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Title: Waist circumference and mortality in Korea: Evidence from the National Health Insurance Health Checkup 2009-2015

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Methods

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Findings

WC in 5 cm increments showed a positively increased all-cause mortality after adjusting for all covariates including BMI. Men showed higher HRs for mortality than women as WC increased, and the HRs were higher in the lower WC levels, but lower in the higher WC levels among the subjects aged 65-85 years than subjects aged 40-65 years. Even in subjects with normal weight and overweight, increased WC (levels 4, 5, and 6) showed increased HRs for mortality (HRs = 1.156, 1.412, and 1.614 in normal BMI and 1.145, 1.401, and 1.909 in overweight, respectively).

Interpretation

This study provides evidence of the need to lose WC in the subjects with normal or overweight BMI categories. The importance of assessing WC routinely should be raised and the guidelines to keep proper WC are stressed.

Funding

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Waist circumference and mortality in Korea: Evidence from the National Health Insurance Health Checkup 2009–2015

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Keywords: Waist circumference; body mass index; obesity; mortality; Korean National Health Insurance Corporation

Introduction

Obesity is a status of excessive body fat and defined as a body mass index (BMI) of more than 30 kg/m² in the United States, or 25 kg/m² in Asian countries including South Korea.^{1,2} Obesity is one of the major risk factors for co-morbidities and mortality,^{3,4} and in two Korean studies, BMI was associated with reverse J shaped all-cause mortality curves.^{5,6} However, BMI itself has limitations in explaining the relationship between obesity and morbidity or mortality because BMI does not account for the exact fat mass, especially visceral adipose tissue.^{3,7,8}

Waist circumference (WC) is an index for abdominal obesity⁹ and has been known as a better predictor than BMI for the prevalence or incidence of co-morbidities such as type 2 diabetes mellitus (DM),¹⁰⁻¹² hypertension,¹² dyslipidemia,^{12,13} and coronary heart diseases.¹⁴ Many studies have shown that a larger WC is also associated with increased mortality although the strength of the association varies among studies.^{8,15-24} Moreover, many studies have shown this association even after adjusting for BMI.^{17,20,22-24} Even in a pooled analysis, higher WC was positively associated with increased mortality in white adults at BMI levels between 20 and 50 kg/m².²⁵ These studies were performed mostly in Europe,^{8,16,17,20} the United States,^{19,21-24,26} or among Chinese women²⁷; however, there was a lack of evidence in the association between WC and mortality in Korean populations. Therefore, we examined the relationship between WC and all-cause mortality using data from the National Health Insurance Service (NHIS) health checkup.

Methods

The NHIS database and NHIS health checkup data

The NHIS manages the NHI program including about 50 million of the Korean population and their medical information. This medical information consists of patients' age, sex, living area, insurer payment coverage, deduction and claims data, and medical utilization/transaction information. The Health Insurance Review and Assessment (HIRA) database contains health insurance claims data of 97.0% of the Korean population and the HIRA service has the source population of the NHIS.^{28,29} All insured Koreans older than 40 years undergo a biannual health checkup supported by the NHIS, and employees older than 20 years are required to undergo health checkup once a year. In the NHI health checkup, weight (kg), height (cm), WC (cm), systolic blood pressure (mmHg), and diastolic blood pressure (mmHg) are measured. Also, fasting blood glucose (mg/dL), total cholesterol (mg/dL), triglyceride (mg/dL), high-density lipoprotein cholesterol (mg/dL), low-density lipoprotein cholesterol (mg/dL) levels are also measured in a fasting state. General health behaviors such as alcohol drinking, smoking, and exercise are surveyed, and past medical history of cancer, tuberculosis, and chronic diseases such as type 2 DM, HTN, and dyslipidemia are obtained by self-reported questionnaires. The quality of the laboratory tests are warranted by the Korean Association for Laboratory Medicine, and the NHIS certifies the hospitals participating in the NHI health checkup programs.³⁰ In this study, we used the NHI health checkup database from 2005 to 2015.

Subjects

From the NHI health checkup between 2005 and 2015, a total of 23,503,802 participants older than 20 years were included. These subjects were followed-up to December 31 2015. We excluded subjects with missing data (n=125,699), those younger than 20 and older than 85 (n=114,209), and subjects with unmatched mortality information (n=16) over 4 consecutive years. Finally, 23,263,878 subjects were included in this study (men = 11,813,850 and women = 11,450,028). The study protocol was approved by the Institutional Review Board of the Korea University Anam Hospital (ED17115) and permission for the use of health checkup data was granted by the NHIS (NHIS-2018-1-035).

Definition of obesity and abdominal obesity

We defined obesity as a BMI ≥ 25 kg/m² and categorized it into underweight (BMI < 18.5 kg/m²), normal ($18.5 \leq$ BMI < 23 kg/m²), overweight ($23 \leq$ BMI < 25 kg/m²), stage I obesity ($25 \leq$ BMI < 30 kg/m²), and stage 2 obesity (BMI ≥ 30 kg/m²) according to the World Health Organization recommendations for Asians.¹ Abdominal obesity was defined as WC ≥ 90 cm in men and ≥ 85 cm in women according to the definition of the Korean Society for the Study of Obesity.³¹ WC was divided into six categories with increments of 5 cm— level 1: <80 cm in men and <75 cm in women, level 2: 80–85 cm in men and 75–80 cm in women, level 3: 85–90 cm in men and 80–85 cm in women, level 4: 90–95 cm in men and 85–90 cm in women, level 5: 95–100 cm in men and 90–95 cm in women, and level 6: ≥ 100 cm in men and ≥ 95 cm in women.

General health behavior and socio-demographic variables

Subjects were also categorized according to smoking status: non-smokers, former smokers, or

current smokers. Alcohol drinking was categorized into none, moderate, or heavy drinkers (≥ 3 times/week) and regular exercise defined as vigorous physical activity for at least 20 min/day. Income was divided by quartile (Q): Q1 (the lowest), Q2, Q3, and Q4 (the highest). Residence in urban areas was also checked.

All-cause mortality

All-cause mortality was checked between 1 January 2009 and 31 December 2015 for each participant, and the number of person-years of follow-up was also counted. All-cause mortality was assessed within 5.39 ± 1.11 years after the last recorded WC value and there was a total of 502,456 deaths.

Statistical analysis

The general characteristics of subjects are presented as means \pm standard deviation (SD) for continuous variables and percentages (SD) for categorical variables, according to the six levels of WC. The hazard ratios (HRs) and 95% confidence intervals (CIs) for all-cause mortality according to the six levels of WC were analyzed using multivariable Cox proportional hazard models, using the level 3 WC (85–90 cm in men and 80–85 cm in women) as a reference group, after adjusting for age and sex in model 1; age, sex, smoking, alcohol drinking, regular exercise, and income (Q1) in model 2; and all covariates of model 2 and BMI in model 3. We did not adjust for chronic diseases such as DM, hypertension, and dyslipidemia to avoid bias because such chronic diseases were known to be related with mortality.³² The HR and 95% CI for all-cause mortality according to the six levels of WC were also obtained using a multivariable Cox model for the different subgroups: sex, three

age groups (20–40 years, 40–64 years, and 65–84 years) after adjusting for all covariates. We also obtained HRs and 95% CI for all-cause mortality of WC levels regarding level 3 WC as the reference level in the five BMI groups ($<18.5 \text{ kg/m}^2$, $18.5\text{--}23 \text{ kg/m}^2$, $23\text{--}25 \text{ kg/m}^2$, $25\text{--}30 \text{ kg/m}^2$, and $\geq 30 \text{ kg/m}^2$). All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC, USA), and $p < 0.05$ for two-tailed t-tests was considered statistically significant.

Results

Table 1 shows the general characteristics of participants by the six levels of WC. As WC level increases, age and BMI $25\text{--}30 \text{ kg/m}^2$ increased until level 5 of WC. The proportion of the 65–84 year age group increased. BMI and BMI $\geq 30 \text{ kg/m}^2$ increased as WC increased. The proportion of non-smokers, non-alcohol drinkers, and the lowest income level (Q1) showed a U-shaped curve as WC increased. The mortality rate increased as WC increased.

The adjusted HRs for all-cause mortality are shown in Table 2 according to the six WC groups. WC and mortality showed a reverse J shaped curve before adjusting for BMI in model 2, but showed a positive linear association between WC and all-cause mortality after adjusting for BMI in model 3.

Figure 1 shows the subgroup analysis in the relationship between WC and mortality according to sex and three age groups. After adjusting for all covariates, both men and

women showed a linear association between WC and all-cause mortality and men showed higher HRs for mortality than women (Fig 1-1). The age group 20–40 years showed a weak association between WC and mortality, but both 40–65 and 65–85 year age groups showed positive linear associations between WC and mortality. In the level 1 and 2 WC categories, the HRs for mortality were higher for ages 65–85 years than the ages 40–65 years, but in levels 4, 5, and 6, the HRs for mortality were higher for ages 40–65 years than the ages of 65–85 years (Fig 1-2).

Figure 2 shows the WC and mortality in the five BMI categories. When WC level 3 was regarded as the reference group, lower levels of WC (levels 1 and 2) showed lower HRs for mortality than level 3 in underweight BMI, but higher levels of WC groups did not show any associations. In subjects with normal weight, overweight, and stage 1 obesity, HRs for mortality increased as WC increased. In WC levels 4 and 5, the HRs were the highest in the normal BMI than overweight and stage 1 obesity BMI (HRs = 1.156 and 1.412 in normal BMI, respectively). In level 6 WC, the HR was the highest in overweight BMI, than normal weight and stage 1 obesity (HRs = 1.909, 1.614, and 1.484, respectively). However, in stage 2 obesity, level 1 WC showed higher HR (HR = 1.292) than level 6 WC (HR = 1.144) and the association between WC and mortality were not significant in the other levels of WC.

Discussion

In this study, 5 cm increments in WC showed increasing all-cause mortality after adjusting

for all covariates independent of BMI. Men showed higher HRs for mortality than women as WC increased, and the HRs were higher in the lower WC levels, but lower in higher WC levels in the subjects with age 65–85 years than subjects aged 40–65 years. Even in subjects with normal weight, higher WC levels showed higher HRs for mortality than lower WC levels, and this association was also found in overweight and stage I obesity.

Our results are consistent with previous studies which showed that higher WC was associated with higher risk for mortality even after adjusting for BMI.^{17,20,22,24,26,27} In a large US cohort study, 10 cm increases in WC was associated with positive increase of all-cause mortality and very high levels of WC (≥ 120 cm in men and ≥ 110 cm in women) were associated with about 2-fold higher relative risk for mortality in men and women compared to low levels of WC (< 90 cm in men and < 75 cm in women) (relative risk = 2.02; 95% CI: 1.71–2.39 in men and 2.36; 95% CI: 1.98–2.82 in women). Women showed higher HRs for all-cause mortality than men at all levels of WC after adjusting for multiple variables including BMI.²⁶

In this study, even in the subjects with normal BMI and overweight BMI subjects with levels 4, 5, and 6 of WC (abdominal obesity) showed increased risks for mortality than subjects with level 3 WC (15.6%, 41.2%, and 61.4%, respectively in normal BMI and 14.5%, 40.1%, and 90.9% in overweight BMI). In the large National Institutes of Health - American Association of Retired Persons (NIH-AARP) cohort, subjects with normal BMI with abdominal obesity (≥ 88 cm in women and ≥ 102 cm in men) had approximately 20% higher risk for mortality than subjects with normal BMI and non-abdominal obesity.²⁴ In the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort and the Nurses' Health Study, WC also showed positive associations with mortality even in the normal range BMI (< 25.0 kg/m²).^{17,24} In the US population study, normal BMI showed stronger

association with WC than other BMI categories.²⁶ In a meta-analysis including 58,609 subjects from 23 studies, higher WC was also associated with higher mortality in the elderly subjects with both normal and overweight BMI.³³ However, in our study, overweight BMI showed the strongest association between WC and mortality than normal BMI. This different result indicates that there may be ethnic differences between WC and mortality and WC is more meaningful in the overweight BMI categories than normal or obesity BMI categories in Koreans. These results mean that we should assess the distribution of body fat especially in the study of mortality and there may be a need to decrease abdominal fat to reduce mortality especially in subjects with normal or overweight BMI.²

Men had higher HR for mortality than women in all WC levels in this study. In the EPIC studies, 5 cm increase of WC was associated with 17% increase of mortality risk in men and 13% increase of mortality risk in women.¹⁷ Men had more visceral fat than subcutaneous fat in the same WC than those of women,³⁴ so men with higher WC may show more increased mortality than women. However, the exact mechanism is unclear. More detailed designed studies regarding these sex differences are needed in the future.

In a US population study, relative risks for mortality associated with WC were lower in men younger than 70 yrs than in those more than 70 yrs.²⁶ The different effect of WC in the different age groups is unclear, but, higher mortality in lower WC levels is maybe explained by low BMI which is associated with higher mortality³ and a weaker association between WC and the volume of visceral fat among younger population than older population.³⁵

The mechanism between increased WC and increased mortality can be explained by the effect of visceral adipose tissue. Higher WC is associated with higher visceral adipose tissue^{36,37} which is more pathogenic than subcutaneous tissue.^{36,38} Visceral adipose tissue secretes some mediators which may develop cardiometabolic diseases which increases the

risk of death in the subjects with higher WC.³⁹ Moreover, increased WC is associated with and inflammation,^{40,41} insulin resistance,^{42,43} type 2 DM,^{10,11} and coronary heart diseases,^{14,44} which all are associated with increased mortality. After adjusting for BMI, the linearity and strength of association between WC and mortality were found. This may be due to a decrease of confounding factors such as pathologic conditions or pre-existing comorbidities, or frailty which are all associated with low BMI.⁴⁵

This study has several limitations. First, we do not know the cause of death. Some cancers or respiratory diseases such as chronic obstructive pulmonary diseases decrease weight and then WC also may decrease. So, low WC may be associated with increased mortality contrary to this study. Second, we only checked WC at one time when study involved, so we could not know the status of WC whether WC has been decreasing or increasing. Third, we don't have body composition data, so we could not know that increased mortality was associated with increased visceral fat or muscle wasting. Fourth, the time of mortality regarding WC is too short. Fifth, we only included Korean population, so this association is hard to be generalized to other ethnicities.

However, this study has some strengths. As we know, this is the first study to examine the relationship between WC and all-cause mortality in the large Korean population. Second, some studies assessed WC by participants' memory, but we measured all participants' WC by trained examiners in certified facilities. Third, this study included 502,456 deaths, which is more than the number of death from the EPIC study and NIH-AARP cohort study.^{17,23} Fourth, we adjusted for variable covariates which potentially affect mortality.

In conclusion, our large cohort study found a linear association between WC and all-cause mortality across the full range of BMI categories and this association was also found in the subjects with normal or overweight BMI. Several guidelines including the National Health

Institute guidelines only suggested the loose of weight or WC in the obese subjects,⁹ but this study provides evidence to the necessity for losing WC in the subjects with normal or overweight BMI categories. Moreover, WC is not routinely measured in the non-obese subjects or older subjects. Physicians are better to check WC routinely especially in the subjects with high WC categories and the guidelines to decrease WC is needed. Further detailed designed studies are needed to evaluate the cause of death be increased WC and the mechanism of this association.

Contributors

KD-H, YH-K, SJ-Y, and WY-L established the cohort. KD-H, JH-J, YH-K, and WY-L gathered the data and analyzed the data. YH-K wrote the first draft of the report. SM-K, SS-L, SW-O, EJ-R, and HS-P commented the interpretation of data and results. All authors contributed to revision of the report and agreed to its publication. KD-H and JH-J had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the analysis.

Declaration of interests

The authors have nothing to disclose.

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References

1. Organization WH. The Asia-Pacific perspective : redefining obesity and its treatment: International Association for the Study of Obesity, 2000.
2. Executive summary of the clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. *Arch Intern Med* 1998; **158**(17): 1855-67.
3. Janssen I, Mark AE. Elevated body mass index and mortality risk in the elderly. *Obes Rev* 2007; **8**(1): 41-59.
4. Prospective Studies C, Whitlock G, Lewington S, et al. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet* 2009; **373**(9669): 1083-96.
5. Jee SH, Sull JW, Park J, et al. Body-mass index and mortality in Korean men and women. *N Engl J Med* 2006; **355**(8): 779-87.
6. Kim NH, Lee J, Kim TJ, et al. Body Mass Index and Mortality in the General Population and in Subjects with Chronic Disease in Korea: A Nationwide Cohort Study (2002-2010). *PLoS One* 2015; **10**(10): e0139924.
7. Strain GW, Zumoff B. The relationship of weight-height indices of obesity to body fat content. *J Am Coll Nutr* 1992; **11**(6): 715-8.
8. Visscher TL, Seidell JC, Molarius A, van der Kuip D, Hofman A, Witteman JC. A

comparison of body mass index, waist-hip ratio and waist circumference as predictors of all-cause mortality among the elderly: the Rotterdam study. *Int J Obes Relat Metab Disord* 2001; **25**(11): 1730-5.

9. Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults--The Evidence Report. National Institutes of Health. *Obes Res* 1998; **6 Suppl 2**: 51S-209S.

10. Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB. Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *Am J Clin Nutr* 2005; **81**(3): 555-63.

11. Carey VJ, Walters EE, Colditz GA, et al. Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women. The Nurses' Health Study. *Am J Epidemiol* 1997; **145**(7): 614-9.

12. Snijder MB, Zimmet PZ, Visser M, Dekker JM, Seidell JC, Shaw JE. Independent and opposite associations of waist and hip circumferences with diabetes, hypertension and dyslipidemia: the AusDiab Study. *Int J Obes Relat Metab Disord* 2004; **28**(3): 402-9.

13. Van Pelt RE, Evans EM, Schechtman KB, Ehsani AA, Kohrt WM. Waist circumference vs body mass index for prediction of disease risk in postmenopausal women. *Int J Obes Relat Metab Disord* 2001; **25**(8): 1183-8.

14. Canoy D. Distribution of body fat and risk of coronary heart disease in men and women. *Curr Opin Cardiol* 2008; **23**(6): 591-8.

15. Katzmarzyk PT, Craig CL, Bouchard C. Adiposity, adipose tissue distribution and mortality rates in the Canada Fitness Survey follow-up study. *Int J Obes Relat Metab Disord* 2002; **26**(8): 1054-9.

16. Lahmann PH, Lissner L, Gullberg B, Berglund G. A prospective study of adiposity and all-cause mortality: the Malmo Diet and Cancer Study. *Obes Res* 2002; **10**(5): 361-9.

17. Pischon T, Boeing H, Hoffmann K, et al. General and abdominal adiposity and risk of death in Europe. *N Engl J Med* 2008; **359**(20): 2105-20.
18. Simpson JA, MacInnis RJ, Peeters A, Hopper JL, Giles GG, English DR. A comparison of adiposity measures as predictors of all-cause mortality: the Melbourne Collaborative Cohort Study. *Obesity (Silver Spring)* 2007; **15**(4): 994-1003.
19. Baik I, Ascherio A, Rimm EB, et al. Adiposity and mortality in men. *Am J Epidemiol* 2000; **152**(3): 264-71.
20. Bigaard J, Tjonneland A, Thomsen BL, Overvad K, Heitmann BL, Sorensen TI. Waist circumference, BMI, smoking, and mortality in middle-aged men and women. *Obes Res* 2003; **11**(7): 895-903.
21. Folsom AR, Kushi LH, Anderson KE, et al. Associations of general and abdominal obesity with multiple health outcomes in older women: the Iowa Women's Health Study. *Arch Intern Med* 2000; **160**(14): 2117-28.
22. Janssen I, Katzmarzyk PT, Ross R. Body mass index is inversely related to mortality in older people after adjustment for waist circumference. *J Am Geriatr Soc* 2005; **53**(12): 2112-8.
23. Koster A, Leitzmann MF, Schatzkin A, et al. Waist circumference and mortality. *Am J Epidemiol* 2008; **167**(12): 1465-75.
24. Zhang C, Rexrode KM, van Dam RM, Li TY, Hu FB. Abdominal obesity and the risk of all-cause, cardiovascular, and cancer mortality: sixteen years of follow-up in US women. *Circulation* 2008; **117**(13): 1658-67.
25. Cerhan JR, Moore SC, Jacobs EJ, et al. A pooled analysis of waist circumference and mortality in 650,000 adults. *Mayo Clin Proc* 2014; **89**(3): 335-45.
26. Jacobs EJ, Newton CC, Wang Y, et al. Waist circumference and all-cause mortality in a large US cohort. *Arch Intern Med* 2010; **170**(15): 1293-301.

27. Zhang X, Shu XO, Yang G, et al. Abdominal adiposity and mortality in Chinese women. *Arch Intern Med* 2007; **167**(9): 886-92.
28. Lee J, Lee JS, Park SH, Shin SA, Kim K. Cohort Profile: The National Health Insurance Service-National Sample Cohort (NHIS-NSC), South Korea. *Int J Epidemiol* 2016.
29. Song SO, Jung CH, Song YD, et al. Background and data configuration process of a nationwide population-based study using the Korean national health insurance system. *Diabetes & metabolism journal* 2014; **38**(5): 395-403.
30. Service NHI. National Health Insurance Service: Health Checkup. . 2006 (accessed Feb 11 2016).
31. Lee SY, Park HS, Kim DJ, et al. Appropriate waist circumference cutoff points for central obesity in Korean adults. *Diabetes Res Clin Pract* 2007; **75**(1): 72-80.
32. Hu F. Obesity and mortality. New York, NY: Oxford University Press; 2008.
33. de Hollander EL, Bemelmans WJ, Boshuizen HC, et al. The association between waist circumference and risk of mortality considering body mass index in 65- to 74-year-olds: a meta-analysis of 29 cohorts involving more than 58 000 elderly persons. *Int J Epidemiol* 2012; **41**(3): 805-17.
34. Krotkiewski M, Bjorntorp P, Sjostrom L, Smith U. Impact of obesity on metabolism in men and women. Importance of regional adipose tissue distribution. *J Clin Invest* 1983; **72**(3): 1150-62.
35. Kuk JL, Lee S, Heymsfield SB, Ross R. Waist circumference and abdominal adipose tissue distribution: influence of age and sex. *Am J Clin Nutr* 2005; **81**(6): 1330-4.
36. Fox CS, Massaro JM, Hoffmann U, et al. Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study. *Circulation* 2007; **116**(1): 39-48.
37. Janssen I, Heymsfield SB, Allison DB, Kotler DP, Ross R. Body mass index and

waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat. *Am J Clin Nutr* 2002; **75**(4): 683-8.

38. Despres JP, Lemieux I, Bergeron J, et al. Abdominal obesity and the metabolic syndrome: contribution to global cardiometabolic risk. *Arterioscler Thromb Vasc Biol* 2008; **28**(6): 1039-49.

39. Haslam DW, James WP. Obesity. *Lancet* 2005; **366**(9492): 1197-209.

40. Festa A, D'Agostino R, Jr., Williams K, et al. The relation of body fat mass and distribution to markers of chronic inflammation. *Int J Obes Relat Metab Disord* 2001; **25**(10): 1407-15.

41. Panagiotakos DB, Pitsavos C, Yannakoulia M, Chrysohoou C, Stefanadis C. The implication of obesity and central fat on markers of chronic inflammation: The ATTICA study. *Atherosclerosis* 2005; **183**(2): 308-15.

42. Farin HM, Abbasi F, Reaven GM. Body mass index and waist circumference correlate to the same degree with insulin-mediated glucose uptake. *Metabolism* 2005; **54**(10): 1323-8.

43. Wannamethee SG, Shaper AG, Morris RW, Whincup PH. Measures of adiposity in the identification of metabolic abnormalities in elderly men. *Am J Clin Nutr* 2005; **81**(6): 1313-21.

44. Klein S, Allison DB, Heymsfield SB, et al. Waist circumference and cardiometabolic risk: a consensus statement from shaping America's health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Diabetes Care* 2007; **30**(6): 1647-52.

45. Snijder MB, van Dam RM, Visser M, Seidell JC. What aspects of body fat are particularly hazardous and how do we measure them? *Int J Epidemiol* 2006; **35**(1): 83-92.

Table 1. General characteristics of participants by waist circumference

	Waist circumference group					
	1	2	3	4	5	6
N	8672967	5362342	4538812	2714222	1253456	722079
Men (yes,%)	3450338(39.78)	3079604(57.43)	2648218(58.35)	1604864(59.13)	679425(54.2)	351401(48.67)
Age (yr)	42.69±13.76	48.24±13.42	50.91±13.44	52.43±13.67	53.33±14.18	52.5±15.11
Age group (yes,%)						
20 - 40	3596630(41.47)	1384164(25.81)	915952(20.18)	492555(18.15)	225771(18.01)	158788(21.99)
40 - 64	4399758(50.73)	3297574(61.5)	2842275(62.62)	1651324(60.84)	720342(57.47)	381554(52.84)
65 - 85	676579(7.8)	680604(12.69)	780585(17.2)	570343(21.01)	307343(24.52)	181737(25.17)
Body mass index (kg/m ²)	21.05±2.04	23.51±1.89	24.99±2.01	26.47±2.16	28.04±2.37	30.68±3.21
<18.5	901949(10.4)	24771(0.46)	6702(0.15)	2197(0.08)	638(0.05)	287(0.04)
18.5~23	6323446(72.91)	2090324(38.98)	678158(14.94)	125309(4.62)	20215(1.61)	5471(0.76)
23~25	1213690(13.99)	2156699(40.22)	1637121(36.07)	516685(19.04)	90541(7.22)	14870(2.06)
25~30	230364(2.66)	1080974(20.16)	2167188(47.75)	1925391(70.94)	897990(71.64)	288858(40)
≥30	3518(0.04)	9574(0.18)	49643(1.09)	144640(5.33)	244072(19.47)	412593(57.14)
Smoking (yes,%)						
Non	5964846(68.78)	3106503(57.93)	2592749(57.12)	1531141(56.41)	741549(59.16)	446954(61.9)
Former	786403(9.07)	812076(15.14)	765533(16.87)	481828(17.75)	205172(16.37)	100249(13.88)
Current	1921718(22.16)	1443763(26.92)	1180530(26.01)	701253(25.84)	306735(24.47)	174876(24.22)

Alcohol drinking (yes,%)						
Non	4784499(55·17)	2741740(51·13)	2368663(52·19)	1433874(52·83)	700834(55·91)	425314(58·9)
Moderate	3422946(39·47)	2178086(40·62)	1756031(38·69)	1006673(37·09)	426554(34·03)	225813(31·27)
Heavy	465522(5·37)	442516(8·25)	414118(9·12)	273675(10·08)	126068(10·06)	70952(9·83)
Regular exercise (yes,%)	1405021(16·2)	1027051(19·15)	864575(19·05)	498760(18·38)	216517(17·27)	112544(15·59)
Income (Q1) (yes,%)	1931941(22·28)	1090911(20·34)	911431(20·08)	551669(20·33)	265490(21·18)	163770(22·68)
Urban living (yes,%)	4058601(46·82)	2471135(46·11)	2065373(45·53)	1211852(44·68)	549845(43·91)	312001(43·27)
Death (yes,%)	149733(1·73)	111307(2·08)	106771(2·35)	72606(2·68)	37763(3·01)	24276(3·36)

Table 2. Waist circumference and all-cause mortality

WC group	N	Death	Duration	Incidence Rate	HR (95% C.I.)		
					Model 1	Model 2	Model 3
1	8672967	149733	46394946·4	3·22736	1·375(1·364-1·386)	1·328(1·317-1·338)	0·927(0·919-0·936)
2	5362342	111307	29089043·6	3·82642	1·069(1·060-1·078)	1·060(1·051-1·069)	0·925(0·917-0·933)
3	4538812	106771	24633745·2	4·33434	1	1	1
4	2714222	72606	14677575·8	4·94673	0·993(0·984-1·003)	0·995(0·985-1·004)	1·102(1·091-1·113)
5	1253456	37763	6731707·3	5·60972	1·063(1·051-1·076)	1·061(1·048-1·073)	1·242(1·226-1·257)
6	722079	24276	3814427·1	6·36426	1·262(1·245-1·28)	1·247(1·230-1·264)	1·481(1·457-1·505)

Model 1 was adjusted for age and sex

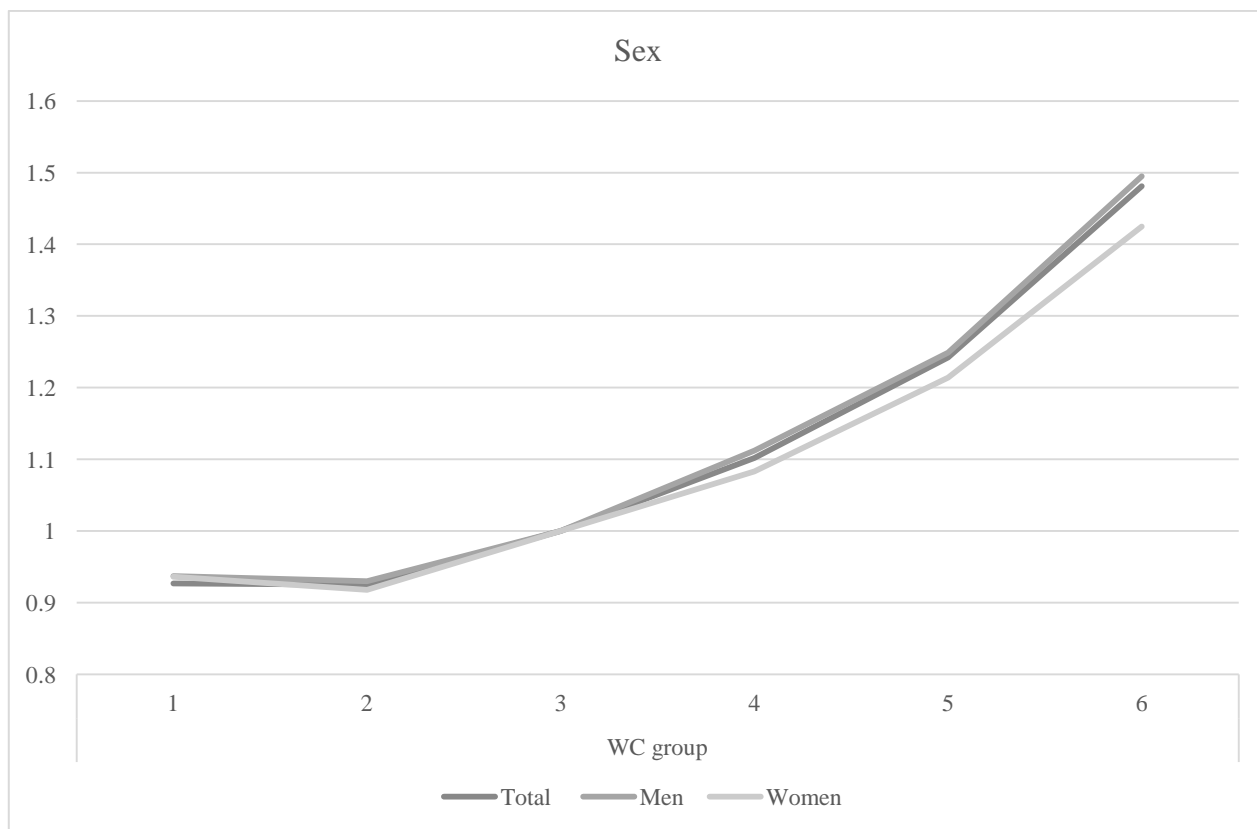
Model 2 was adjusted for age, sex, smoking, drinking, exercise, and income.

Model 3 was adjusted for age, sex, smoking, drinking, exercise, income, and body mass index

WC; waist circumference, HR; hazards ratio, and C.I.; confidence interval

Figure 1. Hazzard ratio for all-cause mortality by sex and age group in WC groups.

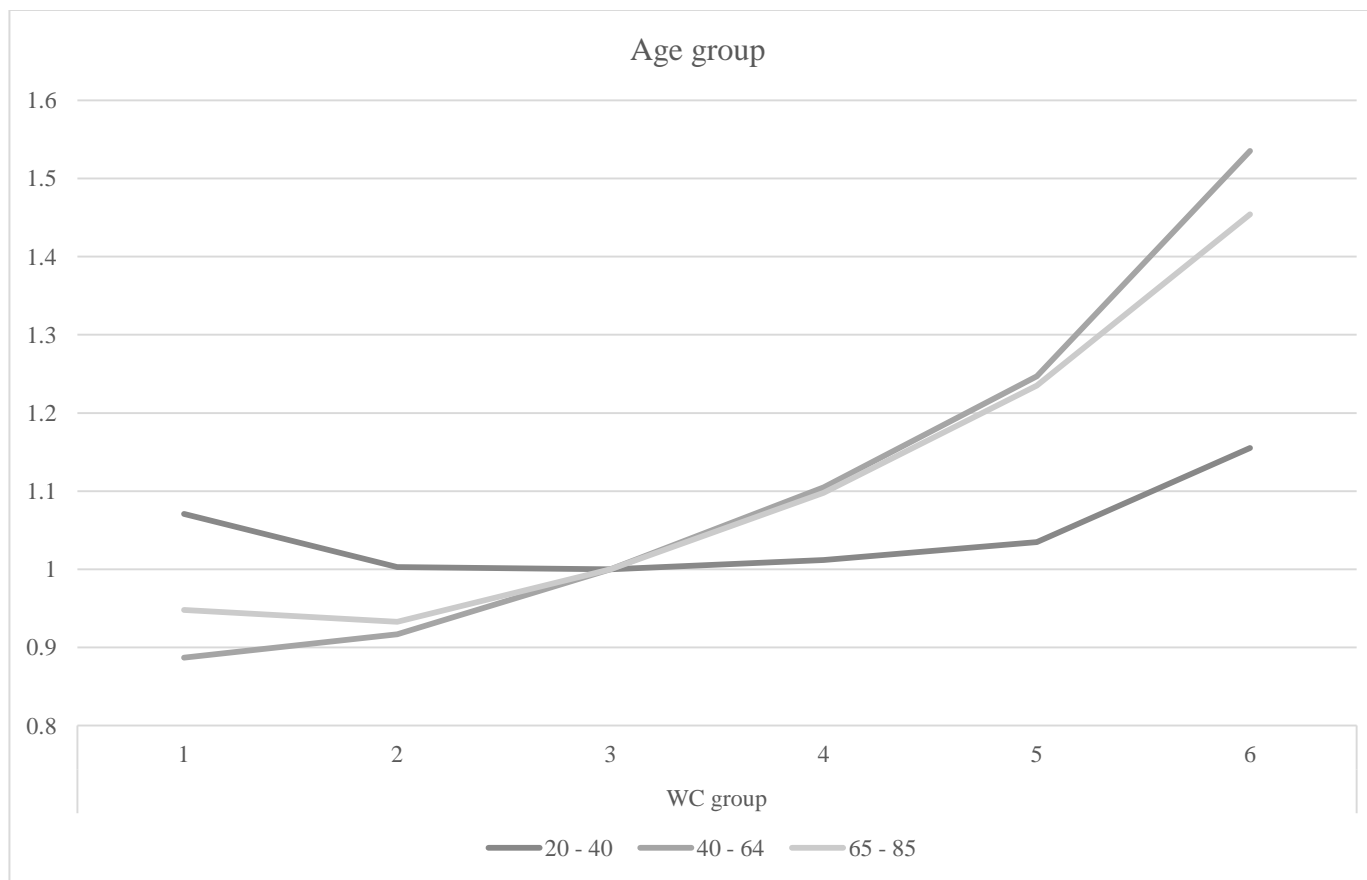
a) Sex



Adjusted for age, sex, smoking, drinking, exercise, income, and body mass index.

WC; waist circumference, HR; hazards ratio, C.I.; confidence interval

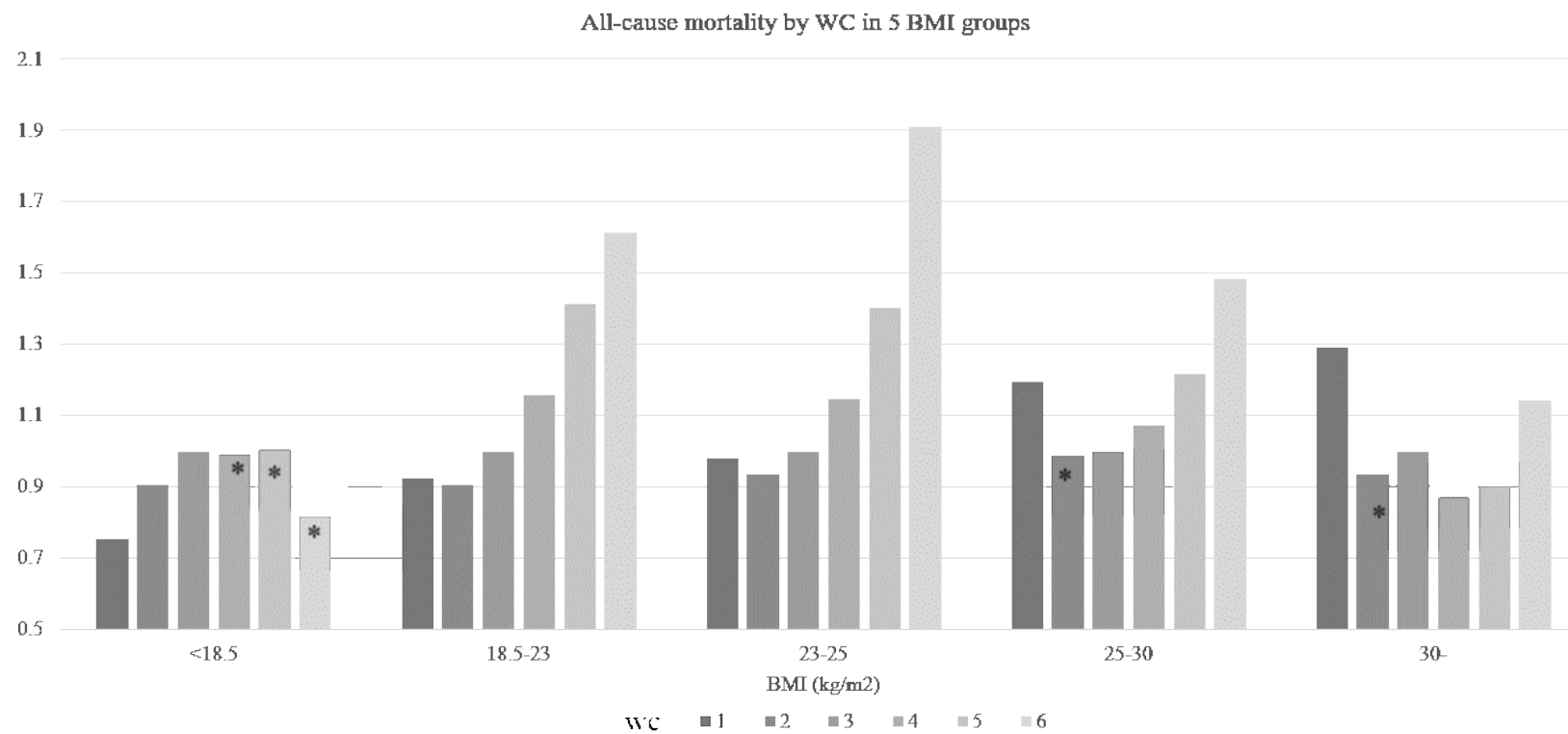
b) Age group



Adjusted for age, sex, smoking, drinking, exercise, income, and body mass index.

WC; waist circumference, HR; hazards ratio, C.I.; confidence interval

Figure 2. All-cause mortality by waist circumference and BMI



Adjusted for age, sex, smoking, drinking, exercise, income, and body mass index.

WC; waist circumference, HR; hazards ratio, and C.I.; confidence interval

* Statistically not significant