Original Research Communications

Cardiometabolic risk factors and obesity: does it matter whether BMI or waist circumference is the index of obesity?[1–3]

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ABSTRACT

Background: It has been suggested that the cardiometabolic risk associated with excess adiposity is particularly related to central obesity.

Objective: The objective was to compare the associations between cardiometabolic risk of apparently healthy individuals and measures of central obesity [waist circumference (WC)] and overall obesity [body mass index (BMI)].

Design: In this cross-sectional, observational study, 492 subjects (306 women and 303 non-Hispanic whites) were classified by BMI (in kg/m^2) as normal weight (BMI <25) or overweight/obese (BMI = 25.0–34.9) and as having an abnormal WC (≥80 cm in women and ≥94 cm in men) or a normal WC (<80 cm in women and <94 cm in men). Measurements were also made of the cardiometabolic risk factors age, systolic blood pressure (SBP), and fasting plasma glucose (FPG), triglyceride, and high-density lipoprotein (HDL)-cholesterol concentrations. Associations among cardiometabolic risk factors and BMI and WC were evaluated with Pearson correlations.

Results: There was a considerable overlap in the normal and abnormal categories of BMI and WC, and ~81% of the subjects had both an abnormal BMI and WC. In women, BMI and WC correlated with SBP (r = 0.30 and 0.19, respectively), FPG (r = 0.25 and 0.22, respectively), triglycerides (r = 0.17 and 0.20, respectively), and HDL cholesterol (r = −0.23 and −0.20, respectively) (P < 0.01 for all). In men, BMI and WC also correlated with SBP (r = 0.22 and 0.22, respectively), FPG (r = 0.22 and 0.25, respectively), triglycerides (r = 0.21 and 0.18, respectively), and HDL cholesterol (r = −0.20 and −0.13, respectively) [P < 0.05 for all, except for the association of WC with HDL cholesterol (P = 0.08)].

Conclusions: Most individuals with an abnormal BMI also have an abnormal WC. Both indexes of excess adiposity are positively associated with SBP, FPG, and triglycerides and inversely associated with HDL cholesterol. *Am J Clin Nutr* 2013;98:637–40.

INTRODUCTION

Although the relation between obesity and cardiometabolic risk is well recognized, controversy continues about how best to identify those overweight/obese individuals who are at greatest risk. More recently, emphasis (1) has been placed on abdominal obesity, as measured by waist circumference (WC)[4], as more reflective of such high-risk individuals than knowledge of BMI.

The superiority of using WC, rather than BMI, as an indicator of increased cardiometabolic risk is exemplified by its incorporation as 1 of the 5 criteria used to make a diagnosis of the metabolic syndrome (1). However, there is published evidence that the difference between abdominal obesity (WC) and overall obesity (BMI; in kg/m^2) in predicting cardiometabolic risk is somewhat overstated (2–4). Furthermore, the elements that comprise the determination of BMI, height and weight, are routinely measured in physician-patient encounters, whereas WC is rarely measured. The goal of this study was to estimate the association between cardiometabolic risk factors and obesity by using 2 different measures of obesity.

SUBJECTS AND METHODS

Study subjects

The experimental observations were collected from 306 women and 186 men, approximately two-thirds of whom were of European ancestry. Participants had responded to newspaper advertisements from 1999 to 2010 describing our studies of the relation among obesity, insulin resistance, and cardiometabolic disease. Volunteers had normal findings on medical history, physical examination, and laboratory tests and had a BMI between 20.0 and 34.9. Individuals with a diagnosis of diabetes or a fasting plasma glucose (FPG) concentration ≥126 mg/dL were excluded. Stanford University's Human Subjects Committee approved the study protocols, and subjects gave written informed consent.

Experimental measurements

Height and weight were determined while subjects were wearing light clothing and no shoes, and BMI was calculated by dividing

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[4] Abbreviations used: FPG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.

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weight (kg) by height (m)^2. Subjects with a BMI <25.0 were defined as normal weight and those with a BMI 25.0–34.9 as overweight/obese. WC was determined according to the NHANES III protocol during normal minimal respiration by placing a measuring tape around the waist just above the uppermost lateral border of the iliac crest (5). On the basis of the newly harmonized criteria for diagnosing the metabolic syndrome, women with a WC ≥80 cm and men with a WC ≥94 cm were classified as having an abnormal WC and women with a WC <80 cm and men with a WC <94 cm as having a normal WC (1). Blood pressure measurements were made with a Dinamap automatic blood pressure recorder (model 1846 SX), with an appropriate cuff size, while subjects sat quietly in a chair (6). Fasting lipid and lipoprotein concentrations were assayed in the core laboratory at Stanford University Medical Center by using standardized methods approved by the CDC; plasma glucose concentrations were measured as described previously (7, 8).

Statistical analysis

Summary statistics are presented as means ± SDs, means ± SEMs, or medians (IQRs). Linear associations of each cardiometabolic risk factor with BMI and WC were estimated with Pearson correlation coefficients, conducted separately for men and women because of possible sex differences in the association between cardiometabolic risk and obesity. Cardiometabolic risk factors—systolic blood pressure (SBP) and FPG, triglyceride, and HDL-cholesterol concentrations—were compared across the following 4 groups: *1*) normal BMI and normal WC (n = 44), *2*) normal BMI and abnormal WC (n = 26), *3*) abnormal BMI and normal WC (n = 22), and *4*) abnormal BMI and abnormal WC (n = 400). For each cardiometabolic risk factor, an omnibus 1-factor ANOVA was used to compare differences in group means. Follow-up pairwise comparisons were conducted by using least-significant difference tests. Triglyceride concentrations were log transformed to improve normality for parametric statistical tests. Statistical analyses were performed by using statistical software SPSS-IBM version 20.0.

RESULTS

The demographic and metabolic characteristic of all study participants (n = 492) are shown in **Table 1**. The mean (±SD) age of the participants was 50 ± 9 y. Most of the participants were women (62%) and of white non-Hispanic descent (61.6%) The average values for BMI and WC indicated that the study participants tended to be overweight/obese.

The considerable overlap in the normal and abnormal categories of BMI and WC among the 492 individuals is shown in **Table 2**. Of the 426 volunteers with abnormal WC, 400 (94%) were also overweight/obese as defined by BMI criteria. Similarly, of the 422 volunteers classified as overweight/obese by their BMI, 400 (95%) were classified as abnormal by WC. The overlap in the number of individuals classified as abnormal by both criteria was consistent with the observed linear correlation between BMI and WC (r = 0.75, $P < 0.001$).

The mean (±SEM) cardiometabolic risk factor profiles of individuals who had both a normal BMI and WC (n = 44), only an abnormal WC (n = 26), only an abnormal BMI (n = 22), or both an abnormal BMI and WC (n = 400) are shown in **Figure 1**. These data are relevant to 2 issues. First, they emphasize the degree of overlap of the 2 indexes: 48 individuals had only one abnormality (26 with only an abnormal WC and 22 with only an elevated BMI). Second, they indicate that individuals with both abnormal BMI and abnormal WC had a more adverse cardiometabolic profile ($P < 0.0001$) than did those with neither of the indexes being elevated. Individuals with only one abnormality (abnormal BMI) had a significantly higher mean SBP (P = 0.003) and triglyceride concentration (P = 0.001) and lower mean HDL-cholesterol concentration (P = 0.001) than did those with both normal BMI and WC. On the other hand, subjects with only abnormal WC did not have a significantly higher mean SBP (P = 0.36), FPG concentration (P = 0.25), or triglyceride concentration (P = 0.12) or lower mean HDL-cholesterol concentration (P = 0.67) compared with those with both a normal BMI and WC.

The relations between the 2 indexes of obesity (ie, BMI and WC) and cardiometabolic risk were estimated for women and men (**Table 3**). In women, statistically significant correlations were found between each measure of obesity and SBP, FPG, triglycerides, and HDL cholesterol. In men, the results were essentially similar to those seen in women. Specifically, both BMI and WC significantly correlated with SBP, FPG, and triglycerides. However, in this instance, BMI, but not WC, was significantly related to HDL cholesterol.

TABLE 1
Clinical and metabolic characteristics of the study volunteers[1]

Variable	Whole group (n = 492)	Women (n = 306)	Men (n = 186)
Age (y)	50 ± 9[2]	49 ± 9	51 ± 9
Non-Hispanic white (n)	303	176	127
BMI (kg/m^2)	28.5 ± 3.5	28.3 ± 3.5	28.8 ± 3.5
WC (cm)	96 ± 11	93 ± 11	101 ± 9
SBP (mm Hg)	122 ± 16	119 ± 16	127 ± 15
Triglycerides (mg/dL)	135 ± 119 107 (72, 162)[3]	117 ± 114 94 (69, 140)	165 ± 120 129 (90, 199)
HDL cholesterol (mg/dL)	48 ± 14	52 ± 13	40 ± 10
FPG (mg/dL)	96 ± 10	95 ± 10	98 ± 10

[1] FPG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.
[2] Mean ± SD (all such values).
[3] Median; IQR in parentheses (all such values).

DISCUSSION

It seems essential before beginning the discussion of the findings of this study to distinguish between the following 2

TABLE 2
Overlap among the individuals (n = 492) classified as normal or abnormal by BMI and WC[1]

	Normal WC (n = 66)	Abnormal WC (n = 426)
	n	n
Normal weight (n = 70)	44	26
Overweight/obese (n = 422)	22	400

[1] Individuals with a BMI (in kg/m^2) <25.0 were defined as normal weight and those with a BMI of 25.0–34.9 as overweight/obese. Women with a WC <80 cm and men with a WC <94 cm were classified as having a normal WC and women with a WC ≥80 cm and men with a WC ≥94 cm as having an abnormal WC. WC, waist circumference.

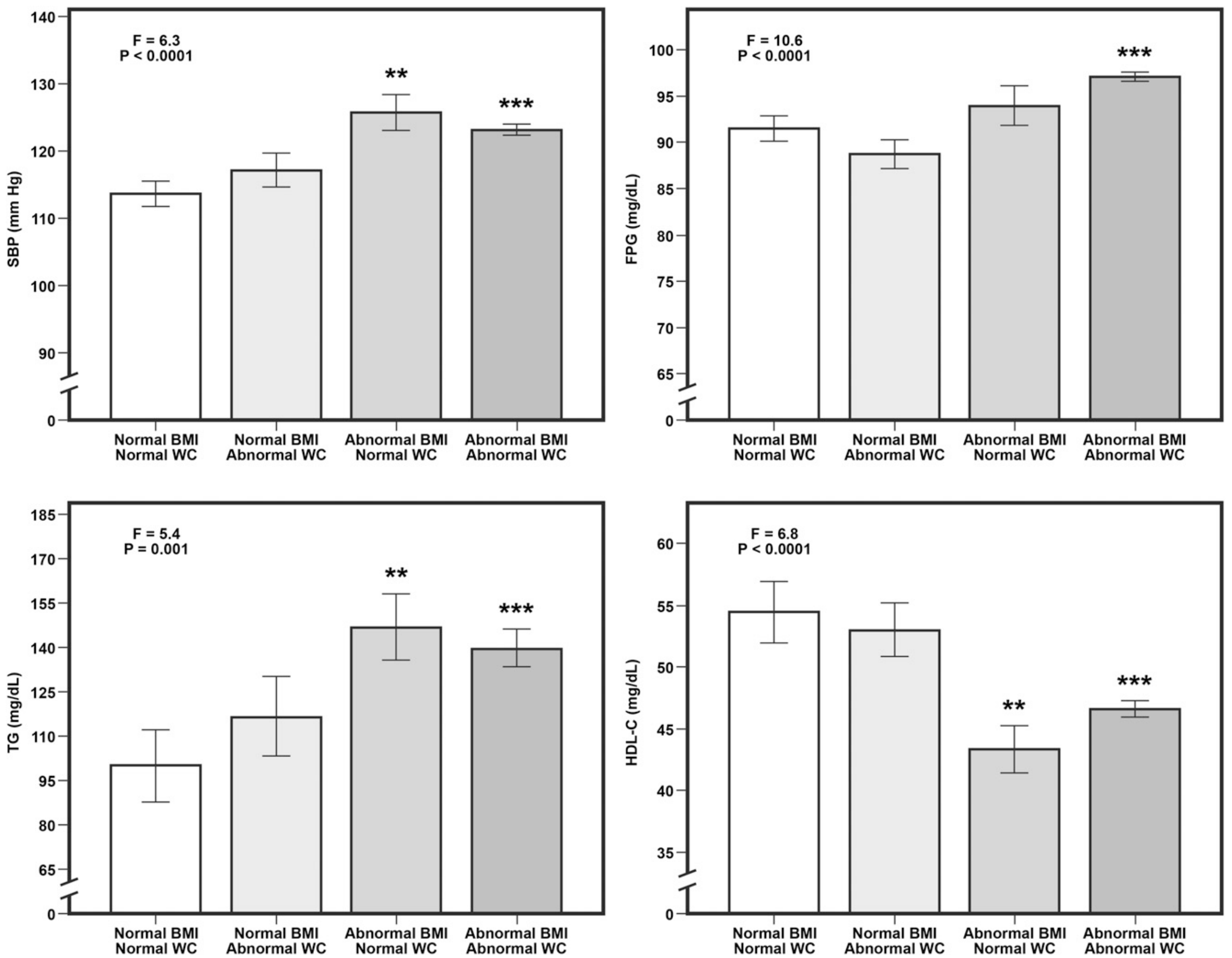

FIGURE 1. Mean (±SEM) values for cardiometabolic risk factors in individuals with normal BMI and normal WC (*n* = 44), normal BMI and abnormal WC (*n* = 26), abnormal BMI and normal WC (*n* = 22), and abnormal WC and abnormal BMI (*n* = 400). In each panel, the *F* statistic and the accompanying *P* value indicate the overall difference in means between the 4 groups (1-factor ANOVA). Significant differences in means between the groups: ***$P < 0.0001$ and **$P < 0.01$ for comparison with the normal BMI and normal WC group (least-significant difference pairwise comparison test). Normal BMI (in kg/m^2), <25.0; abnormal BMI, 25.0–34.9; normal WC, <80 cm (women) and <94 cm (men); and abnormal WC, ≥80 cm (women) and ≥94 cm (men). C, cholesterol; FPG, fasting plasma glucose; SBP, systolic blood pressure; TG, triglycerides; WC, waist circumference.

basically different, but related issues: *1*) why are overweight/obese individuals more likely to have the cardiometabolic risk factors associated with insulin resistance, and *2*) what index of obesity provides the most useful clinical information in identifying enhanced cardiometabolic risk in apparently healthy individuals. It is obvious that the focus of our study was on the second question.

If the clinical goal is to identify individuals at increased cardiometabolic risk associated with excess adiposity, it is obvious from Table 2 that there were essentially as many individuals

TABLE 3
Associations of cardiometabolic risk factors with BMI and WC in women and men[1]

	Women (*n* = 306)				Men (*n* = 186)			
	BMI		WC		BMI		WC	
Risk factor	*r*	*P* (2-tailed)	*r*	*P* (2-tailed)	*r*	*P* (2-tailed)	*r*	*P* (2-tailed)
Age	0.06	0.31	0.19	0.001	0.06	0.46	0.17	0.02
SBP	0.30	<0.001	0.19	0.001	0.22	0.003	0.22	0.003
FPG	0.25	<0.001	0.22	<0.001	0.22	0.003	0.25	0.001
Triglycerides	0.17	0.003	0.20	<0.001	0.21	0.005	0.18	0.02
HDL cholesterol	−0.23	<0.001	−0.20	0.001	−0.20	0.007	−0.13	0.08

[1] Triglyceride concentrations were log transformed for statistical tests. FPG, fasting plasma glucose; SBP, systolic blood pressure; WC, waist circumference.

identified as being overweight/obese (n = 422) as abdominally obese (n = 426). Furthermore, most (95%) of the overweight/obese subjects were abdominally obese, and basically the same proportion (94%) of abdominally obese individuals was overweight/obese. This enormous degree of overlap, by itself, suggests that either index of excess adiposity will identify the same persons.

More specific evidence for the notion that BMI and WC both identify individuals whose excess adiposity puts them at increased cardiometabolic risk is provided in Table 3. Thus, in women, statistically significant associations were observed between WC and all the variables measured, and BMI correlated with all variables except age. The results were somewhat different in men in that WC was not significantly related to HDL cholesterol.

On the basis of the results presented, it seems justified to extrapolate to the clinical situation by concluding that the cardiometabolic risk profile of individuals whose BMI defines them as being overweight/obese will not differ substantially from that of subjects identified as being abdominally obese because of their enlarged WC. On the other hand, it must be acknowledged that our findings are only relevant to the goal of identifying individuals at increased cardiometabolic risk and may not apply to the index of excess adiposity best able to predict clinical outcome. We do not have outcome data, but this issue has been addressed in other studies (9–12), which showed that the 2 indexes of excess adiposity did not differ in their ability to predict cardiovascular disease, type 2 diabetes, or excess mortality. Furthermore, perhaps of greater relevance, is evidence that obesity, per se, may not be the crucial issue. Thus, Ninomiya et al (13), using data from NHANES III, concluded that obesity, as estimated from WC, was not an independent predictor of myocardial infarction, whereas insulin resistance, hypertension, low HDL cholesterol, and hypertriglyceridemia were "independently and significantly related." Similarly, The Emerging Risk Factors Collaboration, based on prospective studies of 221,934 individuals from 17 countries (14), concluded that "BMI, waist circumference, and waist-to-hip ratio, whether assessed singly or in combination, do not importantly improve cardiovascular disease risk prediction in people in developed countries when additional information is available for systolic blood pressure, history of diabetes, and lipids." Consequently, it could be argued that the central clinical question should be how to best identify the subset of those individuals who are at increased risk of developing many adverse clinical syndromes because of excess adiposity. We suggest that our findings show that documenting the presence of abdominal obesity by measuring WC offers no clinical advantage over using BMI to accomplish that goal.

Although our findings are straightforward, our experimental protocol suffers from ≥2 drawbacks. As indicated previously, our findings are relevant to risk of disease, not disease outcome. Furthermore, 61.6% of our population was of European ancestry; the remainder consisting of South Asians (13.8%), East Asians (10%), Hispanics (8.9%), and African Americans (5.9%). Thus, our findings may not apply to these other groups. On the other hand, we addressed these issues in a large number of subjects with a broad evaluation of cardiometabolic risk factors.

In conclusion, a similar number of individuals at increased cardiometabolic risk because of excess adiposity will be identified by having a BMI ≥25.0 rather than because of satisfying current WC criteria for abdominal obesity (1), and the ensuing risk profile will be of comparable clinical utility. Therefore, clinicians could continue to use BMI, and not substitute it with WC, to identify overweight/obese individuals who are potentially at increased cardiometabolic risk.

The authors' responsibilities were as follows—FA: had full access to all of the data in the study, collected the data, and takes responsibility for the integrity of the data and the accuracy of the data analysis; FA and GMR: designed the study; FA and CB: analyzed the data; and FA, CB, and GMR: interpreted the results and wrote the manuscript. None of the authors had a potential conflict of interest.

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