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Original Contribution

Waist Circumference and Mortality

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The authors examined the association between waist circumference and mortality among 154,776 men and 90,757 women aged 51–72 years at baseline (1996–1997) in the NIH-AARP Diet and Health Study. Additionally, the combined effects of waist circumference and body mass index (BMI; weight (kg)/height (m)^2) were examined. All-cause mortality was assessed over 9 years of follow-up (1996–2005). After adjustment for BMI and other covariates, a large waist circumference (fifth quintile vs. second) was associated with an approximately 25% increased mortality risk (men: hazard ratio (HR) = 1.22, 95% confidence interval (CI): 1.15, 1.29; women: HR = 1.28, 95% CI: 1.16, 1.41). The waist circumference-mortality association was found in persons with and without prevalent disease, in smokers and nonsmokers, and across different racial/ethnic groups (non-Hispanic Whites, non-Hispanic Blacks, Hispanics, and Asians). Compared with subjects with a combination of normal BMI (18.5–<25) and normal waist circumference, those in the normal-BMI group with a large waist circumference (men: ≥102 cm; women: ≥88 cm) had an approximately 20% higher mortality risk (men: HR = 1.23, 95% CI: 1.08, 1.39; women: HR = 1.22, 95% CI: 1.09, 1.36). The finding that persons with a normal BMI but a large waist circumference had a higher mortality risk in this study suggests that increased waist circumference should be considered a risk factor for mortality, in addition to BMI.

abdominal fat; adiposity; body composition; body fat distribution; body mass index; mortality

Abbreviations: BMI, body mass index; CI, confidence interval; HR, hazard ratio.

Obesity and overweight have been associated with increased risk of diseases such as diabetes, heart disease, arthritis, and cancer (1–3). The association between body weight and mortality remains controversial. In most previous studies, investigators have reported an increased risk of mortality among very lean and obese persons (4–6), but not all have found an increased risk of mortality among overweight persons (6).

Most previous investigations of body weight and mortality have used body mass index (BMI) as the measure of adiposity. Fat distribution, however, may be more important than total body fat. In particular, increased visceral or abdominal fat is positively associated with metabolic disease risk (7, 8) independent of overall adiposity (9–11). Waist circumference is strongly related to visceral fat depot and is therefore a measure of abdominal obesity (12, 13). However, the association between waist circumference and mortality has not been studied extensively, and results have been inconsistent (14–20). In most previous studies, researchers took into account BMI but did not evaluate the combined effects of waist circumference and BMI on mortality. Additionally, studies examining the association within specific racial/ethnic groups are lacking.

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In this study, we examined the association between waist circumference and all-cause mortality in the NIH-AARP (National Institutes of Health–American Association of Retired Persons) Diet and Health Study. The relation of waist circumference to mortality was assessed according to smoking status, disease status, and racial/ethnic group. Additionally, the combined associations between waist circumference and BMI and the risk of mortality were examined.

MATERIALS AND METHODS

Study population

The NIH-AARP Diet and Health Study began in 1995–1996 when an extensive baseline questionnaire was mailed to members of the American Association of Retired Persons aged 50–71 years who resided in one of six US states (California, Florida, Louisiana, New Jersey, North Carolina, and Pennsylvania) or one of two US metropolitan areas (Atlanta, Georgia, and Detroit, Michigan) (21). A total of 567,169 baseline questionnaires were satisfactorily completed (response rate, 16.2 percent). In 1996–1997, a second questionnaire was sent to participants who successfully completed the baseline questionnaire for collection of additional information on diet, family history of cancer, anthropometric measures (including waist circumference), physical activity, and use of menopausal hormone therapy. A total of 337,076 respondents completed the second questionnaire, the return of which represented the start of follow-up in the current study.

The records of 2,166 persons were excluded because they died or moved out of the study area before the second questionnaire was scanned. We also excluded 83,860 persons who provided no data on waist circumference, those with a waist circumference less than 60 cm ($n = 549$), those with missing data on height or weight ($n = 4,425$), and those with a BMI less than 15 ($n = 471$) or higher than 60 ($n = 72$); this resulted in a total of 245,533 participants for the present analysis. The NIH-AARP Study was approved by the Special Studies Institutional Review Board of the National Cancer Institute. Completion of the self-administered baseline questionnaire was considered to imply informed consent.

Measures

Mortality. From 1996–1997 through December 31, 2005, vital status was determined by annual linkage of the cohort to the Social Security Administration Death Master File, a file that contains data on all deaths in the United States (22). For matching purposes, virtually complete data on first and last name, address history, sex, and date of birth were available. For participants who were matched to the Social Security Administration Death Master File, follow-up searches of the National Death Index were performed. Follow-up for deaths in our cohort was more than 95 percent complete.

Waist circumference. Using a pictured instruction, participants were requested to measure their waist with a tape measure 1 inch (2.5 cm) above the navel while standing and to report values to the nearest quarter inch (0.6 cm). Inches were converted into centimeters. Previous studies have used self-measured waist circumference (14, 23). Self-reported waist circumference has been found to be a valid approximation of measured waist circumference. In a study carried out among 123 men aged 40–75 years and 140 women aged 41–65 years, Rimm et al. (24) reported crude Pearson correlation coefficients comparing self-reported and measured waist circumferences of 0.95 for men and 0.89 for women.

Sex-specific quintiles of waist circumference were created, and the second quintile was used as the reference group (18). In a separate analysis, a large waist circumference was classified according to cutpoints of $\geq$102 cm for men and $\geq$88 cm for women as recommended by the World Health Organization (25).

Covariates. Information on covariates was collected using a self-administered, mailed questionnaire. Sociodemographic factors included age and racial/ethnic group (non-Hispanic White, non-Hispanic Black, Hispanic, Asian, and Pacific Islander or American Indian). Categories of educational level were 11 years or less, 12 years or high school completion, post-high school education or some college, and college graduation or postgraduate education. Smoking status was categorized as never smoker, former smoker who stopped smoking 10 or more years previously, former smoker who stopped smoking less than 10 years previously, and current smoker. Physical activity was assessed by a question on the baseline questionnaire about how often the respondent participated in physical activity at work or at home (including exercise, sports, and activities such as carrying heavy loads for at least 20 minutes) that caused heavy breathing, an increase in heart rate, or sweating during a typical month in the past 12 months. Categories of physical activity were never, rarely, 1–3 times per month, 1–2 times per week, 3–4 times per week, and five or more times per week. Alcohol consumption over the past 12 months was assessed by means of a food frequency questionnaire (21). From total alcohol intake in grams per day, four categories were created: 0, 0–<5, 5–<15, and $\geq$15 g/day. Current height was reported in feet and inches (converted into meters), and weight was reported to the nearest pound (converted into kilograms). BMI was calculated as weight in kilograms divided by height in meters squared and divided into five categories: <18.5, 18.5–<25, 25–<30, 30–<35, and $\geq$35. Prevalent chronic diseases included cancer, heart disease, stroke, diabetes, emphysema, and renal failure.

Statistical analyses

Age-standardized mortality rates were calculated, standardized to the age distribution of the cohort in men and women using 5-year age categories. Cox proportional hazards models were fitted to study the associations between sex-specific quintiles of waist circumference and time to death in men and women. Persons who survived were censored at December 31, 2005, and those lost to follow-up were censored at their last study contact. Three models were fitted. Model 1 adjusted for age; model 2 additionally adjusted for racial/ethnic group, education, smoking status, physical activity, alcohol consumption, and height. In model 3, we included BMI as a measure of relative weight to assess

TABLE 1. Baseline characteristics of participants by sex-specific quintile of waist circumference, NIH-AARP Diet and Health Study, 1996–1997

	Quintile* of waist circumference									
	Men (*n* = 154,776)					Women (*n* = 90,757)				
	1	2	3	4	5	1	2	3	4	5
Mean waist circumference (cm)	84.3 (3.4)†	90.9 (1.3)	95.9 (1.3)	101.8 (2.0)	113.8 (8.1)	68.6 (3.0)	76.3 (1.9)	83.4 (2.1)	91.0 (2.3)	105.5 (9.1)
Mean body mass index‡	23.3 (2.2)	25.1 (2.2)	26.4 (2.4)	27.8 (2.6)	31.6 (4.3)	21.5 (2.3)	23.3 (2.4)	25.4 (3.0)	27.5 (3.4)	32.5 (5.6)
Mean height (m)	1.75 (0.07)	1.78 (0.07)	1.79 (0.07)	1.79 (0.07)	1.80 (0.08)	1.62 (0.06)	1.63 (0.06)	1.64 (0.07)	1.64 (0.07)	1.64 (0.07)
Mean age (years)	62.5 (5.4)	63.1 (5.2)	63.3 (5.2)	63.5 (5.2)	63.1 (5.2)	61.9 (5.4)	62.5 (5.3)	63.0 (5.2)	63.2 (5.2)	62.9 (5.3)
Racial/ethnic group (%)										
Non-Hispanic White	89.9	93.7	94.8	95.6	95.6	93.3	93.2	91.5	91.8	91.6
Non-Hispanic Black	2.8	2.0	1.7	1.4	1.7	2.5	2.4	4.2	4.6	5.1
Hispanic	2.1	1.8	1.5	1.4	1.3	1.2	1.6	2.0	1.7	1.3
Asian	3.6	1.4	0.7	0.5	0.2	1.8	1.4	1.0	0.5	0.2
College or postgraduate education (%)	50.8	50.2	49.0	48.4	42.9	39.0	37.4	33.5	31.8	29.6
Smoking status (%)										
Never smoker	35.5	32.9	31.5	28.8	25.5	46.3	46.1	45.4	44.7	44.4
Former smoker who had stopped smoking ≥10 years previously	40.4	45.6	47.4	48.8	48.8	27.1	28.9	28.1	28.4	29.2
Former smoker who had stopped smoking <10 years previously	9.2	10.6	11.7	13.6	16.3	9.7	10.8	12.6	13.6	15.1
Current smoker	13.3	9.3	8.1	7.4	7.9	15.6	12.9	12.6	12.1	10.2
Mean frequency of physical activity (no. of times per week)	3.2 (2.0)	3.0 (1.9)	2.8 (1.9)	2.6 (1.9)	2.2 (1.9)	2.9 (2.0)	2.7 (1.9)	2.4 (1.9)	2.2 (1.9)	1.8 (1.8)
Alcohol intake of ≥15 g/day (%)	28.7	29.8	29.8	29.9	26.8	13.3	14.2	13.0	12.0	8.9
Two or more diseases (%)§	3.8	4.3	4.7	5.8	8.8	1.4	1.8	2.4	3.5	6.5

* Quintile cutpoints—men: 88.9, 94.0, 99.1, and 106.7 cm; women: 73.7, 80.0, 87.0, and 95.9 cm.
† Numbers in parentheses, standard deviation.
‡ Weight (kg)/height (m)^2.
§ Diseases included self-reported cancer, heart disease, stroke, diabetes, emphysema, and renal failure.

TABLE 2. Mortality rates and hazard ratios for mortality by sex-specific quintile of waist circumference in the total study population and in selected subgroups, NIH-AARP Diet and Health Study, 1996–2005

Quintile* of waist circumference	Men							Women						
	Mortality rate†	Model 1‡		Model 2§		Model 3¶		Mortality rate†	Model 1‡		Model 2§		Model 3¶	
		HR#	95% CI#	HR	95% CI	HR	95% CI		HR	95% CI	HR	95% CI	HR	95% CI
Total study population				n = 154,776							n = 90,757			
1	1,321	1.10	1.04, 1.15	1.08	1.02, 1.13	1.10	1.04, 1.16	778	1.08	0.99, 1.17	1.06	0.98, 1.15	1.07	0.99, 1.17
2	1,209	1.00		1.00		1.00		716	1.00		1.00		1.00	
3	1,240	1.02	0.98, 1.08	1.01	0.96, 1.06	1.00	0.95, 1.05	750	1.05	0.97, 1.13	1.00	0.93, 1.08	0.99	0.91, 1.07
4	1,319	1.09	1.04, 1.14	1.04	0.99, 1.09	1.01	0.96, 1.07	794	1.10	1.02, 1.20	1.03	0.95, 1.12	1.00	0.92, 1.09
5	1,805	1.51	1.44, 1.57	1.30	1.24, 1.36	1.22	1.15, 1.29	1,108	1.56	1.44, 1.68	1.36	1.26, 1.47	1.28	1.16, 1.41
Disease status**														
No prevalent disease				n = 109,333							n = 73,683			
1	950	1.14	1.06, 1.22	1.11	1.04, 1.19	1.15	1.07, 1.23	594	1.07	0.97, 1.18	1.04	0.94, 1.15	1.06	0.95, 1.17
2	844	1.00		1.00		1.00		552	1.00		1.00		1.00	
3	866	1.02	0.96, 1.10	1.02	0.95, 1.09	1.00	0.93, 1.07	567	1.03	0.93, 1.13	1.00	0.90, 1.10	0.98	0.88, 1.08
4	919	1.09	1.01, 1.16	1.06	0.99, 1.13	1.01	0.94, 1.09	592	1.07	0.96, 1.18	1.03	0.93, 1.14	1.00	0.89, 1.12
5	1,167	1.39	1.31, 1.49	1.25	1.17, 1.34	1.13	1.04, 1.23	776	1.41	1.28, 1.56	1.33	1.20, 1.47	1.24	1.08, 1.41
Prevalent disease				n = 45,443							n = 17,074			
1	2,418	1.09	1.02, 1.17	1.08	1.00, 1.16	1.07	0.99, 1.15	1,872	1.15	1.00, 1.32	1.14	0.99, 1.31	1.13	0.98, 1.30
2	2,207	1.00		1.00		1.00		1,643	1.00		1.00		1.00	
3	2,183	0.99	0.93, 1.06	0.97	0.91, 1.04	0.98	0.91, 1.05	1,628	0.98	0.86, 1.12	0.95	0.83, 1.08	0.96	0.84, 1.09
4	2,240	1.01	0.95, 1.08	0.97	0.91, 1.04	0.98	0.92, 1.05	1,624	0.96	0.85, 1.10	0.90	0.79, 1.03	0.92	0.80, 1.05
5	2,957	1.34	1.26, 1.42	1.16	1.09, 1.23	1.19	1.10, 1.29	1,937	1.19	1.05, 1.33	1.05	0.93, 1.18	1.09	0.94, 1.27
Smoking status														
Never smoker				n = 47,441							n = 41,156			
1	712	0.89	0.80, 1.00	0.91	0.82, 1.02	1.00	0.89, 1.12	464	1.02	0.88, 1.19	1.03	0.88, 1.20	1.06	0.91, 1.24
2	793	1.00		1.00		1.00		452	1.00		1.00		1.00	
3	830	1.05	0.95, 1.17	1.03	0.93, 1.14	0.97	0.87, 1.08	490	1.08	0.93, 1.24	1.04	0.90, 1.20	1.01	0.87, 1.16
4	891	1.13	1.01, 1.26	1.09	0.97, 1.21	0.95	0.85, 1.07	495	1.09	0.94, 1.26	1.04	0.90, 1.21	0.97	0.83, 1.14
5	1,228	1.58	1.43, 1.74	1.38	1.25, 1.53	1.02	0.89, 1.17	788	1.74	1.53, 2.00	1.57	1.37, 1.80	1.35	1.13, 1.61
Former smoker				n = 90,976							n = 36,894			
1	1,279	1.07	1.00, 1.14	1.09	1.02, 1.17	1.10	1.03, 1.18	767	1.00	0.87, 1.14	1.02	0.89, 1.17	1.04	0.91, 1.19
2	1,200	1.00		1.00		1.00		763	1.00		1.00		1.00	
3	1,267	1.06	0.99, 1.13	1.03	0.97, 1.10	1.02	0.96, 1.09	751	0.99	0.88, 1.12	0.92	0.81, 1.04	0.91	0.80, 1.02
4	1,357	1.13	1.06, 1.20	1.05	0.99, 1.12	1.04	0.97, 1.11	851	1.11	0.99, 1.26	0.99	0.87, 1.12	0.95	0.84, 1.09
5	1,821	1.53	1.44, 1.62	1.29	1.22, 1.37	1.25	1.16, 1.34	1,202	1.59	1.42, 1.78	1.25	1.11, 1.40	1.16	1.00, 1.35

Current smoker			n = 14,104								n = 11,505			
1	3,321	1.16	1.04, 1.28	1.15	1.04, 1.27	1.11	1.00, 1.24	1,824	1.09	0.94, 1.27	1.11	0.96, 1.30	1.09	0.93, 1.27
2	2,934	1.00		1.00		1.00		1,625	1.00		1.00		1.00	
3	2,733	0.94	0.84, 1.06	0.93	0.83, 1.04	0.95	0.84, 1.07	1,730	1.07	0.92, 1.24	1.06	0.91, 1.23	1.08	0.93, 1.27
4	2,736	0.95	0.84, 1.07	0.93	0.83, 1.05	0.97	0.86, 1.11	1,780	1.10	0.93, 1.29	1.06	0.90, 1.25	1.12	0.94, 1.33
5	3,636	1.29	1.16, 1.44	1.21	1.08, 1.34	1.33	1.16, 1.52	2,184	1.33	1.13, 1.56	1.25	1.07, 1.47	1.39	1.13, 1.72
Racial/ethnic group														
Non-Hispanic White			n = 145,553								n = 83,739			
1	1,329	1.10	1.05, 1.16	1.08	1.02, 1.14	1.10	1.04, 1.16	774	1.07	0.98, 1.16	1.05	0.96, 1.14	1.06	0.97, 1.16
2	1,209	1.00		1.00		1.00		719	1.00		1.00		1.00	
3	1,233	1.02	0.97, 1.07	1.00	0.96, 1.06	0.99	0.94, 1.04	751	1.04	0.96, 1.13	1.00	0.92, 1.08	0.98	0.91, 1.07
4	1,311	1.08	1.03, 1.14	1.03	0.98, 1.09	1.01	0.95, 1.06	790	1.09	1.00, 1.19	1.02	0.94, 1.11	1.00	0.91, 1.09
5	1,795	1.50	1.43, 1.57	1.29	1.23, 1.35	1.21	1.14, 1.28	1,101	1.54	1.42, 1.66	1.36	1.26, 1.47	1.28	1.16, 1.42
Non-Hispanic Black			n = 2,926								n = 3,415			
1	1,602	0.97	0.71, 1.31	0.91	0.67, 1.23	0.87	0.63, 1.20	972	1.36	0.83, 2.24	1.29	0.78, 2.13	1.30	0.78, 2.15
2	1,612	1.00		1.00		1.00		737	1.00		1.00		1.00	
3	1,559	0.96	0.69, 1.33	0.96	0.69, 1.34	0.98	0.70, 1.37	890	1.16	0.74, 1.82	1.09	0.69, 1.70	1.08	0.69, 1.70
4	1,545	1.00	0.71, 1.41	0.95	0.67, 1.34	0.99	0.69, 1.43	725	0.98	0.61, 1.57	0.92	0.57, 1.47	0.90	0.56, 1.47
5	2,237	1.33	0.98, 1.77	1.20	0.89, 1.63	1.33	0.91, 1.95	1,212	1.56	1.02, 2.40	1.34	0.86, 2.07	1.30	0.78, 2.16
Hispanic			n = 2,513								n = 1,436			
1	1,284	1.41	0.95, 2.08	1.39	0.93, 2.06	1.47	0.98, 2.19	466	0.69	0.28, 1.69	0.68	0.28, 1.69	0.81	0.33, 2.02
2	895	1.00		1.00		1.00		607	1.00		1.00		1.00	
3	1,030	1.13	0.74, 1.72	1.12	0.73, 1.71	1.08	0.70, 1.66	434	0.72	0.36, 1.46	0.69	0.34, 1.41	0.53	0.26, 1.09
4	958	1.04	0.67, 1.62	0.98	0.62, 1.53	0.91	0.57, 1.44	895	1.50	0.77, 2.91	1.52	0.77, 2.99	0.86	0.41, 1.77
5	1,731	1.91	1.30, 2.81	1.66	1.12, 2.46	1.38	0.84, 2.26	699	1.13	0.54, 2.33	1.12	0.53, 2.36	0.30	0.11, 0.82
Asian			n = 1,858								n = 908			
1	792	0.86	0.57, 1.30	1.00	0.66, 1.53	0.94	0.59, 1.48	518	0.81	0.40, 1.66	0.82	0.40, 1.72	0.92	0.43, 1.98
2	925	1.00		1.00		1.00		681	1.00		1.00		1.00	
3	1,000	1.15	0.67, 1.99	1.28	0.74, 2.22	1.32	0.76, 2.30	353	0.57	0.23, 1.40	0.52	0.21, 1.30	0.47	0.18, 1.20
4	1,468	1.66	0.95, 2.92	1.73	0.97, 3.07	1.87	1.01,3.45	886	1.33	0.54, 3.26	1.41	0.56, 3.54	1.11	0.39, 3.18
5	892	0.98	0.35, 2.77	0.92	0.32, 2.62	1.07	0.35, 3.29	580	0.85	0.19, 3.72	0.79	0.18, 3.55	0.53	0.09, 3.10

* Quintile cutpoints—men: 88.9, 94.0, 99.1, and 106.7 cm; women: 73.7, 80.0, 87.0, and 95.9 cm.
† Age-standardized mortality per 100,000 person-years, standardized to the age distribution of the cohort in men and women.
‡ Adjusted for age.
§ Adjusted for age, racial/ethnic group, education, smoking status, physical activity, alcohol consumption, and height.
¶ Adjusted for age, racial/ethnic group, education, smoking status, physical activity, alcohol consumption, height, and body mass index.
# HR, hazard ratio; CI, confidence interval.
** Diseases included self-reported cancer, heart disease, stroke, diabetes, emphysema, and renal failure.

the impact of waist circumference on mortality independent of BMI. Stratified analyses were conducted according to disease status, smoking status, and racial/ethnic group. In additional analyses, we excluded the first 2 years of follow-up to exclude persons who died during the first few years of the study. We also considered the World Health Organization cutpoints for waist circumference, stratified by racial/ethnic group. Finally, the combined effects of BMI and waist circumference on time to death were examined. We investigated the proportional hazards assumption by testing the constancy of the log hazard ratio over time by means of log-minus-log survival plots; according to the test, the proportional hazards assumption was not violated. Analyses were performed using SPSS, version 14.0 (SPSS, Inc., Chicago, Illinois).

RESULTS

During 9 years of follow-up, 18,282 men and 6,538 women died. Table 1 shows the baseline characteristics of the study population according to quintiles of waist circumference in men and women. Men and women in the highest quintile of waist circumference had a lower level of education, were less likely to currently smoke, were less physically active, had a slightly lower alcohol intake, and had a higher prevalence of diseases than those with a lower waist circumference.

In the total study population, persons in the highest quintile of waist circumference had an approximately 50 percent higher risk of mortality than persons in the second quintile of waist circumference (men: hazard ratio (HR) = 1.51, 95 percent confidence interval (CI): 1.44, 1.57; women: HR = 1.56, 95 percent CI: 1.44, 1.68) (table 2, model 1). Risks were attenuated after additional adjustment for potential confounders (model 2), but they remained statistically significant. After adjustment for BMI in model 3, persons with a large waist circumference still had a significantly higher death risk (men: HR = 1.22, 95 percent CI: 1.15, 1.29; women: HR = 1.28, 95 percent CI: 1.16, 1.41). Very similar results were found for younger (age <65 years) and older (age ≥65 years) persons (data not shown).

The association between waist circumference and mortality was J-shaped; subjects in the lowest waist circumference quintile had approximately a 5–10 percent higher risk of mortality than those in the second quintile of waist circumference, although the risk among women in the lowest quintile was not statistically significant. The associations between waist circumference and mortality were similar in men with and without prevalent disease. The mortality risk among women with prevalent disease and a large waist circumference was not significantly elevated in the multivariate model. The interaction between disease status and waist circumference was borderline statistically significant in women ($p = 0.07$) but not in men ($p = 0.72$). In additional analyses, we excluded the first 2 years of follow-up to exclude persons who died during the first few years of the study. Very similar results were found (results not tabulated).

A significant interaction between smoking status and waist circumference was found in both men and women ($p < 0.05$).

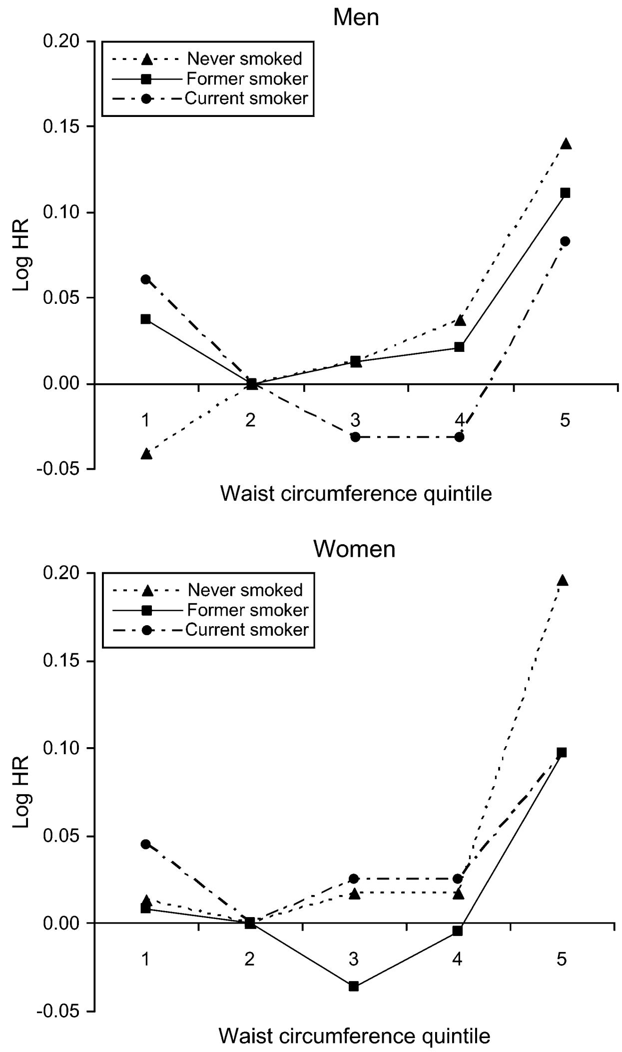

FIGURE 1. Adjusted hazard ratios (HRs) for mortality in relation to waist circumference according to smoking status in men and women, NIH-AARP Diet and Health Study, 1996–2005. Hazard ratios were adjusted for age, racial/ethnic group, education, physical activity, alcohol consumption, and height.

Before adjustment for BMI, the positive association between large waist circumference and mortality was stronger in never smokers than in former or current smokers. In addition, in never smokers there was no increased risk of mortality among subjects in the lowest waist circumference quintile. The model 2 hazard ratios by smoking status are also shown in figure 1. After adjustment for BMI, the waist circumference-mortality association became statistically nonsignificant in male never smokers, while it remained evident in former and current smokers. In contrast, among women, the association between waist circumference and mortality remained apparent both before and after BMI adjustment. Figure 2 shows the waist circumference-mortality association among never-smoking men and women without prevalent disease.

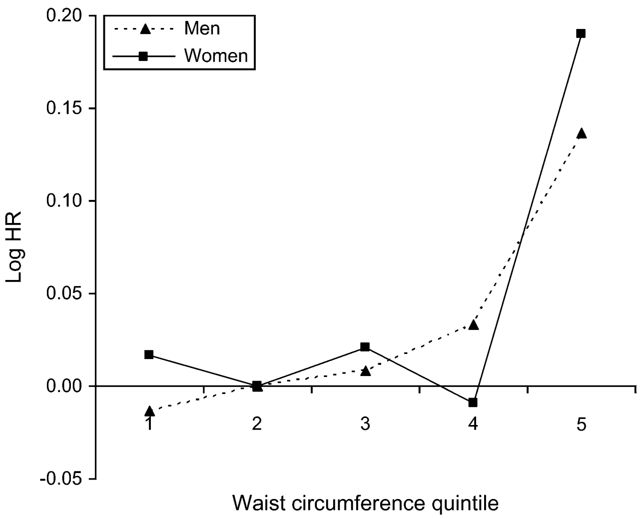

FIGURE 2. Adjusted hazard ratios (HRs) for mortality in relation to quintile of waist circumference among men and women without prevalent disease who had never smoked, NIH-AARP Diet and Health Study, 1996–2005. Hazard ratios were adjusted for age, racial/ethnic group, education, physical activity, alcohol consumption, and height.

Because our study population was predominantly non-Hispanic White, results for this group were similar to the overall results. No significant association between waist circumference and mortality was observed in non-Hispanic Blacks in the multivariate model. Hispanic men with a large waist circumference had a significantly higher mortality risk than those in the reference group, whereas no association was seen in Hispanic women. In Asian men, a significantly higher mortality risk was found for the fourth quintile of waist circumference but not the highest quintile; however, there were only 53 cases in the highest quintile. No association was found for Asian women. The interaction between racial/ethnic group and waist circumference was not statistically significant in either men or women ($p > 0.10$).

Table 3 shows the association with waist circumference according to the cutpoints recommended by the World Health Organization (25), by racial/ethnic group. Non-Hispanic White men and women with a large waist circumference had a 20 percent higher risk of mortality than those with a normal waist circumference (table 3, model 2). Results were not statistically significant for non-Hispanic Blacks. A strong association between waist circumference and mortality risk was found in Hispanics (men: HR = 1.38, 95 percent CI: 1.04, 1.82; women: HR = 1.74, 95 percent CI: 1.08, 2.80). A positive relation was also found in Asians, but results were not statistically significant. Results were similar in persons without prevalent disease. The waist circumference-mortality association was somewhat stronger in never smokers among non-Hispanic Whites and Hispanic women.

The combined effects of BMI and waist circumference on mortality are shown in table 4. The group with a BMI of 18.5–<25 and a normal waist circumference was used as the reference group. The lowest BMI group (<18.5) consisted only of people with a normal waist circumference, and the highest BMI group (≥35) included only people with a large waist circumference. Within the other strata of BMI, persons with a large waist circumference had a higher risk of mortality than those with a normal waist circumference. For example, compared with subjects with a combination of normal BMI (18.5–<25) and normal waist circumference, those in the normal-BMI group with a large waist circumference had an approximately 20 percent higher mortality risk. The highest mortality risks were found in the groups with a very low BMI (<18.5) and a very high BMI (≥35). Risks were somewhat higher in never smokers.

DISCUSSION

In this large, 9-year prospective cohort study, a large waist circumference was associated with an approximately 50 percent increased risk of mortality in both men and women. Even after adjustment for BMI and other covariates, a large waist circumference remained associated with an approximately 25 percent increased mortality risk. A positive association between waist circumference and mortality was found in persons with and without prevalent disease, in smokers and nonsmokers, and in different racial/ethnic groups. The combined associations of BMI and waist circumference showed that having a large waist circumference while being in the normal BMI range represents an important risk factor for mortality.

Waist circumference is strongly related to visceral fat and may therefore be a risk indicator of mortality caused by visceral fat. A larger waist circumference remained associated with a higher mortality risk after BMI was taken into account, which suggests that visceral fat is associated with mortality independently of total body mass. The visceral fat-mortality association should be confirmed by studies that have direct measures of visceral fat. Such studies are very limited at present (26). Our study suggests that body composition rather than body weight is an important predictor of mortality, since we did not find a higher mortality risk among overweight and obese people with a normal waist circumference. It has been hypothesized that for persons with the same BMIs, waist circumference is a reflection of total or abdominal fat, while for persons with the same waist circumferences, BMI is a reflection of lean mass (15, 16). Results from previous studies that found higher mortality risks among obese people (4–6) may have been driven by abdominal obesity in this group.

Investigators in previous studies have reported inconsistent associations between waist circumference and mortality. Men and women in the Melbourne Collaborative Cohort Study with a waist circumference in the top quintile had a 30 percent higher mortality risk than men and women with a waist circumference in the second quintile (19). A large Danish study showed a strong positive dose-response relation between waist circumference and mortality in both men and women (15). A large waist circumference was associated with an increased mortality risk after BMI was accounted for in men and women aged 65 years or more

TABLE 3. Mortality rates and hazard ratios for mortality according to waist circumference using the cutpoints* recommended by the World Health Organization in the total study population and by racial/ethnic group, NIH-AARP Diet and Health Study, 1996–2005

Waist circumference	Men						Women					
	No. of subjects	Mortality rate†	Model 1‡		Model 2§		No. of subjects	Mortality rate†	Model 1‡		Model 2§	
			HR¶	95% CI¶	HR	95% CI			HR	95% CI	HR	95% CI
Total study population												
Normal	109,315	1,268	1.00		1.00		58,579	744	1.00		1.00	
Large	45,461	1,673	1.33	1.29, 1.37	1.19	1.15, 1.22	32,178	968	1.30	1.24, 1.37	1.20	1.14, 1.26
No prevalent disease												
Normal	79,786	892	1.00		1.00		49,582	567	1.00		1.00	
Large	29,547	1,093	1.23	1.17, 1.29	1.14	1.09, 1.20	24,101	690	1.22	1.14, 1.30	1.18	1.10, 1.26
Never smokers												
Normal	35,606	796	1.00		1.00		26,825	468	1.00		1.00	
Large	11,835	1,135	1.44	1.34, 1.55	1.29	1.20, 1.39	14,331	658	1.41	1.29, 1.54	1.31	1.19, 1.43
Non-Hispanic Whites												
Normal	102,025	1,265	1.00		1.00		54,242	744	1.00		1.00	
Large	43,528	1,665	1.32	1.28, 1.36	1.18	1.15, 1.22	29,497	962	1.29	1.23, 1.36	1.20	1.14, 1.26
No prevalent disease												
Normal	74,444	886	1.00		1.00		45,936	563	1.00		1.00	
Large	28,308	1,086	1.23	1.17, 1.29	1.14	1.09, 1.20	22,178	686	1.22	1.14, 1.30	1.19	1.11, 1.28
Never smokers												
Normal	33,122	784	1.00		1.00		24,617	744	1.00		1.00	
Large	11,347	1,132	1.46	1.36, 1.57	1.32	1.10, 1.12	13,119	1,075	1.41	1.29, 1.54	1.31	1.19, 1.44
Non-Hispanic Blacks												
Normal	2,192	1,558	1.00		1.00		1,839	850	1.00		1.00	
Large	734	1,884	1.16	0.93, 1.45	1.10	0.88, 1.38	1,576	1,004	1.14	0.89, 1.46	1.07	0.83, 1.38
No prevalent disease												
Normal	1,645	1,285	1.00		1.00		1,494	667	1.00		1.00	
Large	458	1,204	0.90	0.64, 1.26	0.89	0.63, 1.26	1,112	739	1.05	0.76, 1.45	1.05	0.75, 1.46
Never smokers												
Normal	668	1,418	1.00		1.00		825	616	1.00		1.00	
Large	187	1,672	1.03	0.63, 1.67	0.90	0.55, 1.48	698	731	1.12	0.73, 1.73	1.11	0.71, 1.72
Hispanics												
Normal	1,931	1,023	1.00		1.00		955	489	1.00		1.00	
Large	582	1,568	1.51	1.15, 1.99	1.38	1.04, 1.82	481	821	1.71	1.08, 2.70	1.74	1.08, 2.80
No prevalent disease												
Normal	1,413	744	1.00		1.00		857	467	1.00		1.00	
Large	369	1,162	1.40	0.94, 2.10	1.24	0.82, 1.89	362	534	1.23	0.68, 2.21	1.36	0.74, 2.49
Never smokers												
Normal	653	865	1.00		1.00		541	451	1.00		1.00	
Large	147	866	1.00	0.52, 1.93	0.87	0.44, 1.73	244	897	2.02	1.10, 3.71	2.06	1.09, 3.89
Asians												
Normal	1,760	886	1.00		1.00		791	525	1.00		1.00	
Large	98	1,319	1.49	0.80, 2.75	1.29	0.69, 2.42	117	816	1.65	0.80, 3.41	1.70	0.80, 3.64
No prevalent disease												
Normal	1,294	623	1.00		1.00		674	438	1.00		1.00	
Large	69	892	1.43	0.58, 3.54	1.18	0.46, 3.00	91	606	1.43	0.55, 3.71	1.60	0.58, 4.44
Never smokers												
Normal	797	629	1.00		1.00		525	444	1.00		1.00	
Large	35	1,701	1.60	0.50, 5.16	1.33	0.40, 4.44	69	669	1.68	0.63, 1.46	1.49	0.53, 4.20

* 88 cm for women; 102 cm for men.
† Age-standardized mortality per 100,000 person-years, standardized to the age distribution of the cohort in men and women.
‡ Adjusted for age.
§ Adjusted for age, racial/ethnic group, education, smoking status, physical activity, alcohol consumption, and height.
¶ HR, hazard ratio; CI, confidence interval.

TABLE 4. Mortality rates and hazard ratios for mortality according to body mass index and waist circumference using the cutpoints* recommended by the World Health Organization, NIH-AARP Diet and Health Study, 1996–2005

Body mass index†	Waist circumference	Men						Women					
		No. of subjects	Mortality rate‡	Model 1§		Model 2¶		No. of subjects	Mortality rate‡	Model 1‡		Model 2§	
				HR#	95% CI#	HR	95% CI			HR	95% CI	HR	95% CI
Total study population													
<18.5	Normal	894	2,520	1.91	1.66, 2.22	1.55	1.33, 1.80	1,375	1,675	2.23	1.93, 2.57	1.84	1.59, 2.13
18.5–<25	Normal	47,603	1,309	1.00		1.00		41,313	747	1.00		1.00	
	Large	1,534	1,930	1.47	1.30, 1.66	1.23	1.08, 1.39	3,683	1,061	1.41	1.26, 1.57	1.22	1.09, 1.36
25–<30	Normal	55,228	1,199	0.92	0.89, 0.95	0.92	0.89, 0.95	13,989	641	0.86	0.79, 0.93	0.90	0.83, 0.97
	Large	20,291	1,453	1.11	1.06, 1.16	1.02	0.98, 1.07	14,143	855	1.14	1.07, 1.23	1.07	1.00, 1.15
30–<35	Normal	5,458	1,338	1.05	0.96, 1.15	0.98	0.89, 1.07	1,650	709	0.96	0.79, 1.18	0.97	0.79, 1.19
	Large	17,580	1,701	1.32	1.25, 1.38	1.16	1.11, 1.22	9,195	924	1.24	1.14, 1.35	1.19	1.10, 1.30
≥35	Large	6,188	2,334	1.88	1.76, 2.01	1.57	1.47, 1.67	5,409	1,326	1.81	1.65, 1.98	1.68	1.53, 1.85
No prevalent disease													
<18.5	Normal	608	1,738	1.85	1.49, 2.29	1.47	1.17, 1.83	1,089	1,110	1.90	1.56, 2.31	1.59	1.30, 1.94
18.5–<25	Normal	35,162	919	1.00		1.00		35,503	576	1.00		1.00	
	Large	1,017	1,190	1.28	1.06, 1.55	1.06	0.87, 1.29	2,862	756	1.32	1.14, 1.52	1.18	1.02, 1.36
25–<30	Normal	40,221	852	0.93	0.88, 0.98	0.94	0.90, 1.00	11,715	492	0.86	0.78, 0.95	0.92	0.83, 1.02
	Large	13,820	943	1.03	0.96, 1.10	0.97	0.91, 1.04	11,053	621	1.08	0.98, 1.18	1.05	0.96, 1.15
30–<35	Normal	3,711	890	1.01	0.89, 1.15	0.99	0.98, 1.13	1,304	489	0.86	0.65, 1.13	0.89	0.68, 1.18
	Large	11,259	1,191	1.30	1.22, 1.40	1.21	1.13, 1.30	6,754	686	1.20	1.07, 1.33	1.24	1.11, 1.38
≥35	Large	3,535	1,443	1.63	1.46, 1.81	1.50	1.34, 1.67	3,603	908	1.59	1.37, 1.81	1.63	1.42, 1.87
Never smokers													
<18.5	Normal	294	1,709	2.15	1.57, 2.94	1.67	1.20, 2.32	545	738	1.59	1.15, 2.21	1.51	1.08, 2.11
18.5–<25	Normal	16,674	760	1.00		1.00		18,567	464	1.00		1.00	
	Large	379	1,359	1.76	1.31, 2.36	1.49	1.11, 2.02	1,452	578	1.25	0.99, 1.56	1.19	0.95, 4.95
25–<30	Normal	17,077	801	1.06	0.98, 1.16	1.04	0.96, 1.13	6,735	453	0.98	0.85, 1.12	0.95	0.93, 1.10
	Large	5,282	897	1.18	1.05, 1.32	1.09	0.97, 1.22	6,081	566	1.22	1.07, 1.39	1.16	1.02, 1.32
30–<35	Normal	1,532	914	1.27	1.04, 1.54	1.18	0.96, 1.44	832	410	0.91	0.63, 1.31	0.85	0.59, 1.23
	Large	4,564	1,177	1.58	1.41, 1.76	1.40	1.25, 1.57	4,338	627	1.36	1.17, 1.56	1.25	1.08, 1.44
≥35	Large	1,639	1,950	2.71	2.35, 3.13	2.21	1.91, 2.56	2,606	1,016	2.25	1.94, 2.62	1.93	1.65, 2.26

* 88 cm for women; 102 cm for men.
† Weight (kg)/height (m)^2.
‡ Age-standardized mortality per 100,000 person-years, standardized to the age distribution of the cohort in men and women.
§ Adjusted for age.
¶ Adjusted for age, racial/ethnic group, education, smoking status, physical activity, alcohol consumption, and height.
# HR, hazard ratio; CI, confidence interval.

participating in the Cardiovascular Health Study (16). In contrast, in a recent large study of people over age 75 years in the United Kingdom, Price et al. (17) reported no association between waist circumference and mortality. In the Health Professionals Follow-up Study, a positive association between waist circumference and all-cause mortality was found only among men younger than 65 years (14). In the Rotterdam Study, Visscher et al. (18) found a positive association with waist circumference and mortality only among never-smoking men and not among women. In a recent large cohort study among 55- to 69-year-old women participating in the Iowa Women's Health Study, waist circumference was weakly associated with mortality; waist-hip ratio was a stronger predictor (20).

The association between waist circumference and mortality in the present study was J-shaped. A slightly higher mortality risk was found in the lowest quintile of waist circumference, although significantly so only in men. A J-shaped association between waist circumference and all-cause mortality has been reported in recent studies (20, 27). Previous studies that examined the association between BMI and mortality also found a J- or U-shaped relation

(4, 6). We considered whether the higher mortality risk with low waist circumference was explained by reverse causation due to preexisting disease, since chronic conditions are associated with both lower body weight and higher mortality. After excluding the first 2 years of follow-up, we found very similar results. Using the same data, Adams et al. (4) previously examined the association between BMI and all-cause mortality and showed that the risk of death was consistently stronger in men and women without preexisting disease than among those with preexisting disease. The waist circumference-mortality relations, however, were similar for persons with and without prevalent disease, particularly among men.

Before adjustment for BMI, the waist circumference-mortality relation appeared to be stronger in never smokers than in current or former smokers, and no J-shaped relation was found in never smokers. However, current smokers with a large waist circumference versus a small waist circumference also had a significantly greater mortality risk. Among male never smokers, the effect of waist circumference was attenuated after BMI was taken into account, while the effect of waist circumference on mortality risk in male former and current smokers was independent of BMI. There is some evidence that smoking is related to visceral fat accumulation (28). A recent study showed that smoking cessation is associated with a substantial increase in waist circumference (29). How this affects mortality risk is unknown. Future studies should examine the combined associations of smoking status and waist circumference with mortality.

Unlike previous investigators, we were able to examine the waist circumference-mortality relation in different racial/ethnic groups. Based on the waist circumference cutpoints recommended by the World Health Organization, there was only a weak association between waist circumference and mortality risk in non-Hispanic Blacks, while stronger associations were found in Hispanics and Asians, especially among women. In our study, only 5.3 percent of Asian men and 12.9 percent of Asian women had a large waist circumference on the basis of the World Health Organization cutpoints, while in the other racial/ethnic groups the distributions ranged from 23 percent to 30 percent in men and from 34 percent to 46 percent in women. The results from the analyses based on quintiles of waist circumference in the overall study population showed that the highest risk of death among Asians was found in the fourth quintile of waist circumference, not the fifth quintile, for both men and women; this was probably due to the small number of Asian cases in the highest quintile. This suggests that in comparison with other racial/ethnic groups, a relatively lower waist circumference is associated with mortality risk in Asians, especially Asian men.

A few limitations of the study should be considered. Waist circumference was self-measured by participants. Previous research has shown, however, that the validity of self-measured waist circumference is fairly high (24). The number of Asians ($n = 2{,}766$) in our study was rather low, especially among women ($n = 908$); therefore our results for Asians should be confirmed in other studies. A recent study in never-smoking Chinese women showed a positive dose-response relation between waist-hip ratio and mortality (30). Overall, more research is needed to examine the waist circumference-mortality association in different racial/ethnic groups.

In conclusion, in this study, a large waist circumference was associated with an increased mortality risk in both men and women. This relation was independent of BMI. The positive waist circumference-mortality association was found in persons with and without prevalent disease, in current, former, and never smokers, and across different racial/ethnic groups. The finding that persons with a normal BMI but a large waist circumference had higher mortality risk in this study suggests that an increased waist circumference should be considered a risk factor for mortality, in addition to BMI.

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Conflict of interest: none declared.

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