent studies. Guo *et al.* [23] found that measurement of neck circumference might improve identification of prehypertension in normal weight children and adolescents beyond BMI. Kurtoglu *et al.* [24] found that neck circumference was associated with blood pressure in Turkey obese children. The inconsistency may be due to different races.

In our study, neck circumference did not add much incremental information when BMI or waist circumference was known. AS BMI and waist circumference (admittedly also anthropometric metrics easy to measure) are easily and routinely measured in clinical practice, the importance of measuring neck circumference is not obvious. BMI and waist circumference are widely used for obesity as recommended. But a recent research suggests that in the independent use of BMI, waist circumference may not be an effective tool to predict metabolic factors and related chronic diseases in Chinese adults [25]. And, there is an association between neck circumference and neck fat with visceral fat in Chinese adults [26]. Further investigations in prospective studies are warranted to verify the validity of measurement of waist circumference as a screening method for cardiovascular risk.

To our knowledge, the present study is among the first to assess the associations of waist circumference with prehypertension in Chinese adults. There are several limitations. Firstly, our results are based on a cross-sectional analysis, thus we could not define a causal relation between waist circumference and prehypertension. Secondly, we have carefully adjusted for the potential confounding in the analyses. However, in our study samples, information of dietary intake, and the lifestyle information is incomplete. Therefore, it is still possible that the residual confounding of these unmeasured variables might influence the associations. Thirdly, neck circumference is used to represent upper-body subcutaneous fat. We did not perform radiographic measures to quantify this depot of fat directly.

In summary, we demonstrated that high neck circumference levels were associated with an increased risk of prehypertension. The mechanism needs to be further explored in prospective research. The causality of the associations needs to be further confirmed in prospective studies. Neck circumference does not add much incremental information when BMI or waist circumference is known. Also, this is merely a preliminary study that warrants further research. The conclusion may be extended to wider populations with some confidence.

Acknowledgments

The authors would like to thank Ying Gong for excellent technical support and Cai Yan Zou for critically reviewing the manuscript.

L.Q.'s research was supported by NIH grants DK091718, HL071981, the American Heart Association Scientist Development Award and the Boston Obesity Nutrition Research Center (DK46200).

J.L.'s research was sponsored by Jiangsu Provincial Bureau of Health Foundation (H201356) & International Exchange Programme and Jiangsu Six Talent Peaks Programme (2013-WSN-013). It was also supported by the Xuzhou Outstanding Medical Academic Leader project and a Xuzhou Science and Technology Grant (XM13B066). We thank all individuals for participating in this study.

Abbreviations

HDL-C	high density lipoprotein cholesterol
LDL-C	low density lipoprotein cholesterol
TC	total cholesterol
WHR	waist-to-hip ratio

References

1. Grunfeld C, Rimland D, Gibert CL, Powderly WG, Sidney S, Shlipak MG, et al. Association of upper trunk and visceral adipose tissue volume with insulin resistance in control and HIV-infected subjects in the FRAM study. *J Acquir Immune Defic Syndr*. 2007; 46:283–290. [PubMed: 18167644]
2. Arnold TJ, Schweitzer A, Hoffman HJ, Onyewu C, Hurtado ME, Hoffman EP, et al. Neck and waist circumference biomarkers of cardiovascular risk in a cohort of predominantly African-American college students: a preliminary study. *J Acad Nutr Diet*. 2014; 114:107–116. [PubMed: 24051106]
3. Zhou JY, Ge H, Zhu MF, Wang LJ, Chen L, Tan YZ, et al. Neck circumference as an independent predictive contributor to cardio-metabolic syndrome. *Cardiovasc Diabetol*. 2013; 12:76. [PubMed: 23680280]

4. Stabe C, Vasques AC, Lima MM, Tambascia MA, Pareja JC, Yamanaka A, et al. Neck circumference as a simple tool for identifying the metabolic syndrome and insulin resistance: results from the Brazilian Metabolic Syndrome Study. *Clin Endocrinol*. 2013; 78:874–881.
5. Vallianou NG, Evangelopoulos AA, Bountziouka V, Vogiatzakis ED, Bonou MS, Barbetseas J, et al. Neck circumference is correlated with triglycerides and inversely related with HDL cholesterol beyond BMI and waist circumference. *Diabetes Metab Res Rev*. 2013; 29:90–97. [PubMed: 23135790]
6. Preis SR, Pencina MJ, D'Agostino RB Sr, Meigs JB, Vasan RS, Fox CS. Neck circumference and the development of cardiovascular disease risk factors in the Framingham Heart Study. *Diabetes Care*. 2013; 36:e3. [PubMed: 23264305]
7. Yan Q, Sun D, Li X, Zheng Q, Li L, Gu C, et al. Neck circumference is a valuable tool for identifying metabolic syndrome and obesity in Chinese elder subjects: a community-based study. *Diabetes Metab Res Rev*. 2014; 30:69–76. [PubMed: 23996612]
8. Preis SR, Massaro JM, Hoffmann U, D'Agostino RB Sr, Levy D, Robins SJ, et al. Neck circumference as a novel measure of cardiometabolic risk: the Framingham Heart study. *J Clin Endocrinol Metab*. 2010; 95:3701–3710. [PubMed: 20484490]
9. Liang J, Xue Y, Zou C, Zhang T, Song H, Qi L. Serum uric acid and prehypertension among Chinese adults. *J Hypertens*. 2009; 27:1761–1765. [PubMed: 19512942]
10. Teng F, Zhu R, Zou C, Xue Y, Yang M, Song H, et al. Interaction between serum uric acid and triglycerides in relation to blood pressure. *J Hum Hypertens*. 2011; 25:686–691. [PubMed: 21160529]
11. Liang J, Zhou N, Teng F, Zou C, Xue Y, Yang M, et al. Hemoglobin A1c levels and aortic arterial stiffness: the Cardiometabolic Risk in Chinese (CRC) study. *PLoS One*. 2012; 7:e38485. [PubMed: 22870185]
12. Liang J, Li Y, Zhou N, Teng F, Zhao J, Zou C, et al. Synergistic effects of serum uric acid and cardiometabolic risk factors on early stage atherosclerosis: the cardiometabolic risk in Chinese study. *PLoS One*. 2012; 7:e51101. [PubMed: 23284659]
13. Liang J, Teng F, Li Y, Liu X, Zou C, Wang Y, et al. Neck circumference and insulin resistance in Chinese adults: the cardiometabolic risk in Chinese (CRC) study. *Diabetes Care*. 2013; 36:e145–e146. [PubMed: 23970724]
14. Liang J, Wang Y, Li H, Liu X, Qiu Q, Qi L. Combination of diabetes risk factors and hepatic steatosis in Chinese: the Cardiometabolic Risk in Chinese (CRC) Study. *PLoS One*. 2014; 9:e90101. [PubMed: 24595017]
15. Wang Y, Wang QJ. The prevalence of prehypertension and hypertension among US adults according to the new joint national committee guidelines: new challenges of the old problem. *Arch Intern Med*. 2004; 164:2126–2134. [PubMed: 15505126]
16. Stojiljkovic MP, Lopes HF, Zhang D, Morrow JD, Goodfriend TL, Egan BM. Increasing plasma fatty acids elevates F2-isoprostanes in humans: implications for the cardiovascular risk factor cluster. *J Hypertens*. 2002; 20:1215–1221. [PubMed: 12023694]
17. Piro S, Spampinato D, Spadaro L, Oliveri CE, Purrello F, Rabuazzo AM. Direct apoptotic effects of free fatty acids on human endothelial cells. *Nutr Metab Cardiovasc Dis*. 2008; 18:96–104. [PubMed: 17560770]
18. Stojiljkovic MP, Zhang D, Lopes HF, Lee CG, Goodfriend TL, Egan BM. Hemodynamic effects of lipids in humans. *Am J Physiol Regul Integr Comp Physiol*. 2001; 280:R1674–R1679. [PubMed: 11353670]
19. Nielsen S, Guo Z, Johnson CM, Hensrud DD, Jensen MD. Splanchnic lipolysis in human obesity. *J Clin Invest*. 2004; 113:1582–1588. [PubMed: 15173884]
20. Young T, Shahar E, Nieto FJ, Redline S, Newman AB, Gottlieb DJ, et al. Predictors of sleep-disordered breathing in community-dwelling adults: the Sleep Heart Health Study. *Arch Intern Med*. 2002; 162:893–900. [PubMed: 11966340]
21. Redolfi S, Yumino D, Ruttanaumpawan P, Yau B, Su MC, Lam J, et al. Relationship between overnight rostral fluid shift and obstructive sleep apnea in nonobese men. *Am J Respir Crit Care Med*. 2009; 179:241–246. [PubMed: 19011149]

22. Grote L, Hedner J, Peter JH. Sleep-related breathing disorder is an independent risk factor for uncontrolled hypertension. *J Hypertens*. 2000; 18:679–685. [PubMed: 10872551]
23. Guo X, Li Y, Sun G, Yang Y, Zheng L, Zhang X, et al. Prehypertension in children and adolescents: association with body weight and neck circumference. *Intern Med*. 2012; 51:23–27. [PubMed: 22214619]
24. Kurtoglu S, Hatipoglu N, Mazicioglu MM, Kondolot M. Neck circumference as a novel parameter to determine metabolic risk factors in obese children. *Eur J Clin Invest*. 2012; 42:623–630. [PubMed: 22129208]
25. Gu JJ, Rafalson L, Zhao GM, Wu HY, Zhou Y, Jiang QW, et al. Anthropometric measurements for prediction of metabolic risk among Chinese adults in Pudong new area of Shanghai. *Exp Clin Endocrinol Diabetes*. 2011; 119:387–394. [PubMed: 21553364]
26. Li HX, Zhang F, Zhao D, Xin Z, Guo SQ, Wang SM, et al. Neck circumference as a measure of neck fat and abdominal visceral fat in Chinese adults. *BMC Public Health*. 2014; 14:311. [PubMed: 24708638]

TABLE 1

Clinical characteristics of the participants by sex

	Female	Male	<i>P</i>
<i>N</i>	701	1008	
Age (years)	44.17 ± 7.42	45.93 ± 9.22	<0.0001
BMI (kg/m ²)	22.93 ± 3.00	24.90 ± 2.84	<0.0001
WC (cm)	77.79 ± 8.35	88.95 ± 8.01	<0.0001
NC (cm)	32.66 ± 2.30	37.71 ± 2.49	<0.0001
SBP (mmHg)	114.27 ± 11.23	119.98 ± 9.93	<0.0001
DBP (mmHg)	72.07 ± 8.20	76.29 ± 7.16	<0.0001
Glucose (mmol/l)	4.89 ± 0.64	5.26 ± 1.24	<0.0001
TC (mmol/l)	4.97 ± 0.86	5.00 ± 0.87	0.58
TG (mmol/l)	1.16 ± 0.92	1.81 ± 1.60	<0.0001
HDL-C (mmol/l)	1.40 ± 0.31	1.17 ± 0.27	<0.0001
LDL-C (mmol/l)	2.94 ± 0.72	3.00 ± 0.76	0.11

The values are presented as mean ± standard deviation. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NC, neck circumference; TC, total cholesterol; WC, waist circumference.

TABLE 2

Characteristics of participants by neck circumference in quintiles

Variables	NC (in quintiles)					P for trend
	Q1 (women <31, men <36)	Q2 (women 31–32, men 36–37)	Q3 (women 32.1–33, men 37.1–38)	Q4 (women 33.1–34, men 38.1–40)	Q5 (women >34.1, men >40.1)	
N	546	305	285	340	233	
Age (years)	43.6 ± 13.4	43.6 ± 11.9	43.9 ± 10.9	45.7 ± 10.2	45.2 ± 9.5	0.004
BMI (kg/m ²)	22.2 ± 2.4	23.7 ± 2.3	24.7 ± 2.3	25.9 ± 2.5	27.5 ± 3.3	<0.0001
WC (cm)	79.3 ± 7.8	83.4 ± 7.4	86.2 ± 8.0	90.6 ± 7.9	94.6 ± 9.8	<0.0001
HC (cm)	93.0 ± 4.9	96.0 ± 4.3	97.8 ± 5.0	100.3 ± 5.0	103.9 ± 6.2	<0.0001
WHR, %	0.85 ± 0.6	0.87 ± 0.6	0.88 ± 0.7	0.90 ± 0.6	0.91 ± 0.7	<0.0001
Glucose (mmol/l)	5.2 ± 1.5	5.1 ± 0.9	5.3 ± 1.1	5.3 ± 1.1	5.5 ± 1.4	<0.0001
TC (mmol/l)	4.9 ± 0.9	5.1 ± 0.9	5.1 ± 0.9	5.1 ± 0.9	5.2 ± 1.0	<0.0001
TG (mmol/l)	1.4 ± 1.2	1.8 ± 1.9	1.8 ± 1.5	2.1 ± 1.7	2.3 ± 2.6	<0.0001
HDL-C (mmol/l)	1.3 ± 0.3	1.3 ± 0.3	1.2 ± 0.3	1.1 ± 0.3	1.1 ± 0.3	<0.0001
LDL-C (mmol/l)	2.9 ± 0.8	3.0 ± 0.8	3.0 ± 0.8	3.1 ± 0.8	3.1 ± 0.8	0.001

The values are presented as mean ± standard deviation. HC, hip circumference; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride; WC, waist circumference; WHR, waist/hip ratio.

TABLE 3

Partial correlation coefficients between neck circumference and cardiometabolic risk factors

	NC			
	Men		Women	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
BMI	0.665	<0.0001	0.612	<0.0001
WC	0.687	<0.0001	0.660	<0.0001
SBP	0.182	<0.0001	0.202	<0.0001
DBP	0.219	<0.0001	0.186	<0.0001
FBG	0.054	0.027	0.161	<0.0001
TC	0.063	0.028	0.071	0.120
TG	0.204	<0.0001	0.177	<0.0001

TC, total cholesterol; TG, triglyceride; WC, waist circumference.

TABLE 4
Multivariate linear regression analysis of continuous metabolic risk factors on blood pressure

	SBP				DBP			
	Beta	SE	95% CI	P	Beta	SE	95% CI	P
MODEL1	1.224	0.176	0.879 to 1.568	<0.001	1.058	0.127	0.809–1.306	<0.001
MODEL2	1.196	0.167	0.868 to 1.524	<0.001	1.047	0.122	0.807–1.288	<0.001
MODEL3	0.188	0.219	−0.242 to 0.618	0.391	0.371	0.161	0.055–0.687	0.021
MODEL4	0.044	0.208	−0.363 to 0.452	0.832	0.379	0.154	0.077–0.680	0.014

MODEL 1, unadjusted; MODEL 2, adjusted for sex, age; MODEL 3, adjusted for sex, age, WC; MODEL 4, adjusted for sex, age, BMI. CI, confidence interval.

TABLE 5

Association between neck circumference and prehypertension

Prehypertension					
	Beta	SE	wald	OR	95% CI
MODEL1	0.226	0.035	42.019	1.254	1.171~1.343
MODEL2	0.232	0.075	42.656	1.261	1.176~1.352
MODEL3	0.09	0.047	3.725	1.095	1.003~1.202
MODEL4	0.095	0.045	4.473	1.102	1.007~1.201

MODEL 1, unadjusted; MODEL 2, adjusted for sex, age; MODEL 3, adjusted for sex, age, WC; MODEL 4, adjusted for sex, age, BMI. CI, confidence interval; OR, odds ratio.