Original Article

Differences in Anthropometric Measures Based on Sex, Age, and Health Status

Findings From the German National Cohort (NAKO)

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Summary

Background: Obesity is a worldwide health problem. We conducted detailed analyses of anthropometric measures in a comprehensive, population-based, current cohort in Germany

Methods: In the German National Cohort (NAKO), we analyzed cross-sectional data on body mass index (BMI), waist and hip circumference, subcutaneous (SAT) and visceral adipose tissue (VAT) as measured by ultrasound, and body fat percentage. The data were stratified by sex, age, and self-reported physicians' diagnoses of cardiovascular diseases (CVD), metabolic diseases (MetD), cardiometabolic diseases (CMD), and cancer.

Results: Data were available from 204 751 participants (age, 49.9 ± 12.8 years; 50.5% women). Body size measures generally increased with age. Men had a higher BMI, larger waist circumference, and more VAT than women, while women had a larger hip circumference, more SAT, and a higher body fat percentage than men. For example, the mean BMI of participants over age 60 was 28.3 kg/m^2 in men and 27.6 kg/m^2 in women. CVD, MetD, and CMD were associated with higher anthropometric values, while cancer was not. For example, the mean BMI was 25.3 kg/m^2 in healthy women, 29.4 kg/m^2 in women with CMD, and 25.4 kg/m^2 in women with cancer.

Conclusion: Obesity is widespread in Germany, with notable differences between the sexes in anthropometric values. Obesity was more common in older participants and those with chronic diseases other than cancer. Elevated values were especially common in multimorbid individuals.

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Overweight and obesity have reached epidemic proportions, affecting 59% of European adults in 2016 (1). Obesity is a major risk factor for multiple noncommunicable diseases (2) and premature death (3). Overweight is defined as a body mass index (BMI) ≥ 25 kg/m^2, obesity as ≥ 30 kg/m^2. BMI is widely used in epidemiology and clinical practice, although it does not reflect body composition in detail. It does not distinguish between fat and muscle tissue (4) or differentiate between subcutaneous adipose tissue (SAT), located between skin and muscle, and visceral adipose tissue (VAT), found in body cavities (4, 5). Both SAT and VAT are correlated with multiple metabolic risk factors, and VAT, in particular, offers insights beyond those yielded by BMI (6). Alternative body size measures are needed because fat mass varies with sex (7), age (8), and ethnicity (9).

To address the limitations of BMI, the German National Cohort (NAKO) employed additional anthropometric measurements, including waist circumference, which reflects the amount of abdominal fat, and hip circumference, which measures gluteofemoral fat (and muscle mass). Waist and hip circumferences are predictors of premature death, independent of BMI (10, 11). Furthermore, body fat percentage was estimated using bioelectrical impedance analysis (BIA), which offers more detailed information on body composition by virtue of the different electrical conductivities of fat and fat-free mass (12). Additionally, ultrasound was used to measure SAT and VAT. This method provides reproducible and valid estimates and shows strong agreement with measurement by means of magnetic resonance imaging (MRI) (13). Initial NAKO results showed high BMI in both men (70% overweight or obese) and women (51%), together with more VAT but less SAT in men than women (14).

Considering the strong association between obesity and non-communicable

diseases, we present, for the first time, anthropometric measures within the NAKO study population, stratified by sex, age, and health status.

Methods

Study population

NAKO is a prospective cohort study in Germany embracing more than 205 000 men and women aged 20–69 years from 18 study regions. The age- and sex-stratified random samples from residents' registration offices cover both urban and rural areas. NAKO's intention was to recruit 10 000 participants per 10-year age group for ages 20–39 years and 26 667 participants per 10-year age group for ages 40–69 years. The response rate was 17%. The baseline examination (2014–2019) involved touchscreen questionnaires, interviews, physical measurements, and biomaterial collection. About 60 000 participants underwent extended examinations such as additional imaging (e.g., ultrasonography for abdominal fat). Overall, 97% of participants completed the anthropometric assessments, including 80% of those intended for ultrasonography. NAKO obtained approval from local ethics committees. All participants provided written informed consent. Further details are described elsewhere (15).

Anthropometric measures

We measured body height, weight, and waist and hip circumferences; determined the SAT and VAT by means of ultrasound; and assessed body fat percentage with BIA. Height was measured to the nearest 0.1 cm using the seca Stadiometer 274 and weight to the nearest 0.1 kg with the seca Body Composition Analyzer (mBCA) 515. The participants were measured without shoes and in their underwear. BMI was calculated as weight (kg) divided by height in meters squared (m^2). Waist circumference was measured using the seca 201 tape in accordance with World Health Organization (WHO) guidelines at a level midway between the lowest costal arch and the iliac crest (16). In seven study centers, hip circumference was measured by positioning the tape at the widest point of the buttocks, ensuring its horizontal alignment with the aid of a mirror.

The ultrasound measurements of SAT and VAT were conducted post exhalation with participants lying down. SAT was measured from the skin surface to the upper margin of the linea alba, and VAT was measured from the lower margin of the linea alba to the anterior edge of the lumbar vertebra. For the sake of increased accuracy, average values were calculated from duplicate measurements of SAT and VAT.

Body fat percentage was assessed using BIA (mBCA 515, seca). The reported values were measured at 50 Hz. The eight-point method involved a low alternating current, and measurements were carried out for each side of the body using one pair of foot electrodes and three pairs of hand electrodes at frequencies ranging from 1 kHz to 1000 kHz (14).

Independent variables

We calculated anthropometric measures by sex, age (20–39, 40–59, 60+ years), and health status. The latter was assessed via computer-assisted personal interviews, considering physicians' diagnoses of:

- Cardiovascular disease (CVD; defined as any diagnosis of myocardial infarction, angina pectoris, heart failure, cardiac arrhythmia, peripheral artery occlusive disease, or arterial hypertension)
- Metabolic disease (MetD; including diabetes mellitus type 2, hyperlipidemia, hyperuricemia, thyroid dysfunction)
- Cardiometabolic disease (CMD; combination of CVD and MetD)
- Cancer (except non-melanoma skin cancer)
- None of the above

Additionally, we report BMI for obesity-related cancers (17), other cancers, and no cancer.

Statistical analysis

The statistical analyses included frequencies and proportions for categorical variables, means and standard deviations for continuous values, and Pearson correlation coefficients for anthropometric measures. Data were stratified by age and sex and reported separately for each disease category and anthropometric measure. Participants with missing data were excluded. Data analyses were performed using R 4.2.3 (18).

Results

We investigated anthropometric measures in 204 751 participants (50.5% women; average age 49.9±12.8 years). Across all age groups, women were more often underweight or normal weight, while men were more often overweight or obese.

The extent of obesity measures generally increased with age. For example, among women aged 60+ years, 28.4% were obese and 0.8% underweight. By comparison, 11.4% of 20- to 39-year-old women were obese and 3.7% underweight *(Table)*.

The anthropometric measures exhibited mostly moderate to strong correlations. The strongest correlations were found between BMI and waist circumference in women and men of all ages (r 0.89–0.91). The weakest correlation was between SAT and VAT (r 0.10–0.51); the correlation was lower in men than in women and decreased with increasing age in men, while remaining stable in women *(eSupplement-Figure 1)*.

Anthropometric measures by sex and age

On average, men had higher BMI, higher weight, higher waist circumference, and more VAT than women, but lower hip circumference, less SAT, and a lower body fat percentage *(Table)*. Older persons (over 60 years) had the highest BMI, waist and hip circumferences, and body fat percentage and the most VAT, while younger persons (20–39 years) had the lowest BMI, waist and hip circumferences, and body fat percentage and the least VAT. SAT increased with age in women, but showed no clear pattern in men *(Table)*.

Anthropometric measures by health status

Participants with CVD, MetD, or CMD had a higher BMI than healthy participants and those with cancer. Sex differences in BMI diminished with age in participants with

Table

Anthropometric measures according to sex and age

Measure	Men			Women		
	20–39 years, N = 20 504	40–59 years, N = 53 395	60+ years, N = 27 545	20–39 years, N = 21 088	40–59 years, N = 54 575	60+ years, N = 27 644
	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)	Mean (SD)/N (%)
Height (cm)	180.6 (7.0)	179.3 (7.1)	175.9 (6.7)	167.3 (6.5)	166.1 (6.6)	162.5 (6.2)
Missing	336	1194	1092	574	1387	1051
Weight (kg)	83.3 (15.1)	88.1 (15.3)	87.6 (14.7)	67.8 (14.6)	72.1 (15.6)	72.7 (14.6)
Missing	336	1193	1093	575	1387	1049
Body mass index (kg/m²)	25.5 (4.3)	27.4 (4.4)	28.3 (4.4)	24.2 (5.0)	26.1 (5.5)	27.6 (5.5)
Missing	336	1197	1093	575	1389	1051
Body mass index category						
Underweight	245 (1.2%)	138 (0.3%)	61 (0.2%)	763 (3.7%)	712 (1.3%)	221 (0.8%)
Normal weight	10 148 (50.3%)	15 910 (30.5%)	5634 (21.3%)	13 159 (64.1%)	26 291 (49.4%)	9481 (35.7%)
Overweight	7238 (35.9%)	24 269 (46.5%)	12 871 (48.7%)	445 (20.7%)	1578 (29.1%)	9334 (35.1%)
Obesity	2537 (12.6%)	11 881 (22.8%)	7886 (29.8%)	246 (11.4%)	10 705 (20.1%)	7557 (28.4%)
Missing	336	1 197	1 093	575	1 389	1 051
Waist circumference (cm)	88.6 (11.5)	97.1 (12.2)	102.0 (12.1)	79.0 (11.8)	85.8 (13.3)	90.9 (13.2)
Missing	585	2086	1985	934	2328	2007
Hip circumference (cm)	99.9 (7.9)	101.5 (7.8)	101.7 (7.9)	100.2 (9.7)	102.7 (10.6)	103.5 (10.6)
Missing	15 990	41 250	21 306	16 117	41 233	20 960
Subcutaneous fat mass (cm)	1.9 (1.0)	2.1 (0.8)	1.9 (0.7)	2.0 (1.1)	2.3 (1.0)	2.4 (0.9)
Missing	1368	3780	1814	1321	3857	1750
Visceral fat mass (cm)	6.2 (1.9)	7.6 (2.4)	8.2 (2.5)	4.4 (1.5)	5.5 (2.1)	6.4 (2.3)
Missing	1413	3898	1929	1368	4006	1820
Body fat percentage (%)	21.3 (7.5)	25.7 (6.6)	29.1 (6.1)	31.3 (7.6)	36.2 (7.4)	40.9 (6.4)
Missing	711	2708	3066	1559	2997	2873

Underweight: body mass index < 18.5 kg/m²; normal weight: 18.5–24.9 kg/m²; overweight: 25.0–29.9 kg/m²; obesity: ≥ 30.0 kg/m²
SD, Standard deviation

CVD, MetD, or CMD, but increased with age in participants with cancer *(Figure 1, eSupplement-Figure 2)*. Participants with CVD, MetD, and CMD had larger waist circumferences than healthy persons and persons with cancer. Men and older age groups also showed higher values, irrespective of health status *(eSupplement-Figure 2, eSupplement-Figure 3)*.

Hip circumference was greater in diseased than in healthy participants, but showed only a weak association with health status and little variation by sex and age *(eSupplement-Figure 2, eSupplement-Figure 4)*.

Diseased participants had more SAT than their healthy counterparts, particularly in the group of women. For example, women aged 60+ years with CMD had a SAT of 2.5 cm compared with 2.1 cm in healthy women, while in older men SAT was comparable across all health status categories *(Figure 2, eSupplement-Figure 2)*.

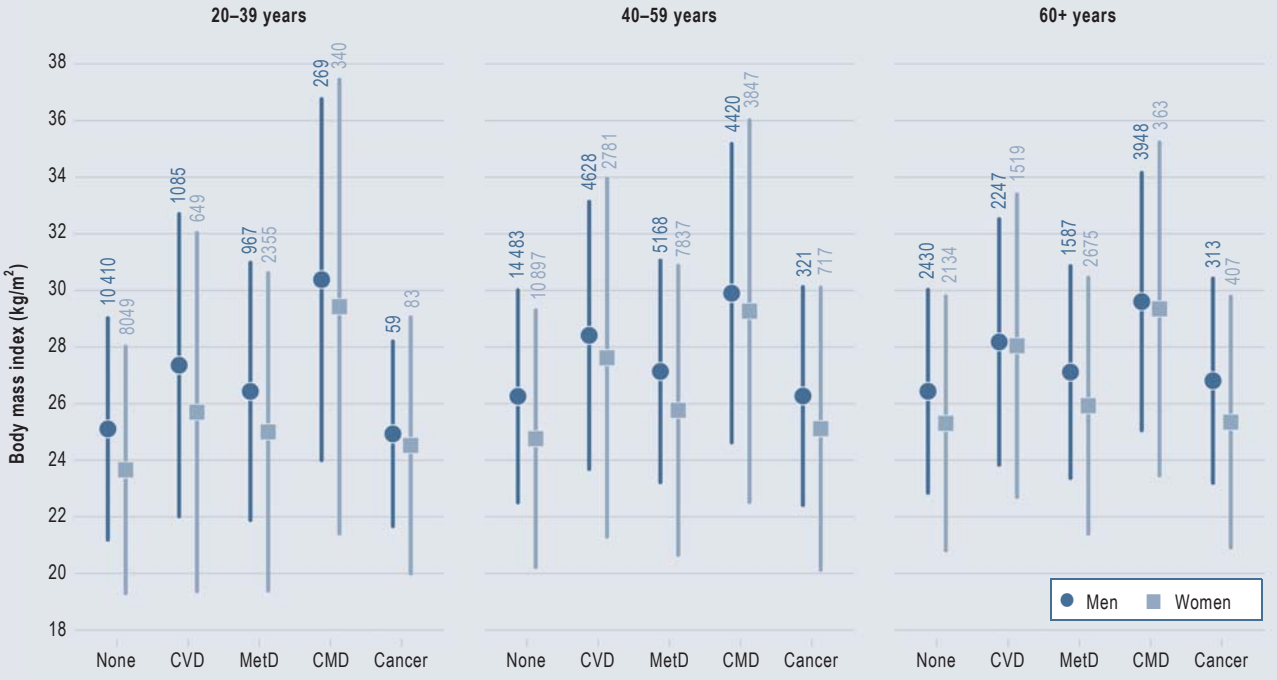
VAT was higher in diseased than healthy participants, yet differences between genders and age groups persisted. The largest VAT difference was between men aged 60+ years with CMD (8.7 cm) and healthy men (7.1 cm) *(eSupplement-Figure 2, eSupplement-Figure 5)*.

Diseased participants exhibited larger body fat percentages. The largest difference was in the group of men aged 20–39 years, where those with CMD averaged 27.5% body fat versus 20.5% in their healthy counterparts *(eSupplement-Figure 2, eSupplement-Figure 6)*.

Body mass index and cancer

Among 7184 cancer cases, 4033 were considered to be associated with obesity, with breast cancer to the fore. BMI was slightly higher in obesity-related cancers, though the BMI differences were negligible. For example, BMI in women aged 60+ years was 27.5 kg/m² without cancer and 27.9 kg/m² with obesity-related cancer *(eSupplement-Figure 7)*.

Figure 1



Mean and standard deviation of body mass index (kg/m²) by sex, age, and health status. The figures represent the numbers of participants. CVD, Cardiovascular disease; MetD, metabolic disease; CMD, cardiometabolic disease

Discussion

We present clinically obtained anthropometric measurements from a large German cohort, stratified by sex, age, and health status. Men showed larger BMI, waist circumference, and VAT than women, but lower hip circumference, SAT, and body fat percentage. Anthropometric measures tended to increase with age. Persons with CMD had larger body size measures than those with either CVD or MetD.

Overweight and obesity were highly prevalent in NAKO, with men showing higher BMI than women. These findings tendentially agree with the 2019/2020 German Health Update (GEDA) (19), the primary distinction being more frequent occurrence of overweight and adiposity in NAKO than in GEDA. One possible reason for the higher BMI in NAKO is the small difference in age distribution. Moreover, we utilized clinically obtained body size measurements, whereas GEDA relied on data supplied by the study participants themselves. Consequently, the self-reported data in GEDA may underestimate the current status of adiposity in Germany. While the prevalence of overweight and obesity in NAKO lies below the European average of 59% (1), it is helpful to consider these factors when interpreting NAKO and GEDA data.

Body size measures generally increased with age, with the exception of SAT in men over the age of 60 years, in whom no further increase was discernable. One possible reason is age-related redistribution of adipose tissue, causing SAT loss (20).

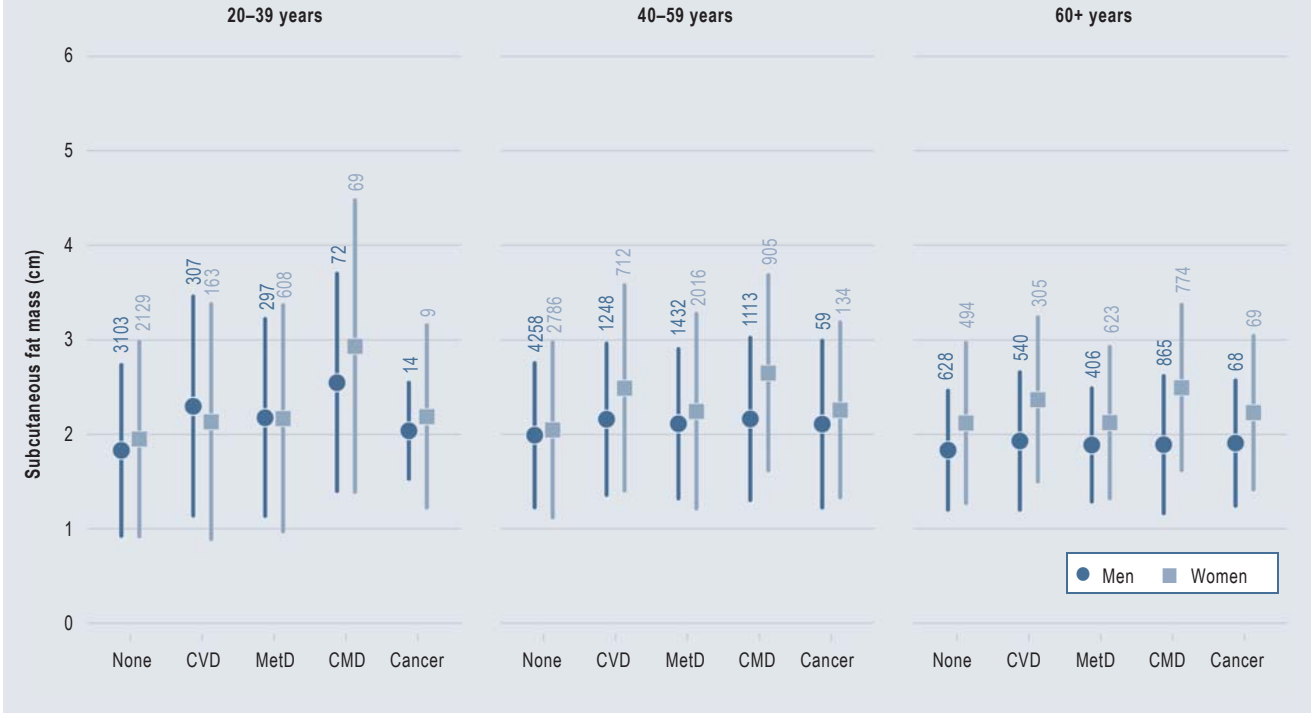
Participants with chronic diseases had higher BMI, waist and hip circumferences, VAT, and body fat percentage than healthy participants. This corresponds to previous findings in adults from the UK with diabetes from the UK (21). Furthermore, these body size measures were greater in participants with CVD than in those with MetD. One possible explanation for the lower body size measures in participants with MetD is the inclusion in our definition of MetD of thyroid hyperfunction, which if left untreated is associated with weight loss (22).

Body size measures were found to be particularly high in participants who had both CVD and MetD. This underlines the central importance of obesity as a risk factor for multimorbidity. Efforts to prevent multimorbidity should therefore focus also on obesity to reduce the complexity of prevention programs with multiple targets (23).

Unlike other body size measures, SAT showed no notable differences between healthy and diseased older men. This was consistent with previous studies showing a weak or inverse association between SAT and comorbidities in both sexes (24–26).

We observed only slight differences in body size measures between healthy participants and those with cancer, in contrast to the more pronounced differences between healthy participants and those with CVD, MetD, or CMD. The small differences in body size between healthy participants and those with cancer may be due to varying effects on body size across different types of cancer: some cancer types are associated with an increase in body size, others with a decrease, leading to minimal changes when considering all cancers together. When we assessed BMI by cancer type, we noted a slight BMI increase among those with obesity-related cancers, with

Figure 2



Mean and standard deviation of subcutaneous adipose tissue by sex, age, and health status. The figures represent the numbers of participants. CVD, Cardiovascular disease; MetD, metabolic disease; CMD, cardiometabolic disease

breast cancer being the predominant entity in this category.

Strengths and limitations

Our study has certain limitations. NAKO does not fully reflect the totality of the German population, limiting the extrapolation of our findings to the general population. The low response rate introduced potential selection bias (15); to counter this, the NAKO study group is developing weightings to achieve better comparability with the target population (27).

We present data without assessing their statistical significance, focusing instead on the clinical relevance of associations. Our cross-sectional design precludes identification of cause–effect relationships between exposures and outcomes, but future NAKO follow-up studies will examine anthropometric measures and their association with disease risk longitudinally.

Data on prevalent diseases were based on self-reports by the participants, yet they are comparable with physician-reported data (28, 29). To enhance the validity of the disease data, the NAKO study group is currently setting up continuous systematic linkage with health insurance, cancer registry, and death registry data (15).

Despite certain limitations, our study provides comprehensive current data on anthropometric measures from Germany's largest health study to date. Furthermore, it enables international comparisons and goes beyond BMI to offer a broader view through detailed analysis of body composition. Centralized data control and standardized data collection yielded higher-quality data than previous self-report-based studies. This is especially important for the documentation of body mass, as self-reports underestimate body weight with increasing obesity (30).

Conclusion

We used state-of-the-art measurement procedures to obtain comprehensive contemporary anthropometric data on over 200 000 men and women in Germany. Our results provide important insights into the relationships between body size, age, sex, and health status. They clearly show higher anthropometric measures in multimorbid persons. Further research is warranted to explore prospectively the associations between body size measures and the risk of chronic disease in Germany.

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Conflict of interest statement
The authors declare that no conflict of interest exists.

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Supplementary material
eChecklist, eSupplement:
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Supplementary material

Differences in anthropometric measures according to sex, age, and health status in the German National Cohort (NAKO)

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S1. Pearson correlation and 95% confidence intervals of anthropometric measures

	Body mass index	Waist circumference	Hip circumference	SAT	VAT	Body fat %
Men, 20-39 years						
Body mass index	1.00 (1.00, 1.00)	0.91 (0.91, 0.91)	0.85 (0.84, 0.85)	0.72 (0.70, 0.73)	0.63 (0.61, 0.65)	0.83 (0.82, 0.83)
Waist circumference		1.00 (1.00, 1.00)	0.83 (0.82, 0.84)	0.73 (0.72, 0.74)	0.66 (0.64, 0.67)	0.85 (0.85, 0.86)
Hip circumference			1.00 (1.00, 1.00)	0.66 (0.62, 0.70)	0.49 (0.44, 0.54)	0.78 (0.77, 0.79)
SAT				1.00 (1.00, 1.00)	0.46 (0.44, 0.48)	0.76 (0.75, 0.77)
VAT					1.00 (1.00, 1.00)	0.59 (0.57, 0.61)
Body fat %						1.00 (1.00, 1.00)
Men, 40-59 years						
Body mass index	1.00 (1.00, 1.00)	0.91 (0.91, 0.91)	0.84 (0.84, 0.85)	0.48 (0.46, 0.49)	0.65 (0.64, 0.66)	0.79 (0.79, 0.80)
Waist circumference		1.00 (1.00, 1.00)	0.83 (0.82, 0.83)	0.48 (0.46, 0.49)	0.69 (0.68, 0.70)	0.83 (0.82, 0.83)
Hip circumference			1.00 (1.00, 1.00)	0.50 (0.47, 0.53)	0.51 (0.47, 0.53)	0.71 (0.70, 0.71)
SAT				1.00 (1.00, 1.00)	0.26 (0.24, 0.28)	0.52 (0.51, 0.53)
VAT					1.00 (1.00, 1.00)	0.63 (0.62, 0.64)
Body fat %						1.00 (1.00, 1.00)
Men, 60+ years						
Body mass index	1.00 (1.00, 1.00)	0.91 (0.90, 0.91)	0.85 (0.84, 0.86)	0.30 (0.28, 0.33)	0.64 (0.62, 0.65)	0.75 (0.74, 0.75)
Waist circumference		1.00 (1.00, 1.00)	0.83 (0.82, 0.84)	0.29 (0.26, 0.31)	0.67 (0.66, 0.69)	0.77 (0.77, 0.78)
Hip circumference			1.00 (1.00, 1.00)	0.38 (0.33, 0.43)	0.46 (0.41, 0.51)	0.66 (0.65, 0.68)
SAT				1.00 (1.00, 1.00)	0.10 (0.07, 0.12)	0.32 (0.29, 0.34)
VAT					1.00 (1.00, 1.00)	0.60 (0.59, 0.62)
Body fat %						1.00 (1.00, 1.00)

	Body mass index	Waist circumference	Hip circumference	SAT	VAT	Body fat %
Women, 20-39 years						
Body mass index	1.00 (1.00, 1.00)	0.89 (0.89, 0.89)	0.88 (0.88, 0.89)	0.76 (0.74, 0.77)	0.59 (0.58, 0.61)	0.88 (0.87, 0.88)
Waist circumference		1.00 (1.00, 1.00)	0.80 (0.79, 0.81)	0.75 (0.73, 0.76)	0.57 (0.56, 0.59)	0.81 (0.81, 0.82)
Hip circumference			1.00 (1.00, 1.00)	0.66 (0.62, 0.70)	0.42 (0.37, 0.48)	0.82 (0.81, 0.83)
SAT				1.00 (1.00, 1.00)	0.47 (0.45, 0.49)	0.76 (0.75, 0.77)
VAT					1.00 (1.00, 1.00)	0.51 (0.49, 0.54)
Body fat %						1.00 (1.00, 1.00)
Women, 40-59 years						
Body mass index	1.00 (1.00, 1.00)	0.90 (0.90, 0.90)	0.89 (0.89, 0.90)	0.66 (0.65, 0.67)	0.68 (0.67, 0.69)	0.85 (0.85, 0.85)

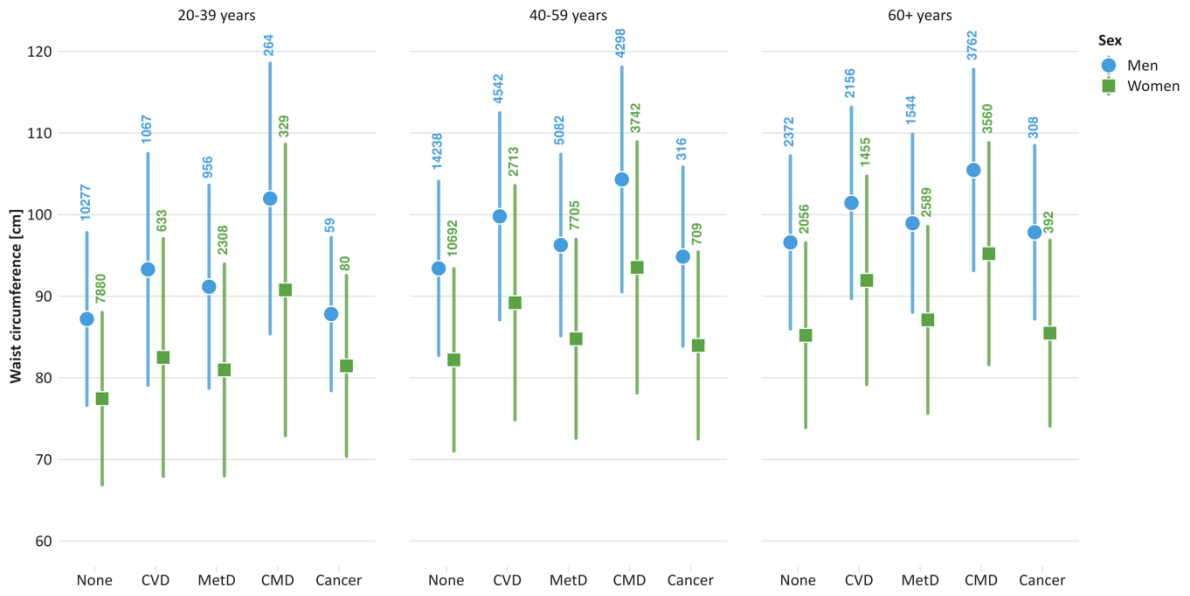
Waist circumference		1.00 (1.00, 1.00)	0.82 (0.82, 0.83)	0.69 (0.68, 0.70)	0.70 (0.69, 0.71)	0.81 (0.80, 0.81)
Hip circumference			1.00 (1.00, 1.00)	0.65 (0.63, 0.67)	0.59 (0.56, 0.61)	0.79 (0.78, 0.80)
SAT				1.00 (1.00, 1.00)	0.51 (0.49, 0.52)	0.69 (0.68, 0.70)
VAT					1.00 (1.00, 1.00)	0.62 (0.61, 0.63)
Body fat %						1.00 (1.00, 1.00)
Women, 60+ years						
Body mass index	1.00 (1.00, 1.00)	0.90 (0.90, 0.90)	0.90 (0.90, 0.91)	0.56 (0.54, 0.57)	0.66 (0.65, 0.68)	0.83 (0.82, 0.83)
Waist circumference		1.00 (1.00, 1.00)	0.84 (0.83, 0.84)	0.56 (0.54, 0.58)	0.70 (0.68, 0.71)	0.77 (0.76, 0.77)
Hip circumference			1.00 (1.00, 1.00)	0.56 (0.51, 0.60)	0.57 (0.52, 0.61)	0.78 (0.77, 0.79)
SAT				1.00 (1.00, 1.00)	0.42 (0.40, 0.44)	0.57 (0.55, 0.58)
VAT					1.00 (1.00, 1.00)	0.58 (0.56, 0.60)
Body fat %						1.00 (1.00, 1.00)
Body mass index measured in kg/m^2; Waist and hip circumference measured in cm; SAT: Subcutaneous adipose tissue in cm; VAT: Visceral adipose tissue in cm						

S2. Anthropometric measures by sex, age, and health status

Measure	**Health status**	**Men**			**Women**		
		20-39 years	**40-59 years**	**60+ years**	**20-39 years**	**40-59 years**	**60+ years**
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Body mass index [kg/m^2]	None	25.10±3.91	26.26±3.75	26.44±3.59	23.66±4.36	24.76±4.54	25.30±4.49
	CVD	27.36±5.35	28.41±4.72	28.18±4.34	25.70±6.33	27.62±6.33	28.04±5.34
	MetD	26.43±4.55	27.14±3.91	27.12±3.74	25.00±5.61	25.76±5.11	25.93±4.52
	CMD	30.38±6.38	29.90±5.28	29.61±4.55	29.43±8.02	29.27±6.75	29.35±5.89
	Cancer	24.93±3.27	26.27±3.85	26.81±3.61	24.53±4.52	25.11±4.99	25.35±4.43
Waist circumference [cm]	None	87.21±10.58	93.41±10.66	96.59±10.61	77.44±10.56	82.20±11.17	85.21±11.31
	CVD	93.29±14.20	99.79±12.68	101.43±11.73	82.50±14.57	89.20±14.34	91.94±12.77
	MetD	91.16±12.44	96.27±11.11	98.94±10.91	80.97±12.97	84.79±12.19	87.10±11.46
	CMD	101.97±16.59	104.31±13.77	105.46±12.33	90.77±17.86	93.53±15.38	95.21±13.61
	Cancer	87.82± 9.39	94.85±10.97	97.83±10.63	81.47±11.07	83.96±11.45	85.47±11.39
Hip circumference [cm]	None	99.41±7.57	100.22±6.85	98.93±6.79	99.45±8.65	100.72±9.44	99.96±8.66
	CVD	101.78± 9.09	103.44± 8.74	101.61± 7.67	104.54±12.62	105.46±12.19	105.18±10.49
	MetD	100.99± 8.12	101.25± 7.28	100.14± 6.35	101.32± 9.46	102.56±10.02	101.00± 8.39
	CMD	105.46± 7.03	104.97± 9.05	103.06± 8.38	108.77±15.81	107.85±13.03	107.15±12.34
	Cancer	100.18± 5.48	99.71± 6.21	99.33± 5.52	102.73±10.41	100.61± 8.82	101.27± 9.61
Subcutaneous adipose tissue [cm]	None	1.83±0.91	1.99±0.76	1.83±0.63	1.95±1.03	2.05±0.93	2.12±0.85
	CVD	2.30±1.16	2.16±0.80	1.93±0.73	2.13±1.24	2.49±1.09	2.37±0.87
	MetD	2.18±1.04	2.11±0.79	1.89±0.60	2.17±1.19	2.24±1.03	2.12±0.80
	CMD	2.55±1.15	2.16±0.86	1.89±0.73	2.93±1.54	2.65±1.03	2.50±0.87

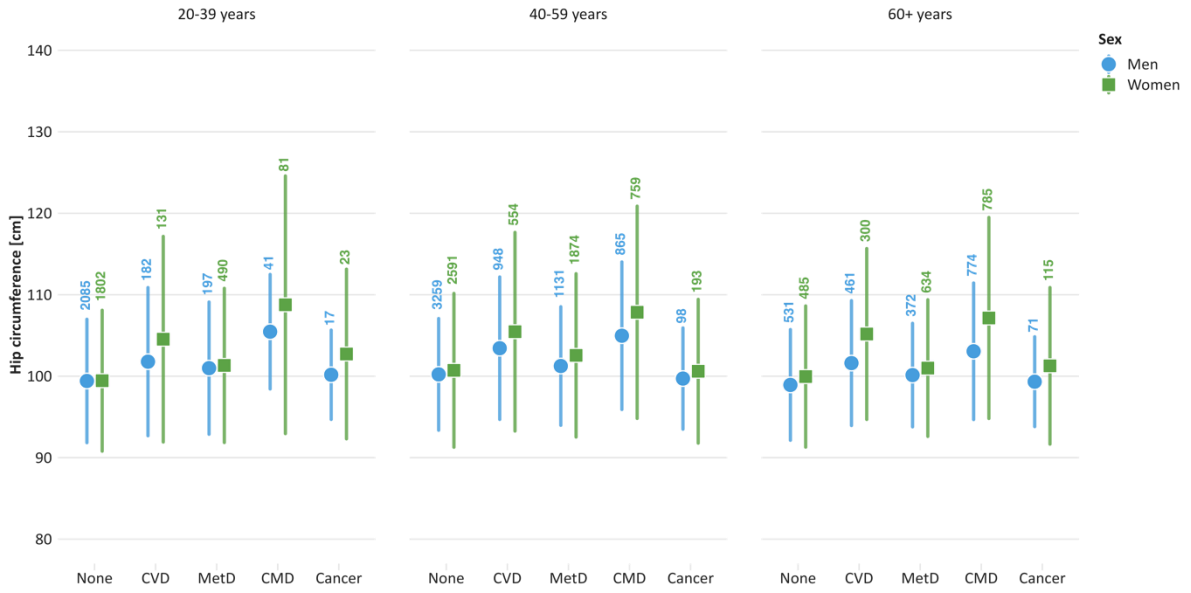
	Cancer	2.04±0.51	2.11±0.88	1.91±0.66	2.19±0.96	2.26±0.92	2.23±0.81
Visceral adipose tissue [cm]	None	5.94±1.79	6.94±2.14	7.13±2.14	4.27±1.38	4.90±1.77	5.44±1.81
	CVD	6.43±2.02	7.84±2.39	8.08±2.38	4.68±1.80	5.87±2.19	6.45±2.26
	MetD	6.70±2.19	7.36±2.22	7.62±2.29	4.52±1.52	5.24±1.93	5.72±2.04
	CMD	7.67±2.47	8.50±2.63	8.68±2.47	5.57±2.47	6.36±2.28	6.84±2.32
	Cancer	6.01±1.96	7.34±2.17	7.49±2.07	5.06±0.75	5.28±1.84	5.70±1.91
Body fat percentage [%]	None	20.52±7.23	24.00±6.28	26.53±5.91	30.36±7.23	34.13±6.90	38.24±6.25
	CVD	23.77±8.34	26.85±6.58	28.72±6.04	33.11±8.61	37.77±7.64	41.49±6.39
	MetD	23.18±7.56	25.67±6.13	27.55±5.75	32.56±8.03	35.69±7.17	39.13±6.05
	CMD	27.77±8.39	28.98±6.46	30.55±5.92	37.91±8.80	40.01±7.33	42.66±6.06
	Cancer	21.42±6.41	24.64±6.90	27.03±6.52	32.94±7.49	35.54±6.53	38.44±6.46
SD: Standard deviation; CVD: Cardiovascular disease; MetD: Metabolic disease; CMD: Cardiometabolic disease (CVD+MetD)							

S3. Mean and standard deviation of waist circumference by sex, age, and health status



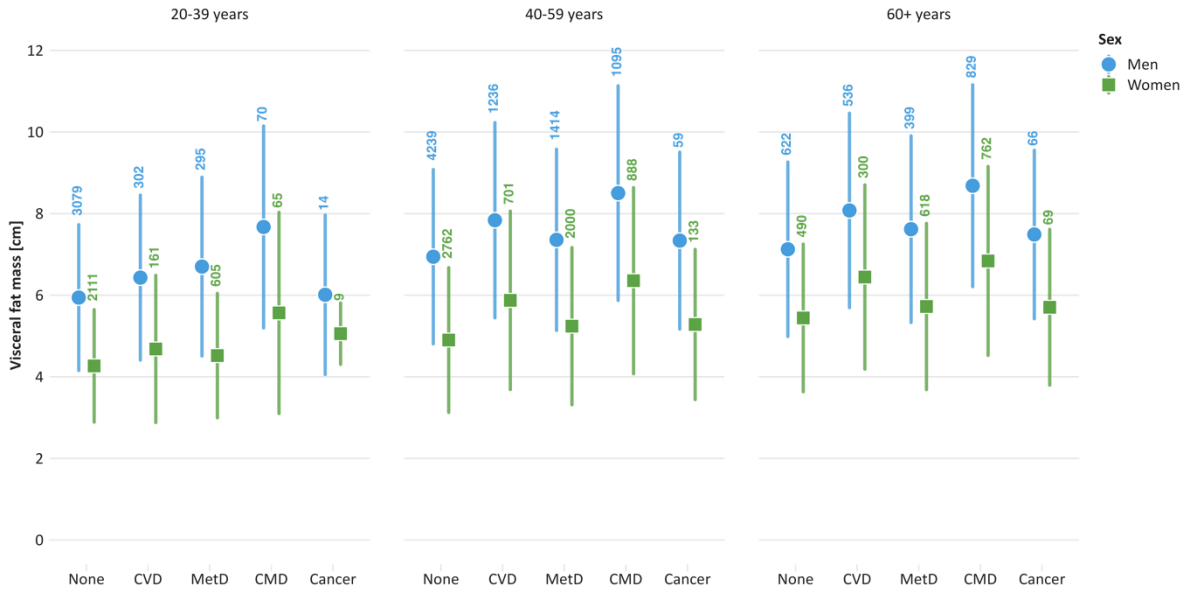
The figures represent the numbers of participants. CVD: Cardiovascular disease; MetD: Metabolic disease; CMD: Cardiometabolic disease

S4. Mean and standard deviation of hip circumference by sex, age, and health status



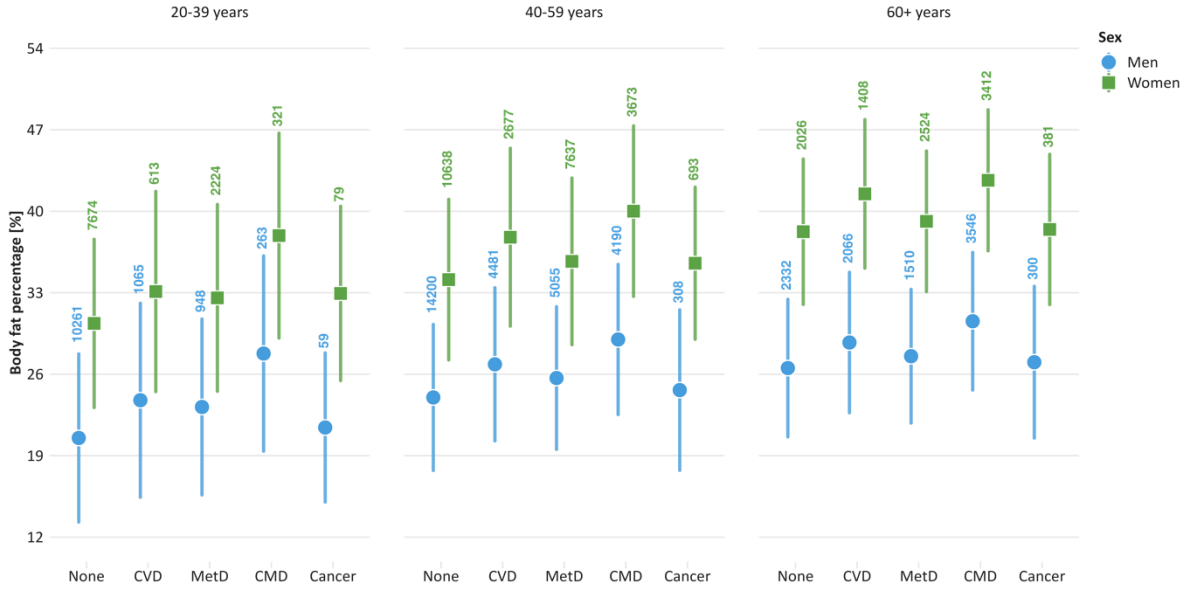
The figures represent the numbers of participants. CVD: Cardiovascular disease; MetD: Metabolic disease; CMD: Cardiometabolic disease

S5. Mean and standard deviation of visceral adipose tissue by sex, age, and health status



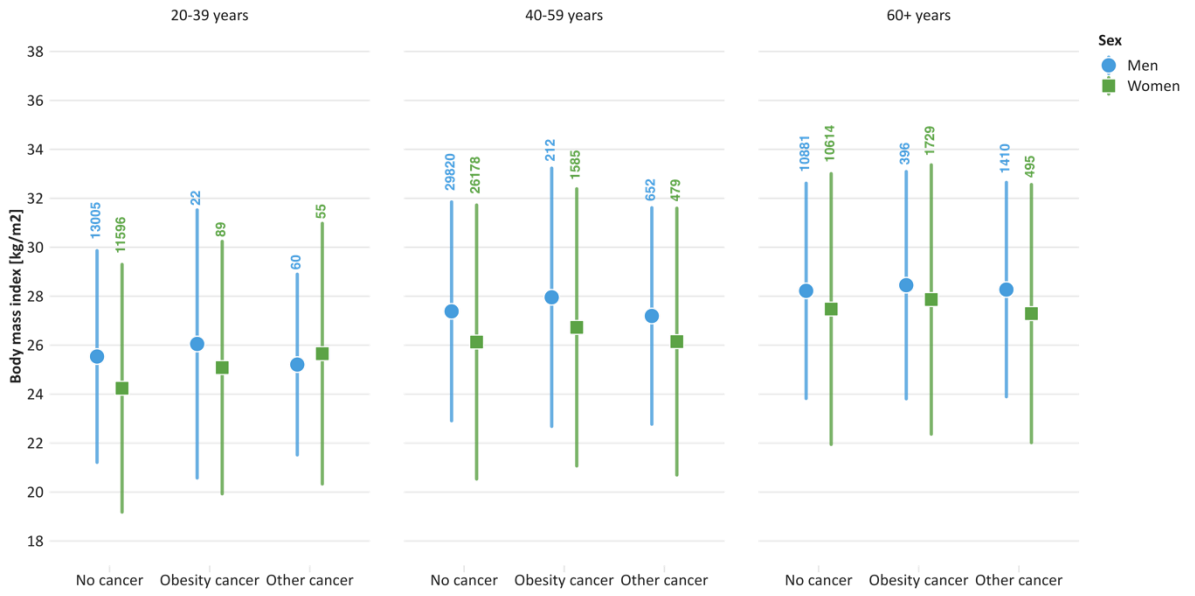
The figures represent the numbers of participants. CVD: Cardiovascular disease; MetD: Metabolic disease; CMD: Cardiometabolic disease

S6. Mean and standard deviation of body fat percentage by sex, age, and health status



The figures represent the numbers of participants. CVD: Cardiovascular disease; MetD: Metabolic disease; CMD: Cardiometabolic disease

S7. Mean and standard deviation of body mass index by sex, age, and cancer



Note: The figures represent the numbers of participants. Obesity-related cancers are esophagus, stomach, colon, rectum, liver, gallbladder, pancreas, breast, corpus uteri, ovary, kidney, brain, thyroid, and bone cancer following reference (17) of the manuscript.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract *The title contains the name of the study (NAKO) and the abstract says that it is a cross-sectional work*	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found *The abstract summarizes methods and results.*	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported *The background and rationale are described in the Introduction section*	3
Objectives	3	State specific objectives, including any prespecified hypotheses *The objective of the study is described in the "Introduction" section (last sentence)*	3
Methods			
Study design	4	Present key elements of study design early in the paper *The study design is described in the section "Study population" (first subsection in the Methods section)*	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection *This information is described in the sections "Study population" and "Anthropometric measures"*	4,5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants *Eligibility criteria is described in the sections "Study population" and "Statistical analysis"*	4,5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable *Outcomes are described in the section "Anthropometric measures".* *Exposures are described in the section "Independent variables"*	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group *Outcomes are described in the section "Anthropometric measures".* *Exposures are described in the section "Independent variables"*	4,5
Bias	9	Describe any efforts to address potential sources of bias *Efforts to reduce bias are described in the sections "Study population", "Anthropometric measures", "Independent variables", and discussed in the Discussion and Strengths & Limitations*	4,5,8,9
Study size	10	Explain how the study size was arrived at *The study sample is described in the sections "Study population" and "Statistical analysis"*	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4,5

		Use of variables is described in the sections "Statistical analysis"	
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding *Statistical methods are discussed in the „Statistical analysis" section*	5
		(*b*) Describe any methods used to examine subgroups and interactions *Described in the „Statistical analysis" section*	5
		(*c*) Explain how missing data were addressed *Described in the „Statistical analysis" section*	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy *Not applicable*	
		(*e*) Describe any sensitivity analyses *There are no sensitivity analyses due to the descriptive nature of the study*	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed *Described in the sub-sectios "Study population"*	4
		(b) Give reasons for non-participation at each stage *Not applicable*	
		(c) Consider use of a flow diagram *Not applicable*	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders *Population characteristics are provided in the Results section and in Table 1 and in Supplement S2*	6,7,15
		(b) Indicate number of participants with missing data for each variable of interest *Missings are presented in Table 1*	15
Outcome data	15*	Report numbers of outcome events or summary measures *Numbers are reported in the Results section and Table 1*	6,7,15
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included *Not applicable, due to descriptive nature of the study*	
		(*b*) Report category boundaries when continuous variables were categorized *Age was categorized as described in the "Independent variables" subsection in the Methods section*	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period *Not applicable*	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses *Not applicable*	
Discussion			

Key results	18	Summarise key results with reference to study objectives *Results are summarized in the first paragraph of the Discussion*	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias *Limitations and bias are discussed at the end of the Discussion*	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence *Overall interpretation is given in the Conclusion section*	10
Generalisability	21	Discuss the generalisability (external validity) of the study results *Limited generalisability is discussed in the Discussion section*	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based *Stated in the "Acknowledgement" section*	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.