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Original Article

Neck circumference can be used as a valuable tool to screen the cardiovascular risk factors in Chinese elderly: a community based study

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Abstract: Objective: This study aimed to investigate the correlation between neck circumference and cardiovascular risk factors including diastolic blood pressure, systolic blood pressure, triglycerides, total cholesterol and fasting plasma glucose in Chinese elderly. Methods: 2074 individuals of the East China elderly population over 65 years old were analyzed. Anthropometric index, lifestyle and past history were recorded. The biomarkers of fasting plasma glucose, total cholesterol, triglyceride and total bilirubin were detected. Pearson's correlation analysis, and multiple linear regression analysis were used to evaluate the correlation between neck circumference and cardiovascular risk factors (diastolic blood pressure, systolic blood pressure, triglycerides, total cholesterol and fasting plasma glucose). Results: Neck circumference was correlated with the investigative cardiovascular risk factors (diastolic blood pressure, systolic blood pressure, triglycerides, fasting plasma glucose) ($P < 0.001$). After adjusting age and gender, multiple linear regression analysis showed that neck circumference was positively correlated with systolic blood pressure, diastolic blood pressure, fasting plasma glucose, and triglycerides ($P < 0.05$). After a further adjustment of smoking, drinking, physical exercise and lifestyle, there was still a significant difference in correlation between neck circumference and each relevant index ($P < 0.05$). Conclusion: We found that neck circumference was closely associated with cardiovascular risk factors including diastolic blood pressure, systolic blood pressure, triglycerides and fasting plasma glucose.

Keywords: Neck circumference, upper body obesity, cardiovascular metabolism, risk factors

Introduction

Overweight and obesity have become a worldwide epidemic, its prevalence sharply increased on a globe scale [1]. In 2002, in data of "China National Nutrition and Health Survey", overweight rate was 22.8% and obesity rate was 7.1% in China adult, compared with data 10 years ago, overweight rate increased by 39% and obesity rate increased by 97% in adult [2]. In 2007-2008, it was estimated that 34.2% of adults aged 20 years and over were overweight and 33.8% are obese in the United States, while in 2009-2010, the prevalence of obesity was 35.5% in adult male and 35.8% in adult female [3, 4]. Overweight and obesity are a serious threat to human health.

Overweight and obesity are closely related to the cardiovascular risk factors such as hypertension, diabetes, hyperlipidemia and other diseases [5]. Overweight and obesity are often accompanied by abnormal lipid metabolism and distribution, and the risk of cardiovascular events resulted by that has an important relationship with the different distribution of adipose tissue [6]. Even in populations with the same total fat, due to the different fat distribution in body, the risk of cardiovascular metabolic diseases happened in them is not the same, and visceral fatty obesity is closely related to risk factors of hypertension, diabetes, dyslipidemia and other cardiovascular diseases [7]. The prognosis of patients with visceral obesity is worse [8], and mortality is more obvious

Table 1. Demographic, lifestyle, anthropometric and clinical characteristics according to genders

Demographics	Females	Males	P
N	1109	965	
Age (years)	73.61±7.00	72.75±6.36	0.004
Lifestyle			
Current smoker n (%)	27 (2.43%)	215 (22.28%)	0.000
Alcohol use n (%)	17 (15.33%)	142 (14.72%)	0.000
Activity time (h/w)	5.254.27	5.914.71	0.001
Anthropometric			
Weight (kg)	57.14±9.84	65.73±10.30	0.000
Height (cm)	154.6±35.87	166.5±56.05	0.000
BMI (kg/m^2)	23.87±3.76	23.67±3.34	0.189
WC (cm)	85.3110.25	87.929.18	0.000
NC (cm)	34.35±2.75	37.81±2.81	0.000
NHtR	0.22±0.02	0.23±0.02	0.000
NWtR	0.61±0.08	0.59±0.07	0.000
Clinical			
History of diabetes n (%)	195 (17.58%)	149 (15.44%)	0.216
History of CHD n (%)	195 (17.58%)	144 (14.92%)	0.109
History of HBP n (%)	584 (52.66%)	476 (49.33%)	0.188
Systolic blood pressure (mmHg)	135.35±15.77	133.71±16.00	0.019
Diastolic blood pressure (mmHg)	77.29±8.53	78.58±8.90	0.001
TG (mmol/L)	1.63±0.92	1.46±0.91	0.000
TC (mmol/L)	5.76±1.02	5.22±0.97	0.000
FPG (mmol/L)	6.32±1.83	6.23±1.59	0.242
TBIL (μmol/L)	11.99±4.57	14.38±5.45	0.000

Notes: BMI: Body mass index; WC: Waist circumference; NC: Neck circumference; NHtR: Neck circumference-height ratio; NWtR: Neck circumference-weight ratio; CHD: Coronary heart disease; HBP: High blood pressure; TG: Triglyceride; TC: Total cholesterol; FPG: Fasting plasma glucose; TBIL: Total bilirubin. *P* values < 0.05 were considered significant.

[9]. Studies have shown that, in the Chinese population, neck circumference (NC) is closely correlated with abdominal visceral adipose tissue [10].

NC, a relatively new method to distinguish normal and abnormal fat distribution, is an important indicator to reflect the upper body subcutaneous fat [11]. In recent years, more and more studies show that upper body fat accumulation plays an important role in metabolic diseases [11, 12] and has a good correlation with multiple cardiovascular risk factors [13-15]. However, the current studies on the assessment of correlation between NC and metabolic risk factors either limit to the younger crowd [16, 17] or stretch across the entire age spectrum [12, 18, 19], there is still a lack of research about data analysis for exploring NC and cardiovascular risk factors in the elderly. Therefore, this study took the East China elderly population over 65 years old in community as study samples to investigate the correlation between NC and cardiovascular metabolic risk factors via cross-sectional analysis.

Materials and methods

Subjects

The cross-sectional study was conducted in 11 urban communities in Shanghai Pudong New Area from January 2012 to March 2012. The total number of people in survey was 2074 subjects (73.21±6.719 years, 46.4% men). Inclusion criteria was: the residents who lived in the communities for over 5 years, aged over 65 years old and were voluntary to join in; Exclusion criteria was: the residents who had thyromegaly had severe systemic diseases (such as liver and kidney dysfunction, cancer, heart failure, AIDS); were body builder or professional and amateur athletes. All participants signed informed consent. The study was approved by Institutional Review Board of No. 3 People Hospital Affiliated to Shanghai Jiaotong University School of Medicine, and complying with the Helsinki Declaration.

Clinical data collection

The standard questionnaire was used to collect age, gender, smoking, alcohol consumption, physical exercise time, previous hypertension, diabetes and the situation of coronary heart disease history. Current smoker were defined as persons who reported smoking every day or every few days and has been smoking at least 100 cigarettes in lifetime during investigation. Alcohol use was defined as that man drinks every day containing alcohol more than 20-30 g

Table 2. Clinical characteristics of Patients with coronary artery diseases

Variables	Without CHD (n=1735)	With CHD (n=339)	*P* value
Age	72.90±6.67	74.82±6.74	< 0.001
Current smoker n (%)	257 (14.81)	34 (10.03)	< 0.001
Alcohol use n (%)	286 (16.48)	44 (12.98)	< 0.001
Activity time (h/w)	5.65±4.56	5.07±4.08	0.031
Height (cm)	160.26±8.323	159.69±8.868	0.253
Weight (kg)	61.07±10.92	61.50±11.02	0.502
WC (cm)	86.36±9.86	87.41±9.79	0.072
NC (cm)	35.71±3.27	36.12±3.26	0.035
BMI (kg/m^2)	23.73±3.60	24.06±3.46	0.118
SBP (mmHg)	134.56±15.97	134.84±15.71	0.766
DBP (mmHg)	78.03±8.80	77.21±8.25	0.112
FPG (mmol/L)	6.25±1.66	6.41±1.99	0.126
TC (mmol/L)	5.53±1.01	5.38±1.11	0.014
TG (mmol/L)	1.54±0.90	1.63±0.98	0.071
TBIL (μmol/L)	13.03±5.01	13.76±5.11	0.015
History of HBP, n (%)	826 (47.6%)	226 (66.95)	< 0.001
History of DM, n (%)	276 (15.9%)	66 (19.5%)	0.061

Notes: WC: Waist circumference; NC: Neck circumference; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; TG: Triglyceride; TC: Total cholesterol; TBIL: Total bilirubin; HBP: High blood pressure; DM: Diabetes mellitus.

or women drinks every day containing alcohol more than 10-20 g. Hypertension referred to systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mmHg or a history of oral anti-hypertensive medication. Coronary artery disease (CHD) was defined as that coronary artery stenosis lumen narrows up to 50% which was determined by coronary angiography or a history of acute myocardial infarction. Dyslipidemia was defined as total cholesterol ≥ 5.2 mmoL/L or triglycerides ≥ 1.7 mmol/L. Abnormal glucose metabolism was defined as fasting plasma glucose ≥ 6.1 mmol/L, or a history of oral antidiabetic or insulin medication.

Anthropometry

It was required that subjects dressed in light clothes and without shoes when measuring height and weight. It was required to measure 2 times after 10 minutes when subjects sit quietly and to record the average value during measurement of blood pressure. The measurement of waist circumference (WC) was conducted at the lever midway between lower rib margin and crista iliac. When measuring NC, head is straight and eyes look forward, and horizontal measurement is conducted in the upper margin of the laryngeal prominence. Body mass index (BMI) was obtained by weight (kg) dividing by square of height (m).

Blood biochemical assays

Venous blood samples that were obtained after 12 hours overnight fast were used to measure fasting plasma glucose (FPG), triglycerides (TG), total cholesterol (TC) and total bilirubin (TBIL). Blood samples were stored at -80°C in low temperature refrigerator.

Statistical analysis

The Kolmogorov-Smimov test was applied to assess the assumption of normality for the data. Data were reported as mean ± standard deviation (SD) or median/interquartile range according to the normal distribution status, and the enumeration data was expressed as rate. Analysis of variance was used to compare the measurement data between multiple groups, and non-parametric test was used to compare the enumeration data. Pearson's correlation analysis was used to analyze the correlation between NC and continuous variables. Multiple linear regression analysis was used to evaluate the effect of increased NC on continuous variables of cardiovascular risk factors. A *P* value < 0.05 was considered statistically significant. SPSS 13.0 statistical package was used for all statistic analysis (SPSS Inc., Chicago, IL, USA).

Results

Baseline characteristics

The study sample comprised 2074 participants over 65 years old 965 (46.5%) men and 1109 women, with a mean age of 72.75±6.36 years for men and 73.61±7.0 years for women. Demographic, lifestyle, anthropometric and clinical characteristics of the study population were presented in **Table 1**. Incidence of history of hypertension was higher in populations with coronary artery disease than non-coronary artery disease. Among anthropomet-

Table 3. The bivariate correlation of anthropological and cardiovascular risk factors

	NC			
	Males		Females	
	r	P	r	P
Age	-0.084	0.009	-0.004	0.890
Height	0.236	< 0.001	0.161	< 0.001
Weight	0.734	< 0.001	0.711	< 0.001
BMI	0.695	< 0.001	0.700	< 0.001
WC	0.735	< 0.001	0.721	< 0.001
SBP	0.144	< 0.001	0.214	< 0.001
DBP	0.140	< 0.001	0.118	< 0.001
FPG	0.195	< 0.001	0.194	< 0.001
TC	0.028	0.382	-0.023	0.453
TG	0.248	< 0.001	0.234	< 0.001
TBIL	0.067	0.037	0.065	0.03

Notes: BMI: Body mass index; WC: Waist circumference; NC: Neck circumference; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; TG: Triglyceride; TC: Total cholesterol; TBIL: Total bilirubin; HBP: High blood pressure; DM: Diabetes mellitus. *P* values < 0.05 were considered significant.

ric indicators, there was significant difference of NC between two groups (**Table 2**).

Correlation of anthropometric indices and cardiovascular risk factors

Among these of anthropometric indices (NC, WC, BMI, NHtR, NWtR), NC was the only one that was positively associated with cardiovascular metabolic risk factors (TC, TG, FPG, TBIL, systolic blood pressure, diastolic blood pressure). Anthropometric indices such as WC, NC and NHtR were positively related with cardiovascular metabolic risk factors (TG, FPG, TC, systolic blood pressure, diastolic blood pressure), while NWtR was inversely correlated with these risk factors.BMI was positively correlated with TG, FPG, systolic blood pressure and diastolic blood pressure. WC and NHtR were positively correlated with TBIL. NWtR was negatively correlated with TBIL. The gender-adjusted NC was not significantly associated with TC. As well after adjusting gender, there was no correlation between WC, NHtR, NWtR and TBIL in the both. However, there was a correlation between BMI and FPG, TG, systolic blood pressure, diastolic blood pressure no matter in male group or female group (**Table 3**).

After adjusting age and gender, multiple linear regression analysis showed that NC was positively correlated with systolic blood pressure (b ± SE: 1.054±0.124, P < 0.0001), diastolic blood pressure (0.382±0.067, P < 0.0001), FPG (0.120±0.013, P < 0.0001) and TG (0.078±0.007, P < 0.0001), and there was no correlation only with TC. After adding smoking, drinking, physical exercise and lifestyle to model 1, the correlation between NC and each relevant index was unchanged (**Table 4**). Further taking the gender subgroup analysis, multiple linear regression analysis still showed that NC wasn't correlated with TC but positively correlated with systolic blood pressure, diastolic blood pressure, TPG, and TG no matter in male group or female group (data was not indicated in the table).

Discussion

In this cross-sectional study of 2,072 cases that came from China elderly population over 65 years old, we investigated the correlation between NC and cardiovascular risk factors. We found that NC was closely associated with cardiovascular metabolic risk factors (diastolic blood pressure, systolic blood pressure, triglycerides, total cholesterol and fasting plasma glucose) and correlated with total bilirubin no matter in male group and female group.

The effects of adipose tissue on cardiovascular system were different with fat distribution in the body (such as visceral fat, upper body subcutaneous fat and lower body subcutaneous fat), and different fat distribution could independently affect cardiovascular disease [20, 21]. As an indicator of upper body obesity, some recent studies showed that NC was a simple valuable tool to screen overweight or obesity [11, 12, 16, 18]. The degree of obesity showed a trend of increase with the aging [22, 23]. We used anthropometric indices (NC, WC and BMI) to explore the relationship between NC and cardiovascular metabolic risk factors in the elderly. The results showed that NC was correlated with diastolic blood pressure, systolic blood pressure, triglycerides, total cholesterol and fasting plasma glucose (P < 0.0001). After adjusting age, gender, smoking, drinking, physical exercise and lifestyle, multiple linear regression analysis showed that NC was positively correlated with FPG, TG, systolic blood

Table 4. Multiple linear regression analysis using each cardiovascular risk factor as the dependent variable

Dependent variable	Anthropometry index independent factor	Mean ± SE	P	Adjusted R2
SBP (mmHg)	NC	0.83±0.10	< 0.001	0.046
	WC	1.05±0.12	< 0.001	0.045
	BMI	0.30±0.04	< 0.001	0.046
DBP (mmHg)	NC	0.38±0.07	< 0.001	0.050
	WC	0.11±0.02	< 0.001	0.051
	BMI	0.34±0.05	< 0.001	0.054
FPG (mmol/L)	NC	0.12±0.01	< 0.001	0.036
	WC	0.04±0.01	< 0.001	0.039
	BMI	0.09±0.01	< 0.001	0.033
TC (mmol/L)	NC	0.00±0.01	0.921	0.074
	WC	0.01±0.01	0.380	0.074
	BMI	0.01±0.01	0.236	0.074
TG (mmol/L)	NC	0.08±0.01	< 0.001	0.076
	WC	0.02±0.01	< 0.001	0.072
	BMI	0.06±0.01	< 0.001	0.065
TBIL (μmol/L)	NC	0.02±0.01	0.039	0.061
	WC	0.12±0.04	0.002	0.063
	BMI	0.06±0.03	0.06	0.060

Notes: After adjusted for age, gender, smoking, drinking and activity time. WC: Waist circumference; NC: Neck circumference; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FPG: Fasting plasma glucose; TG: Triglyceride; TC: Total cholesterol; TBIL: Total bilirubin.

pressure and diastolic blood pressure ($P < 0.05$). In 2010, Preis et al. found in 3307 cases that after correcting the impact of visceral fat and BMI, NC was still associated with multiple cardiovascular risk factors [12], suggesting that NC was a new indicator of cardiovascular risk factors and correlated with multi-kinds of risk factors for cardiovascular disease [12, 14, 24]. As the only endogenous fat soluble antioxidant in the body, bilirubin has a powerful antioxidant and anti-inflammatory effect [25], studies have shown that there is a correlation between serum bilirubin concentration and Framingham risk score of cardiovascular disease [26]; serum bilirubin level is negatively correlated with metabolic syndrome, diabetes, hypertension etc. [27]. Our study found that NC was correlated with serum total bilirubin in the elderly. Our findings are consistent with the recent research findings, NC is correlated with cardiovascular disease [12, 13, 28, 29]. NC can independently lead to cardiovascular metabolic risk [12].

Mechanisms about the relationship between NC and cardiovascular risk are not yet clear. The study has been shown that free fatty acid released by upper body subcutaneous fat is the major source of abnormal free fatty acid metabolism, and the percentage of free fatty acids released by upper body subcutaneous fat into the blood is higher than that by visceral fat, especially in obese individuals [30, 31]. Upper body subcutaneous fat has a more important role on cardiovascular system and metabolism [32]. The excessive release of free fatty acid related to upper body subcutaneous fat may be a mechanism that can explain the correlation between NC and cardiovascular risk factors. Obesity and the elevated systemic free fatty acids are related to insulin resistance, the elevated very low density lipoprotein production, oxidative stress, vascular injury and hypertension [33-35]. The proposed mechanism includes the further abnormality of adipose tissue caused by the excessive release of harmful cytokines accompanying inflammatory cells and the decreased release of adipocytokines with protective effect.

Our study investigated the correlation between NC and cardiovascular risk factors in a large-scale, well-defined queue. After adjusting traditional factors, the results indicated that there was a correlation between NC and systolic blood pressure, diastolic blood pressure, FPG, TG and TBIL, confirming that NC was correlated with serum total bilirubin in the elderly. But there are still limitations in our research. Firstly, this study is a cross-sectional survey that can't clear the causal relationship. Secondly, since the samples in this study come from the China elderly population, the findings can't be deduced directly to other race or age groups. Furthermore, the derivation of single measurement data based on NC also has little effect on the accuracy of this study.

In conclusion, this study shows that NC may be an effective and powerful tool that can be used to identify cardiovascular risk factors in the China elderly population. Of course, it still needs cohort study to further explore the relationship between NC and cardiovascular risk factors.

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Disclosure of conflict of interest

None.

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