



Neck and Wrist Circumferences Propose a Reliable Approach to Qualify Obesity and Insulin Resistance

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Abstract

Objective of this study is to evaluate the association of neck circumference and wrist circumference with traditional abdominal and general obesity measurement parameters, insulin resistance, insulin resistance-related factors such as blood lipids, fasting glucose, insulin concentration and adiponectin, in order to predict their values as obesity measurement parameters. Eighty six female and 20 male subjects between 18-75 years of age were included in the study. Body weight, height, waist, hip, neck and wrist circumferences were measured. Body mass index and waist-to-hip ratio were calculated. Laboratory parameters such as fasting blood glucose, total cholesterol, triglyceride, high density lipoprotein cholesterol, insulin and adiponectin were measured after 12 hours of overnight fasting. Low density lipoprotein cholesterol and the insulin resistance index (HOMA-IR) were calculated. Neck circumference showed positive correlation with age, weight, body mass index, waist and hip circumferences, waist to hip ratio, wrist circumference, insulin, HOMA-IR and negative correlation with adiponectin and high density lipoprotein cholesterol in females and positive correlation with weight, body mass index, waist and hip circumferences, waist to hip ratio and negative correlation with adiponectin in males. Wrist circumference showed positive correlation with weight, body mass index, neck, waist and hip circumferences, waist to hip ratio, insulin, HOMA-IR and negative correlation with adiponectin, high density lipoprotein cholesterol in females. No correlation was found in male subjects. Neck circumference can be a reliable obesity and insulin resistance parameter in both genders. Wrist circumference requires further investigation for the classification of its' possible position in obesity evaluation.

Key words: Obesity, insulin resistance, adiponectin, neck circumference, wrist circumference

(Rec.Date: Jun 04, 2013

Accept Date: Jul 04, 2013)

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Introduction

Obesity is a growing public health problem worldwide defined as the state of excess adipose tissue mass. In clinical practice, obesity is commonly assessed by calculating body mass index (BMI) which is equal to weight in kilograms divided by height in meters squared. There are other methods of assessing obesity other than BMI such as measurement of weight, abdominal sagittal diameter, waist and hip circumferences (WaC, HC) and calculation of waist-to-hip ratio (WHR) [1]. It may not always be practical to perform these measurements, especially in everyday primary care practice. The first step for achieving obesity control is to develop a reliable, simple, cheap and quick method for the assessment of obesity in primary care clinics [2]. Neck circumference (NC) and wrist circumference (WrC) are recently defined non-traditional parameters of body fat distribution. It's known that, NC lower than 34 cm in females and 37 cm in males indicates healthy body weight. Some studies demonstrated that NC is an index of upper body fat distribution that can be used to identify obese patients [3-7]. In some studies, NC is also found to be related to cardiovascular risk factors in severely obese men and women [5]. WrC is another anthropometric parameter which can be used to calculate body frame which is calculated by height in cms divided by WrC in cms. Normal range of body frame for males is 38-43, and for females is 35-41 [8]. There are very few studies concerning WrC conducted on hyperlipidemic and/or hypertensive patients [9], but there is not enough data in the literature evaluating the eligibility of WrC as an obesity parameter.

Adipose tissue secretes a number of cytokines, one of them being adiponectin. Reduced secretion of adiponectin is found to be related with increased insulin resistance, obesity, diabetes, and atherosclerosis [10].

The aim of our present study is to evaluate the association of NC and WrC with traditional abdominal and general obesity measurement parameters, insulin resistance, insulin resistance-related factors such as blood lipids, fasting glucose, insulin concentration and adiponectin, in order to predict their values as obesity measurement parameters.

Materials and methods*1. Study design*

This was a prospective cross-sectional study carried out in Uludag University Medical Faculty outpatient clinics of Endocrinology and Metabolism and General Medicine between March and July 2009.

Consecutive subjects between 18-75 years of age, having no known diagnosis of a disease and/or usage of medication causing insulin resistance were chosen. For female subjects, the condition of being non-pregnant should be fulfilled to be enrolled in the study. A total of 136 subjects were screened and 106 subjects were found to be eligible to enter the study. Among them 86 were females, 20 were males. Informed consent was obtained from all participants, and the study was performed in accordance with the Declaration of Helsinki and with the approval of the local ethics committee.

2. Measurements

Body weight and height were measured in the fasting state in the morning and BMI was computed [1]. WaC was measured midway between the lower rib margin and the superior iliac spine at the end of gentle expiration and HC was measured at the maximal circumference in the gluteal area in standing position [11]. The WHR was calculated by the division of WaC to HC as an index of central obesity [12]. NC was measured at the level of the upper margin of the thyroid cartilage in subjects standing in upright position [11]. WrC was measured from both right and left wrists at the bony prominences of the radial and ulnar styloids [13] and an average was taken.

Baseline laboratory parameters were measured after 12 hours of overnight fasting. Fasting blood glucose (FBG), total cholesterol (T-chol), triglyceride (TG), high density lipoprotein cholesterol (HDL-chol) were determined using colorimetric and enzymatic methods on an Architect c16000 analyzer (Abbott, Illinois, USA). Low density lipoprotein cholesterol (LDL chol) was calculated by Freidewald Formula since all TG levels measured were below 400 mg/dL [14]. Insulin levels were measured using a Cobas e411 analyzer (Roche Diagnostics, Mannheim, Germany). Serum adiponectin levels were measured using a commercial radioimmunoassay kit (Millipore Corporation, Billerica, MA, USA) according to manufacturers' instruction. The intra- and interassay coefficients of variation (CV) were 6.2 % and 8.2 %, respectively.

The insulin resistance (IR) index was estimated from fasting serum insulin and glucose levels using the homeostasis model assessment (HOMA)-IR index {formula: [(fasting glucose (mg/dL) /18) x fasting insulin (μ IU m/L)] /22.5} [15]. In healthy subjects, mean HOMA-IR levels are below 2.7 [16].

3. Statistics

All statistical analysis was done with statistical package programme SPSS 16.0 software (SPSS Inc., Chicago, IL,USA). Normality of variables was tested with Shapiro-Wilk test. According to the distribution of the variables mean $\pm$ standard deviation or median with minimum-maximum values were given as descriptive statistics. In two independent group comparisons, Mann Whitney U test or independent sample t test was used. Correlations among the variables were evaluated by Pearson correlation analysis. Level of significance was determined as 0.05.

Results

A total of 86 female subjects and 20 male subjects entered the study. The mean age of all subjects was 41.2 ± 12 years, the mean BMI was 28.2 ± 7.6 kg/m² with a mean WaC of 91.8 ± 14.8 cm, HC of 108 ± 11.1 cm, WHR of 0.85 ± 0.09 , NC of 35.2 ± 3.8 cm, average WrC of 17 ± 2.1 cm. The demographic features of female and male subjects and their comparisons among genders are seen in Table 1. There were statistically significant differences among female and male genders concerning height, weight, NC, WaC, WHR and WrC.

Table 1. The demographic features of female and male subjects and their comparisons among genders.

Demographic Features	Female (n: 86)	Male (n: 20)	p value
Age (years)	41.2 ± 12.1	41.6 ± 11.7	NS
Height (cm)	160 (144-175)	170 (164-183)	<0.001
Weight (kg)	68.2 (42-198)	80 (61-112)	0.012
BMI (kg/m ²)	27.6 (17.9-82.6)	25.9 (20.6-39.6)	NS
NC (cm)	34.3 ± 3.5	38.9 ± 2.8	<0.001
WaC (cm)	90.5 (64-124)	97.5 (76-123)	0.026
HC (cm)	106.5 (84-136)	104.5 (93-126)	NS
WHR	0.83 ± 0.08	0.92 ± 0.09	<0.001
Avarage WrC (cm)	16.4 (13-22)	18 (14.6-27)	<0.001

BMI: body mass index, NC: neck circumference, WaC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, WrC: wrist circumference, NS: non-significant

The mean FBG of all subjects was 89.1 ± 10.3 mg/dL, insulin 9.45 ± 8.01 μ IU/mL, HOMA-IR 2.09 ± 1.7 , adiponectin 8.59 ± 6.4 μ g/mL, T-chol 195 ± 39 mg/dL, LDL-chol 120 ± 31 mg/dL, HDL-chol 48 ± 13 mg/dL, TG 128 ± 70 mg/dL, respectively. There was a statistically significant difference among genders for FBG and HDL-chol values but not for insulin, HOMA-IR, adiponectin, T-chol, LDL-chol and TG values (Table 2).

Table 2. The biochemical parameters of female and male subjects and their comparisons among genders.

Biochemical Parameters	Female (n: 86)	Male (n: 20)	p values
FBG (mg/dL)	88 (64-124)	83 (67-103)	0.016
Insulin (μ IU/mL)	7.85 (2-36.4)	7.68 (2-62.5)	NS
HOMA-IR	1.74 (0.36-11.14)	1.70 (0.39-10.34)	NS
Adiponectin (μ g/mL)	7.68 (1.04-38.2)	5.80 (1.12-36.51)	NS
T-chol (mg/dL)	192 (121-311)	201 (116-307)	NS
LDL-chol (mg/dL)	119 (57.2-200)	132 (51.2-231.8)	NS
HDL-chol (mg/dL)	48 (27-109)	42 (26-55)	0.014
TG (mg/dL)	107 (36-365)	131 (54-387)	NS

FBG: fasting blood glucose, HOMA-IR: homeostasis model assessment of insulin resistance, T-chol: total cholesterol, LDL-chol: low density lipoprotein cholesterol, HDL-chol: high density lipoprotein cholesterol, TG: triglyceride, NS: non-significant

When evaluated, NC showed statistically significant positive correlations with other obesity measurement parameters as BMI ($p < 0.001$, $r = 0.601$), WaC ($p < 0.001$, $r = 0.618$), HC ($p < 0.001$, $r = 0.646$), WHR ($p = 0.001$, $r = 0.364$), average of WrCs ($p < 0.001$, $r = 0.505$) in female subjects. The correlations of NC with demographic, glucose, lipid, insulin resistance parameters and adiponectin in female subjects are seen in Table 3. NC correlates positively with age, weight, insulin, HOMA-IR and negatively with adiponectin and HDL-chol in females (Table 3).

WrC also showed statistically significant positive correlations with other obesity measurement parameters as BMI ($p < 0.001$, $r = 0.371$), NC ($p < 0.001$, $r = 0.505$), WaC ($p < 0.001$, $r = 0.405$), HC ($p < 0.001$, $r = 0.423$), WHR ($p = 0.024$, $r = 0.243$) in female subjects. The correlations of WrC with demographic, glucose, lipid, insulin resistance parameters and adiponectin in female subjects are seen in Table 3. WrC correlates positively with weight, insulin, HOMA-IR and negatively with adiponectin and HDL-chol in females (Table 3).

Table 3. The correlations of anthropometric measurements with demographic, glucose, lipid, insulin resistance parameters and adiponectin in female subjects.

	NC	WrC	BMI	WaC	HC	WHR
<i>Age</i>	p= 0.024 r= 0.243	NS -	p= 0.018 r= 0.255	p= <0.001 r= 0.521	p= <0.001 r= 0.368	p= <0.001 r= 0.495
<i>Weight</i>	p= <0.001 r= 0.596	p= <0.001 r= 0.389	p= <0.001 r= 0.950	p= <0.001 r= 0.663	p= <0.001 r= 0.688	p= <0.001 r= 0.383
<i>FBG</i>	NS -	NS -	NS -	p= 0.009 r= 0.279	NS -	p= 0.002 r= 0.327
<i>Insulin</i>	p= 0.016 r= 0.260	p= 0.027 r= 0.239	NS -	p= 0.027 r= 0.239	NS -	NS -
<i>HOMA-IR</i>	p= 0.016 r= 0.260	p= 0.022 r= 0.247	NS -	p= 0.016 r= 0.259	NS -	p= 0.022 r= 0.247
<i>Adiponectin</i>	p= 0.039 r= -0.223	p= 0.014 r= -0.263	NS -	NS -	NS -	NS -
<i>T-chol</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>LDL-chol</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>HDL-chol</i>	p= 0.019 r= -0.252	p= 0.03 r= -0.234	NS -	p= 0.01 r= 0.275	p= 0.043 r= 0.219	p= 0.027 r= 0.238
<i>TG</i>	NS -	NS -	NS -	NS -	NS -	NS -

BMI: body mass index, NC: neck circumference, WaC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, WrC: wrist circumference, HOMA-IR: homeostasis model assessment of insulin resistance, FBG: fasting blood glucose, T-chol: total cholesterol, LDL-chol: low density lipoprotein cholesterol, HDL-chol: high density lipoprotein cholesterol, TG: triglyceride, NS: non-significant

In male subjects NC showed statistically significant positive correlations with other obesity measurement parameters except average WrC as BMI (p=0.002, r= 0.652), WaC (p<0.001, r= 0.720), HC (p=0.011, r= 0.554), WHR (p=0.023, r= 0.504). The correlations of NC with demographic, glucose, lipid, insulin resistance parameters and adiponectin in male subjects are seen in Table 4. NC correlates positively with weight only in males (Table 4).

WrC showed no correlation with other obesity measurement, demographic, glucose, lipid, insulin resistance parameters and adiponectin in male subjects as seen in Table 4.

Table 4. The correlations of anthropometric measurements with demographic, glucose, lipid, insulin resistance parameters and adiponectin in male subjects.

	NC	WrC	BMI	WaC	HC	WHR
<i>Age</i>	NS -	NS -	NS -	NS -	NS -	p= 0.021 r= 0.512
<i>Weight</i>	p= 0.003 r= 0.636	NS -	p= <0.001 r= 0.939	p= <0.001 r= 0.841	p= <0.001 r= 0.795	p= 0.035 r= 0.473
<i>FBG</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>Insulin</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>HOMA-IR</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>Adiponectin</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>T-chol</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>LDL-chol</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>HDL-chol</i>	NS -	NS -	NS -	NS -	NS -	NS -
<i>TG</i>	NS -	NS -	NS -	NS -	NS -	p= 0.008 r= 0.579

BMI: body mass index, NC: neck circumference, WaC: waist circumference, HC: hip circumference, WHR: waist-to-hip ratio, WrC: wrist circumference, HOMA-IR: homeostasis model assessment of insulin resistance, FBG: fasting blood glucose, T-chol: total cholesterol, LDL-chol: low density lipoprotein cholesterol, HDL-chol: high density lipoprotein cholesterol, TG: triglyceride, NS: non-significant

As an indicator of insulin resistance, HOMA-IR values showed statistically significant positive correlation with weight (p=0.035, r= 0.228), NC (p=0.016, r= 0.259), WaC (p=0.016, r= 0.259), WHR (p=0.022, r= 0.247), WrC (p=0.022, r= 0.247), FBG (p<0.001, r= 0.473), insulin (p<0.001, r= 0.972), TG (p<0.001, r= 0.385), and negative correlation with adiponectin (p=0.003, r= -0.312), and HDL-chol (p=0.013, r= -0.267) in female subjects, and positive correlation with weight (p= 0.025, r= 0.500) and insulin (p< 0.001, r= 0.991) in male subjects.

Adiponectin values showed statistically significant positive correlation with HDL- chol (p= 0.011, r= 0.272), and negative correlations with NC (p=0.039, r= -0.223), WrC (p=0.014, r= -0.263), insulin (p=0.002, r= -0.332), HOMA-IR (p=0.003, r= -0.312), T-chol (p=0.015, r= -0.261), LDL-chol (p=0.006, r= -0.297), and TG (p<0.001, r= -0.374) in female subjects and positive correlation with LDL-chol (p=0.008, r= 0.590) and negative correlation with NC (p=0.049, r= -0.435) in male subjects. Adiponectin showed negative correlation with NC in both genders.

Discussion

Our study indicated an important relationship between NC and other anthropometric measurements of obesity and adiponectin in both genders, and WrC and other anthropometric measurements of obesity and adiponectin in only female gender.

Some recent studies indicated that NC is an index of upper body fat distribution that can be used to identify overweight and obese patients [3-7]. In the last decade, a few studies have suggested that NC surpasses other antropometric measurements as a powerful marker of both visceral adipose tissue and IR [11, 17-19]. It's reported that, NC lower than 34 cm in females and 37 cm in males indicates healthy body weight. In a study conducted, NC ≥ 37 cm for men and ≥ 34 cm for women identified subjects with BMI ≥ 25.0 kg/m² with 98-99% sensitivity and 89-92% specificity for men and 99-100% sensitivity and 98-100% specificity for women, NC ≥ 39.5 cm for men and ≥ 36.5 cm for women identified subjects with BMI ≥ 30 kg/m² with 93-96% sensitivity and 90-95% specificity for men and 93-97% sensitivity and 98-99% specificity for women [2]. In our study, average of the NCs for female subjects was 34.3 ± 3.5 and for male subjects it was 38.9 ± 2.8 ($p < 0.001$). The medians of the BMI for females and males were 27 (18-82.7) and 25.7 (21-39), respectively. The same study also indicated that NC was associated with age, weight, WaC, HC, WHR and BMI for men and women, but not with HDL-chol [2]. In another study, a negative correlation between NC and HDL-chol was reported in severely obese adults [6]. A different study indicated correlations with NC and T-chol and LDL-chol levels in both men and women, and with triglyceride levels in men [20]. In our study, NC was positively correlated with age, weight, BMI, WaC, HC, WHR, average of WrCs, insulin, HOMA-IR, and negatively correlated with adiponectin, HDL-chol in females; and was positively correlated with weight, BMI, WaC, HC, WHR, and negatively correlated with adiponectin in male subjects. Our study showed compliance with the findings of other studies in the literature.

There are few studies about WrC in the literature. In a study, it was reported that when compared to normolipidemic hypertensive subjects, persons with familial dyslipidemia and hypertension had significantly increased WrC [21]. In another cross-sectional and 8.8 year follow up study including 6393 subjects (3677 females, 2716 males) without prevelant diabetes, WrC was found to be a significant predictor of diabetes and metabolic syndrome. In this study, the predictabilty of

WrC was found to be independent of BMI and WaC -that were the indicators of general and central obesity, respectively- in female subjects [22]. In a study conducted in 1709 (1323 females, 386 males) subjects who were the first degree relatives of diabetic patients, WrC was found to be positively associated with WaC, BMI, LDL-chol and negatively with HDL-chol [23]. In another study evaluating 477 overweight/obese children and adolescents with a mean age of 10.3 years, a positive relation was detected between WrC and insulin and HOMA-IR [24]. All of these new findings attracted attention to WrC as a possible risk factor for developing diabetes, metabolic syndrome and cardiovascular diseases. We found statistically significant positive correlations between WrC and weight, BMI, NC, WaC, HC, WHR, insulin, HOMA-IR, and negative correlations with adiponectin and HDL-chol only in female subjects. No correlation between WrC and the study parameters was found in male subjects in our study. The insufficient number of the male subjects might be the reason for this discordance. According to our study results, WrC seemed to be a useful obesity measurement parameter only for female subjects.

Significant positive association between IR and BMI was demonstrated in a study conducted with women from an obesity clinic [25]. Our study indicates positive correlations between HOMA-IR and weight, NC, WaC, WHR, average of WrCs, FBG, insulin, TG, but negative correlations between HOMA-IR and adiponectin, as well as HDL-chol in female subjects. Within the male subjects, we found positive correlations between HOMA-IR, and weight and insulin. In both genders, we didn't find any correlations between HOMA-IR and BMI and HC which are traditional obesity parameters. Instead, in our female subjects, HOMA-IR levels correlated with NC and WrC which are recently proposed parameters to estimate obesity and IR. In our opinion, both NC and WrC deserve serious attention as obesity measurement parameters in this aspect.

Many different studies in the literature demonstrated that serum adiponectin levels inversely correlated with IR both in nonobese and obese subjects [26-30]. We observed a similar negative correlation between adiponectin and HOMA-IR levels in our female participants. In our group there were 3 female subjects with a BMI > 40 kg/m² with demonstrative results. Their weight, height, BMI, HOMA-IR and adiponectin levels were as follows respectively: 1st subject 94 kg, 150 cm, 41.7 kg/m², 1.8, 12.9 µg/ml; second subject 104 kg, 155 cm, 43.2 kg/m², 4.7, 2.3 µg/ml and 3rd subject 198.5 kg, 155 cm, 82.6 kg/m², 2.9, 1.2 µg/ml. Although all three were seriously obese, the first subject without insulin resistance had the highest adiponectin level among them. On the other hand, we observed no correlation between adiponectin and HOMA-IR levels in male

participants. The situation in males could possibly be explained by the limited number of male subjects in our study. In a conducted study, the plasma levels of adiponectin correlated negatively with BMI, WaC, HC, WHR, fasting plasma insulin and TG, but positively correlated with HDL-chol levels [31]. In another study conducted, adiponectin was negatively correlated with measures of obesity, fasting insulin, HOMA-IR and TG and positively correlated with HDL-chol [25]. In our study, we found that the plasma adiponectin levels correlated negatively with NC, WrC, insulin, HOMA-IR, T-chol, LDL-chol, TG and positively with HDL-chol in female subjects. In males, there was a negative correlation between adiponectin and NC and positive correlation with LDL-chol. Actually, we would also expect to find negative correlations between adiponectin and traditional obesity parameters like weight, WaC, HC, WHR, BMI similar to other studies which was not the case. This fact might indicate that NC and WrC could be much more sensitive anthropometric parameters reflecting serum adiponectin levels.

Lower plasma levels of adiponectin relative to the normal controls were documented in subjects with obesity, type 2 diabetes, or coronary heart disease (CHD) in several studies [32-34]. Previously, it was reported that plasma adiponectin levels were higher in women than in men [33]. In view of the potential cardiovascular protective effects of adiponectin [32, 35-38], higher plasma adiponectin levels in women might in part explain the protective effects in female gender against CHD. Our findings were consistent with the reports in the literature on adiponectin. We found adiponectin levels of the female subjects to be higher than males that did not reach statistical significance ($p=0.06$).

As a conclusion, according to the results of our study, NC can be a reliable obesity and IR parameter in both genders with its' easier usage in daily clinical practice. WrC still requires further investigations for the classification of its' definite position in obesity evaluation with growing new data on its possible role predicting metabolic and cardiovascular diseases. Besides, negative correlation between NC and adiponectin in both genders, and WrC and adiponectin in females pointed out the fact that NC and WrC might give an idea about adiponectin level which is the best known adipocytokine of insulin sensitivity.

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