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Comparing Trends in BMI and Waist Circumference

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The nature of excess body weight may be changing over time to one of greater central adiposity. The aim of this study is to determine whether BMI and waist circumference (WC) are increasing proportionately among population subgroups and the range of bodyweight, and to examine the public health implications of the findings. Our data are from two cross-sectional surveys (the US National Health and Nutrition Examination Studies (NHANES) in 1988–1994 (NHANES III) and 2005–2006), from which we have used samples of 15,349 and 4,176 participants aged ≥20 years. Between 1988–1994 and 2005–2006 BMI increased by an average of 1.8 kg/m^2 and WC by 4.7 cm (adjusted for sex, age, race-ethnicity, and education). The increase in WC was more than could be attributed simply to increases in BMI. This independent increase in WC (of on average, 0.9 cm) was consistent across the different BMI categories, sexes, education levels, and race-ethnicity groups. It occurred in younger but not older age groups. Overall in each BMI category, the prevalence of low-risk WC decreased and the prevalence of increased-risk or substantially increased-risk WC increased. These results suggest that the adverse health consequences associated with obesity may be increasingly underestimated by trends in BMI alone. Since WC is closely linked to adverse cardiovascular outcomes, it is important to know the prevailing trends in both of these parameters.

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The nature of excess body weight may be changing to one of greater central adiposity (1,2). However, it is unclear if this is consistent across population subgroups and body weights. As abdominal obesity appears more strongly correlated with cardiovascular risk than BMI (3,4) changes to greater abdominal obesity have important implications for the burden of obesity-related disease. Comparing recent trends in BMI and waist circumference (WC) will help to elucidate whether the nature of excess body weight is changing over time, and provide insight into whether BMI is capturing risk as well as generally accepted.

The aim of this study is to analyze the degree to which abdominal overweight is increasing beyond what would be expected from changes in BMI alone. In particular, we have studied these differential changes within population subgroups determined by age, sex, education, race-ethnicity, and body weight, and suggest possible public health implications of the findings. We analyzed changes in WC and BMI between 1988–1994 and 2005–2006 using comparable, nationally representative cross-sectional NHANES surveys of the United States.

METHODS

Samples

This study examined data from two cross-sectional surveys of the US population, the National Health and Nutrition Examination Studies (NHANES) (3), conducted from 1988 to 1994 (NHANES III) and 2005 to 2006. Participants were selected using a stratified cluster sampling design representative of the civilian, noninstitutionalized US population. After being interviewed in their homes, participants were invited for a clinical examination at a mobile examination centre, where anthropometric data were collected. Only participants with data from the mobile examination centre were included in the analysis. The household interview response rates and mobile examination centre response rates in the respective surveys were 86 and 78% in NHANES III (1988–1994) and 80 and 77% in 2005–2006. The sample design and weighting methodology was similar in both surveys and the studies included 31,311 and 9,950 individuals, respectively (3,4). We excluded participants with missing height, weight, WC, and education data, those aged <20 years, and pregnant women, leaving 15,349 and 4,176 records for analysis.

Measurement

WC was measured to the nearest 0.1 cm at the high point of the iliac crest at minimal respiration. Weight was measured on a self-zeroing weight scale (Toledo Scale; Toledo, Columbus, OH). Height was measured to the nearest millimeter (5).

WC cut-points classified people into "low risk" (men <94 cm; women <80 cm), "increased risk" (men ≥94–<102 cm; women ≥80–<88 cm), and "substantially increased risk" (men ≥102 cm; women ≥88 cm) (6). BMI was calculated as weight divided by height squared (kg/m^2). Standard cut-points applied to BMI scores classified people into underweight (<18.5 kg/m^2), normal weight (18.5–24.99 kg/m^2), overweight (25–29.99 kg/m^2), and obese (≥30 kg/m^2) (7).

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Other variables

In addition to BMI and WC, other variables included in this analysis are sex, age group, education, and race-ethnicity.

Analysis

We calculated the mean WC and BMI in each survey. Analyses were stratified by sex, age group, and race-ethnicity and analyzed in SAS (SAS version 9.1.3; SAS Institute, Cary, NC). Linear regression examined changes in the level of WC for a given level of BMI. The analysis accounted for the complex, multistage, cluster sampling design by using the Taylor expansion method to estimate sampling errors of estimators (8).

RESULTS

Mean age and sex were similar across the surveys, as were the response rates. Overall, the proportion of non-Hispanic whites increased and the proportion of non-Hispanic blacks and Mexican Americans decreased. The proportion completing high school increased.

Between 1988–1994 and 2005–2006, increases in both BMI and WC were observed. Mean BMI increased from 27.1 to 28.7 kg/m^2, and mean WC increased from 93.3 to 98.1 cm.

After adjusting for sex, age, race-ethnicity, and education, BMI increased between 1988–1994 and 2005–2006 by 1.8 kg/m^2 and WC by 4.7 cm. After additional adjustment for BMI, WC increased by 0.9 cm (95% confidence interval 0.5–1.2). After adjusting for WC, there was no significant change in BMI (−0.0 kg/m^2; 95% confidence interval −0.2 to 0.1).

There were independent increases in WC in all three BMI categories (Table 1). On average in 2005–2006 individuals in the normal-weight, overweight, and obese groups had WC 0.6, 0.8, and 1.0 cm larger than those in 1988–1994. There were similar independent WC increases in both sexes, education levels, and in the three most common race-ethnicity groups. Interactions with age group were statistically significant. There were independent increases in WC in those aged 20–49 years but not those aged 50+ years. The consequences of this was that on average in 2005–2006 individuals aged 20–29, 30–39, and 40–49 years has waists 1.8, 1.2, and 0.7 cm larger than their counterparts in 1988–1994.

Within each BMI category the proportion of higher-risk WC increased for males and females aged <50 years. In 1988–1994

Table 1 Changes in waist circumference independent of BMI between 1988–1994 and 2005–2006 using linear regression

	Change in WC (cm) (95% CI) over and above changes in BMI	Mean WC	
		1988–1994	2005–2006
Total population	0.86 (0.53–1.19)	93.33 (92.97–93.69)	98.08 (97.01–99.16)
BMI categories			
Normal-weight population (BMI 18.5–25 kg/m^2)	0.62 (0.25–0.98)[b]	81.71 (81.30–82.11)	83.25 (82.71–83.78)
Overweight population (BMI 25–30 kg/m^2)	0.75 (0.29–1.16)[b]	95.12 (94.78–95.46)	96.63 (96.00–97.25)
Obese population (BMI ≥30 kg/m^2)	0.95 (0.43–1.48)[b]	109.69 (109.32–110.06)	113.14 (112.19–114.10)
Age group[a]			
20–29	1.84 (1.38–2.30)[b]	85.30 (84.69–85.90)	91.35 (89.65–93.06)
30–39	1.24 (0.74–1.73)[b]	91.30 (90.57–92.04)	96.43 (94.89–97.97)
40–49	0.72 (0.15–1.28)[b]	95.27 (94.66–95.89)	99.19 (97.63–100.74)
50–59	−0.02 (−0.75 to 0.70)	97.79 (97.05–98.54)	100.60 (98.98–102.22)
60–69	−0.25 (−0.23 to 0.73)	98.89 (98.28–99.50)	102.75 (101.21–104.29)
70+	0.67 (−0.12 to 1.47)	96.00 (95.52–96.48)	99.37 (97.86–100.89)
Sex			
Males	0.79 (0.51–1.07)[b]	95.38 (94.95–95.81)	100.80 (99.48–102.12)
Females	0.72 (0.13–1.30)[b]	91.44 (90.92–91.96)	95.22 (94.08–96.35)
Education			
Did not complete high school	0.68 (0.18–1.17)[b]	95.20 (94.70–95.69)	98.64 (97.65–99.62)
Completed high school	0.92 (0.60–1.25)[b]	92.07 (91.65–92.50)	97.88 (96.66–99.10)
Race-ethnicity			
Non-Hispanic white	0.89 (0.33–1.45)[b]	93.69 (93.15–94.24)	98.48 (96.98–99.98)
Non-Hispanic black	0.50 (0.13–0.87)[b]	93.11 (92.50–93.71)	99.29 (98.17–100.42)
Mexican American	0.95 (0.52–1.39)[b]	93.53 (92.80–94.26)	97.18 (96.13–98.24)
Other race (including mixed race)	0.93 (−0.60 to 2.46)	87.11 (84.93–89.29)	92.91 (90.06–95.75)
Other Hispanic	0.88 (−0.07 to 1.82)	91.19 (90.13–92.26)	94.86 (92.60–97.13)

Adjustment for age, sex, race-ethnicity, education, and BMI.
CI, confidence interval; WC, waist circumference.
[a]Changes differ significantly by age group. [b]Significant increase in WC independent of BMI.

of those aged <50 years in the normal-weight BMI category, 3.0% of men and 29.5% of women had an increased-risk or substantially increased-risk WC, but in 2005–2006 this had increased to 5.9 and 43.0%, respectively. Similarly, whereas in 1988–1994 the proportion of nonobese (BMI < 30) males and females aged <50 years with substantially-increased-risk WC was 5.1 and 25.2%, by 2005–2006 this had increased to 11.5 and 33.4%, respectively. The proportion of obese males and females aged <50 years without a substantially-increased-risk WC decreased from 11.6 and 1.9% in 1988–1994 to 6.9 and 0.6% in 2005, respectively.

DISCUSSION

Between 1988–1994 and 2005–2006 there was an independent average increase of 0.9 cm in the WC of American adults over and above that for BMI. This independent increase occurred in all BMI categories, in both sexes, education levels and in the three most common race-ethnicity groups. However, it occurred in younger but not older people.

The consequence of these differential changes in weight and WC was that within each of the normal-weight, overweight, and obese BMI categories the proportion of those with higher-risk WC increased for males and females aged <50 years. The apparent greater association of WC than BMI with metabolic risk (3,4) may mean that overall in each BMI category, the prevalence of having a low-risk WC decreased and the prevalence of an increased-risk or substantially increased-risk WC increased. These changes affected the normal-weight category as well as the overweight and obese BMI categories.

Our findings are consistent with a number of studies that have suggested an independent increase in WC over and above that for BMI (1,9–12). However, some of these studies are based on differences in the percentage change in BMI and WC, which does not inform whether one indicator has moved independently further than the other, due to the nature of the relationship between BMI and WC. In our analysis, while there was a marginally greater percentage change in BMI (5.9%) than WC (5.1%), we demonstrated that increases in WC were greater than expected based on increases in BMI. Elobeid *et al*. conducted the only study to specifically look at increases in WC independent of increases in BMI (1). The strengths of our study are that we looked at the increase in WC independent of increases in BMI over a range of demographic groups, and that we quantified these absolute changes in WC.

There were no differences in sampling design between the surveys and the survey response rates were similar, reducing the impact of bias from these sources. The discrepancy between the total sample size and the number of participants for whom data were analyzed—due to participants missing height, weight, WC, and/or education variables—is likely to incur bias. Nonresponse has been associated with having a higher body weight and lower socioeconomic status (also associated with a higher body weight in high-income countries) (13,14). However, it is unlikely that this bias would affect the key finding of this paper of an independent increase of WC over and above the increase in BMI. That the mean WC values are close to the cut-points for abdominal obesity could explain why a small increase in WC could lead to a large increase in the prevalence of increased risk WC (9). However, this appears not to be the case in this study as we have used linear regression to explore the continuous changes in WC over and above BMI.

Changing ethnic makeup may explain the changes in body fat distribution; however, we obtained similar results after stratifying by race-ethnicity. Other possible contributors include declining physical activity levels, sleep deprivation, stress, endocrine disruptors, and certain pharmaceuticals (15).

The changes occurred for all races, education levels, sexes, and body weights, including in people considered "normal weight." The nature of the changes suggest that using solely BMI to monitor the impact of increasing weight status in the population may lead to an underestimation of the associated health burden. That the independent increase in WC has been shown in people aged <50 years but not older age groups suggests that the changes in our environment have impacted more on younger adults, or that they are the result of more recent environmental changes.

The findings suggest that within each BMI category the mean WC has increased. To date these independent changes have been restricted to younger people. Considering the association between WC and the level of metabolic risk, the sole use of BMI to monitor the impact of increasing population weight may lead to an underestimation of the obesity-related health burden.

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DISCLOSURE

The authors declared no conflict of interest.

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