General and abdominal obesity and incident asthma in adults: The HUNT Study.

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Abstract

Measures of body mass index (BMI) and waist circumference (WC) define general obesity and abdominal obesity respectively. While high BMI has been established as a risk factor for asthma in adults, WC has seldom been investigated.

To determine the association between BMI, WC, and incident asthma in adults, we conducted a prospective study (n=23 245) in a population living in Nord-Trøndelag, Norway in 1995-2008.

Baseline BMI and WC were measured and categorised as general obesity (BMI ≥30.0 kg/m^2) and abdominal obesity (WC ≥88 cm in women and ≥102 cm in men). Incident asthma was self-reported new-onset cases during an 11-year follow-up period. Odds ratios (ORs) for asthma associated with obesity were calculated using multivariable logistic regression.

General obesity was a risk factor for asthma in women (OR 1.96, 95% confidence interval (CI) 1.52-2.52) and men (OR 1.84, 95% CI 1.30-2.59). In women, after additional adjustment for BMI, abdominal obesity remained a risk factor for asthma development (OR 1.46, 95% CI 1.04-2.05). Abdominal obesity seems to increase the risk of incident asthma in women additionally to BMI, indicating that using both measures of BMI and WC in women may be a superior clinical assessment for asthma risk than any measure alone.

Key words: body mass index, prospective study, waist circumference.

Abbreviations: BMI = body mass index; CI = confidence interval;
COPD = chronic obstructive pulmonary disease; GERD = Gastroesophageal reflux disease;
HUNT = Nord-Trøndelag Health Study; OR = odds ratio; SDB = sleep disorder breathing;
WC = waist circumference; WHO = World Health Organisation.

Introduction

Obesity is defined as an excess of body fat and is commonly reflected by the measurements of body mass index (BMI) or waist circumference (WC) [1]. The prevalence and incidence of obesity have increased substantially in the last few decades [1]. The International Obesity Task Force estimates that globally 475 million adults are obese and 1 billion are overweight [2]. In the European Union this represents about 60% of the adult population [2]. Obesity is the fifth leading risk factor for global deaths and a strong risk factor for type 2 diabetes, cardiovascular disease and various types of cancer [1, 2]. Waist circumference is a measure of abdominal obesity and is associated with all-cause mortality [3, 4]. Recent studies show that abdominal obesity is increasing at an even higher rate than general obesity [5]. The global obesity epidemic is projected to continue to rise and becomes the most significant cause of poor health.

A number of studies have prospectively investigated the association between obesity and asthma. Overweight and obesity, as measured by BMI have been found to increase the incidence of asthma in a dose-dependent manner but sex-related differences in the association are inconsistent [6]. Body mass index however cannot distinguish between fat mass and muscle mass [7]. Most notably BMI has limitations in predicting abdominal fat deposition, which is associated with reduced pulmonary function, metabolic syndrome and cardiovascular complications [8-10]. Abdominal subcutaneous and visceral fat deposits as measured by WC may be metabolically different from other body fat; indicating a separate risk for common medical complications from peripheral fatness measured by BMI [8]. Only a few studies have investigated the association between abdominal obesity and asthma, most of which have been cross-sectional and have not taken BMI into consideration [11-17]. BMI and WC are highly correlated [4], to study the association between WC and asthma, BMI should be considered.

This study aimed to prospectively explore the associations of BMI and WC with incident asthma in women and men.

Methods

Study population

The Nord-Trøndelag Health Study (HUNT) is a population of women and men aged 19 years or older living in the Nord-Trøndelag County (22 463 km^2), Norway [18]. The county is situated in central Norway and typically has cold dry winters and mild summers. The county population in 1995 was 127 000, with the majority being Caucasians [18]. The county is characterized by several cities and farming towns, with the majority of the population residing in urban areas.

The cohort members in the current analysis participated in health surveys in 1995 to 1997 (HUNT 2), and in 2006 to 2008 (HUNT 3). Of the 65 215 participants who attended HUNT 2 [19], 37 059 subjects also participated in HUNT 3, 11 years apart. We established a cohort population including all subjects who participated in both HUNT 2 and HUNT 3 and were aged <65 years in HUNT 3 (n=25 616) (Figure 1). The age limit was set prior to conducting the study for two main reasons: 1) There is an increased possibility of misclassification of chronic obstructive pulmonary disease (COPD) as asthma in the elderly. 2) Obesity increases overall mortality [3, 4]. If senior asthma patients, who are obese, are more likely to die compared with those who are not obese, it can result in an under-estimation of the association of interest. To study incident asthma, we excluded 56 participants with missing information on asthma in HUNT 2 and HUNT 3, and 1995 subjects with asthma at baseline, leaving 23 566 subjects free from asthma in the study cohort.

Measures of general and abdominal obesity

Height, weight, and WC were measured in both surveys by trained nurses. Height was measured to the nearest centimetre (cm), and weight to the nearest half-kilogram (kg). High BMI reflects general overweight and obesity. To calculate BMI, body weight in kilograms was divided by the squared value of the body height in meters (kg/m^2). We adopted categories of BMI from the World Health Organisation (WHO): BMI <25.0 kg/m^2 (normal/underweight), BMI 25.0-29.9 kg/m^2 (general overweight), and BMI ≥30.0 kg/m^2 (general obese) [20].

Waist circumference was measured to the nearest centimetre, horizontally at the level of the umbilicus with the participants standing and arms hanging relaxed. Waist circumference is commonly used to reflect abdominal obesity. We adopted categories of WC from the WHO and Lean et al.: WC <80.0 cm (normal), WC 80.0-87.9 cm (abdominal overweight) and WC ≥88.0 cm (abdominal obese) in women; WC <94.0 cm (normal), WC 94.0-101.9 cm (abdominal overweight) and WC ≥102.0 cm (abdominal obese) in men [20, 21].

Covariables

Important variables at baseline were collected by self-administered questionnaires, including age (19-29, 30-39, 40-49, 50-55 years), years of education (<10, 10-12, ≥13 years), current smoker (yes/no), physical activity (<1, 1-2, ≥3 hours/week), family history of asthma (yes/no), social benefit recipient (yes/no), and economic difficulty (yes/no). Family history of asthma included any family member (father, mother, brother or sister) with asthma. Social benefit included participants that received sick pay, rehabilitation benefits, retraining benefits, disability pension, old age pension, family income supplement, unemployment benefits, transitional benefits, widow's pension or any other benefit. Economic difficulties included participants that had difficulties meeting the cost of food, transport, and/or housing.

Asthma outcome

HUNT 2 and HUNT 3 included the same survey question on asthma, i.e., "Do you have or have you had asthma?" We defined incident asthma as "no" to this question in HUNT 2 and "yes" in HUNT 3. Self-reported asthma is commonly used in population based studies, this method has been rigorously evaluated and displays high sensitivity and specificity [22-24].

Statistical methods

The association of overweight and obesity with incident asthma was analysed in 23 245 participants with complete information on BMI, WC and asthma. Pearson chi-square tests were used to compare baseline characteristics between women and men. Correlation of BMI and WC was assessed using Pearson's correlation coefficient. We calculated the cumulative incidence of asthma risk according to the categories of overweight and obesity in logistic regression models, reporting odds ratios (ORs) and the 95% confidence intervals (CIs). For test of trend, we calculated the association with incident asthma by treating the categories of BMI and WC as ordinal variables. ORs for cumulative incidence of asthma were also calculated with BMI and WC as continuous variables. In the multivariable logistic regression analyses we adjusted for covariates including education, smoking status, physical activity, family history of asthma, social benefit, economic difficulty, and age. Additionally, models for abdominal obesity were adjusted for BMI as a continuous variable to reduce the degrees of freedom in the model. We assessed the linearity of associations by introducing a term for the square of BMI or WC in the logistic regression models and comparing models with and without the squared term in likelihood ratio tests. Tests for interaction between BMI categories (<25.0, 25.0-29.9, ≥30.0) and sex were performed as likelihood ratio tests in logistic regression models. Subgroup analyses were completed by stratifying on age (<40 and ≥40 years), years of education (<13, ≥13 years), physical activity (<1, 1-2, ≥3 hours/week), family history of asthma (yes/no), current smoking status (yes/no), social benefit (yes/no) and

economic difficulties (yes/no) at baseline. To assess the robustness of our findings, we performed sensitivity analyses repeating the study with a stricter definition for incident asthma; i.e. self-reported asthma and use of asthma medication at HUNT 3, without report of attacks of wheezing at baseline (n=510) vs. the reference group with no asthma and no wheeze at baseline or follow-up (n=19 702). We also repeated the analyses excluding subjects who reported having chronic bronchitis, emphysema or COPD i.e., "Have you had or do you have any of the following: chronic bronchitis, emphysema or COPD?" (n=22 857 for analysis). We used STATA 11.1 for windows, for all statistical analyses (StataCorp LP, College Station, Texas).

Ethics

The project was approved by the Regional Committee for Ethics in Medical Research. All participants signed informed consent for participation and the use of data in research.

Results

Of the 23 245 adults in the analysis, the prevalence of general obesity at baseline was 12% in both sexes (Table 1), but the prevalence of abdominal obesity was higher in women than in men (17.5% vs. 8.9%). There was a higher 11-year cumulative incidence of asthma in women compared with men (4.1% vs. 2.9%). Body mass index and WC values were highly correlated with Pearson correlation coefficient 0.89 in women and 0.84 in men ($P<0.001$ for both correlations). A higher proportion of women reported family history of asthma, economic difficulty, receiving social benefit, smoking and more hours of physical activity than men.

Body mass index was associated with incident asthma in both sexes. After adjustment for covariates, the ORs for general obesity when compared to normal BMI were 1.96 (95% CI 1.52-2.52) in women and 1.84 (95% CI 1.30-2.59) in men (Table 2). A dose response relationship between BMI and incident asthma was observed and the adjusted ORs for BMI categories were similar for women and men (p for interaction = 0.66). The adjusted OR for BMI (per 5kg/m^2) as a continuous variable in women was 1.32 (95% CI 1.19-1.45) and 1.38 (95% CI 1.17-1.62) in men.

The adjusted ORs for abdominal obesity, compared to normal WC were 1.88 (95% CI 1.51-2.34) in women and 1.55 (95% CI 1.08-2.21) in men (Table 3). Further adjustment for BMI, i.e. when subjects had similar BMI values, those with abdominal obesity yielded ORs of 1.46 (95% CI 1.04-2.05) in women and 0.88 (95% CI 0.53-1.47) in men. A dose response relationship between WC and incident asthma was observed in women (p for trend = 0.03) but not in men (p for trend = 0.53) after adjustment for BMI. ORs for incident asthma after adjustment for BMI rose steadily in women with increasing WC, while ORs remained stable along the reference level line in men (Figure 2). The ORs for WC (per 10 cm) as a continuous

variable after adjustment for BMI were 1.23 (95% CI 1.04-1.44) in women and 0.97 (95% CI 0.76-1.23) in men.

A subgroup analyses by age revealed some variation in men (Table 4). A higher OR for incident asthma was observed in general obese men over the age of 40 years (adjusted OR 2.35, 95% CI 1.50-3.68), compared to those less than 40 years of age (adjusted OR 1.28, 95% CI 0.71-2.32). We also observed general obese people with 13 years or more education (adjusted OR 3.35, 95% CI 1.91-5.90 in women and adjusted OR 3.70, 95% CI 1.82-7.52 in men) were at a higher risk of developing asthma than those with less than 13 years' education (OR 1.76, 95% CI 1.32-2.33 in women and OR 1.56, 95% CI 1.05-2.33 in men). The association in the subgroups of education <10 years and 10-12 years were similar; therefore these subgroups were combined to improve power in the analysis. We found no other strong variations within subgroups by physical activity, family history of asthma, smoking status, social benefit and economic difficulties.

The sensitivity analyses using a stricter case definition of asthma, gave similar results to the original analyses. After adjustment for covariates, the ORs for general obesity when compared to normal BMI were 2.22 (95% CI 1.63-3.03) in women and 1.89 (95% CI 1.23-2.91) in men. The adjusted ORs for incident asthma associated with BMI continuous (per 5 kg/m^2) were 1.35 (95% CI 1.20-1.53) in women and 1.42 (95% CI 1.15-1.75) in men. After adjustment for covariates and BMI, the ORs for abdominal obesity when compared to normal WC were 1.38 (95% CI 0.90-2.13) in women and 0.59 (95% CI 0.30-1.17) in men. The OR for WC continuous (per 10 cm) were 1.25 (95% CI 1.02-1.54) in women and 0.87 (95% CI 0.64-1.21) in men. The sensitivity analyses excluding subjects with chronic bronchitis, emphysema or COPD gave similar results to the original analyses (data not shown).

Discussion

In the 11-year follow-up, we found that BMI derived general overweight and obesity was a risk factor for incident asthma and there was no difference between women and men. Additionally to BMI we found that WC derived abdominal obesity was a risk factor for incident asthma in women.

Our results on the BMI-derived obesity and asthma association are consistent with previous prospective studies which found that BMI had a strong dose response relationship with asthma development [6, 17, 25-30]. In a most recent meta-analysis study [6], Beuther and Sutherland analysed seven prospective studies (n=333 102) evaluating BMI and incident asthma. The OR for incident asthma associated with general obesity was 1.92 (95% CI 1.43-2.59) in this meta-analysis, similar to our finding in both women and men. Although BMI derived obesity increases the incidence of asthma, sex-related differences in the association have been inconsistent [6, 12, 13]. The finding in our study suggests no difference between women and men in the association between general obesity and incident asthma in this Norwegian population. Our results conform to Beuther and Sutherland's findings that obesity measured by BMI, and incident asthma, does not differ between sexes [6].

We observed that, after adjustment for BMI, being abdominal overweight or obese remained risk factors for incident asthma in women. This means that, when women had similar BMI values, those with abdominal obesity seemed to have an independent risk for asthma development. Therefore, large WC, in addition to BMI, seems to add to the risk of developing asthma in women. Our observations indicate the use of both measures of BMI and WC as a superior clinical assessment for asthma risk than any measure alone, particularly among women. This is one of the first prospective studies to observe the association of WC in addition to BMI with incident asthma. A few studies have investigated the association of WC

and asthma [11-17], and considerably fewer studies have taken BMI into consideration in the association [15, 17]. Most of these studies are cross-sectional in nature, which are subject to reverse causality and their observed association of WC with asthma may be confounded by BMI [11-16]. In the Nurses' Health Study of 85 911 women, WC was not found to be associated with incident asthma after adjustment for BMI [17]. Some of the differences could be related to the latter study having a shorter follow-up duration for WC (2 years vs. 11 years) and being carried out in different populations (United States vs. Norway). Conversely, a cross-sectional study published recently provided supportive evidence for our finding. Von Behren et al. studied 88 304 women in the California Teachers Study (CTS) cohort and observed, when stratifying abdominal obesity by general obesity, an OR for abdominally obese women without general obesity of being 1.67 (95% CI 1.51-1.85) [15]. .

Several proposed explanations may support obesity as a risk factor for asthma development. Shore and Johnston have suggested mechanistic mechanisms including reduced airway size and also gastroesophageal reflux disease (GERD), sleep disordered breathing (SDB), obesity-associated cytokines, chemokines and energy regulating hormones to be underlying mechanisms for obesity-related asthma [31, 32]. The additional contribution of abdominal obesity in women however suggests that the distribution of adipose tissue may play a role in asthma development. WC reflects abdominal subcutaneous and visceral adipose tissue which may be metabolically different from peripheral fatness measured by BMI [8]. Visceral adipose tissue has a major role in metabolic and cardiovascular complications related to obesity [8, 10]. Recent research has shed light on a positive association between metabolic syndrome and asthma prevalence [33]. There is also a possibility that the additional contribution of abdominal obesity on asthma is due to mechanical reasons. Beuther and colleagues suggest that excess adipose tissue results in reduced lung volumes, rapid shallow breathing and reduced peripheral airway diameter, which may contribute to airway hyper-

responsiveness and asthma [34]. These mechanical mechanisms may be more pronounced in people with abdominal than with general obesity. As evidence, reduced pulmonary function has been demonstrated among subjects with large WC irrespective of BMI [9]. Although non-significant, there seemed to be a sex-specific association between WC and incident asthma after adjustment for BMI in our study. The reasons behind this variation between sexes are unknown, but the mechanical theory may partially explain this sex-specificity. Compared to men, women have a smaller airway size relative to lung size [13]. An additional reduction in airway size caused by abdominal obesity may disproportionately increase the susceptibility of women to asthma. Further studies are needed to confirm the occurrence of this difference and the potential mechanisms that underlie this association.

The subgroup analyses revealed general obese men 40 years or older were at higher risk of asthma compared to men less than 40 years. This may be due to changes in body type between these two subgroups. It has been suggested that BMI may be a poor indicator of general obesity in young men, who can have a high BMI due to high muscle mass [12]. This may explain the non-significant association between general obesity and incident asthma observed in men <40 years of age. In women and men we observed a stronger association between general obesity and asthma among those with 13 years or more education compared to those with less than 13 years' education. Previous studies have suggested that low education may be a surrogate measure of other risk factors associated with low economic status [35]. These underlying factors may play a greater role in asthma development in the less educated subgroup compared to the higher education group. The absence of these risk factors in highly educated adults may leave general obesity to play a greater role in the development of asthma. Reporting bias may also exist if adults with high years of education are more likely to seek medical attention and diagnosed with asthma more regularly than adults with low education.

The major criticism of epidemiological studies of asthma and a limitation of our study is the lack of a true gold standard for asthma diagnosis. The use of self-reported asthma may have resulted in misclassification. Previous studies, however, suggest that validity and reliability of self-reported asthma are acceptable [22-24, 36]. To reduce misclassification we performed a sensitivity analysis with a stricter definition for asthma i.e. self-reported asthma, no wheeze at baseline and asthma medication use at follow up. To reduce misclassification of COPD with asthma we excluded people over the age of 65 years at follow-up in the study cohort. Additionally we performed analyses excluding participants who reported chronic bronchitis, emphysema or COPD in HUNT 3. Chronic obstructive pulmonary disease patients are more prone to be ex-smokers. Adjustment for smoking status i.e. current, ex-smoker and never smoker, was tested and no change was observed in our estimates. In general the sensitivity analyses supported our original findings. Misclassification of obesity is also a major concern for epidemiological studies. In our study BMI and WC were objectively measured to avoid reporting bias. Detection bias may also exist if obese people are more likely to come in contact with the health care system and diagnosed more frequently with asthma than non-obese individuals. However studies of asthma diagnosis have been inconsistent and it is uncertain whether detection bias exists between obese and non-obese people [36]. Even though the detailed health survey allowed us to examine a large range of baseline characteristics, residual confounding from unknown characteristics may have limited our study. Dietary constituents may affect both obesity and incident asthma [28, 36], and this could not be evaluated in our study. Obesity has also been suggested to increase the risk of asthma through comorbidities [32], for example, GERD and SDB are important risk factors for asthma in obese people. We did not have measures of GERD and SDB in our data but previous studies suggested that GERD and SDB may be on the causative pathway between obesity and asthma [31, 37]. Our prior hypothesis was that the association between obesity

and asthma might differ among senior vs. Younger and middle-aged people. Therefore, because of the age limit (<65 years) set in our study, we need to be cautious when generalizing these results. Our study population was in relative uniformity in terms of ethnicity (97% Caucasians), and environmental factors [18]. This would reduce the possibility of confounding by unmeasured factors. Importantly, the study design indicates the direction of the obesity-asthma association. It is also one of the first to prospectively study the impact of WC on incident asthma taking BMI into consideration.

In summary, general obesity is a risk factor for incident asthma in both men and women. However in women, measures of both general obesity and abdominal obesity may be superior for assessment of asthma risk than any measure alone. Further research is necessary to explore the mechanisms of how general and abdominal obesity contributes to asthma development.

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Table 1. Characteristics of the analysis cohort participants by sex, Nord-Trøndelag Health Study (HUNT), Norway.

	Women (n=12,784)		Men (n=10,461)		P value
	n	%	n	%	
Age (years)					
19-29	2,025	15.8	1,473	14.1	<0.001
30-39	3,884	30.4	3,022	28.9	
40-49	4,899	38.3	4,223	40.4	
50-55	1,976	15.5	1,743	16.7	
Smoking†					
Yes	4,074	33.7	2,631	26.4	<0.001
No	8,019	66.3	7,340	73.6	
Education (years) †					
<10	2,723	21.5	1,947	18.8	<0.001
10-12	6,509	51.4	5,816	56.1	
≥13 years	3,443	27.2	2,608	25.2	
Physical activity (hrs/wk) †					
<1	2,586	22.2	2,675	29.1	<0.001
1-2	4,997	42.8	3,385	36.9	
≥3	4,088	35.0	3,120	34.0	
Social benefit†					
Yes	2,900	27.4	1,076	13.1	<0.001
No	7,694	72.6	7,126	86.9	
Economic difficulties†					
Yes	3,699	33.1	2,692	31.0	0.002
No	7,480	66.9	5,989	69.0	
Family history of asthma†					
Yes	2,145	18.7	1,244	13.0	<0.001
No	9,345	81.3	8,313	87.0	
General obesity*	1,534	12.0	1,258	12.0	0.95
Abdominal obesity**	2,241	17.5	929	8.9	<0.001
Cumulative incidence of asthma	519	4.1	299	2.9	<0.001

Hrs: hours. Wk: week.

†Numbers do not sum up to the total cohort due to missing.

*General obesity (BMI ≥30.0 kg/m^2).

**Abdominal obesity (WC ≥88.0 cm women, WC≥102.0 cm men).

Table 2. General overweight and obesity at baseline in association with incident asthma in the Nord-Trøndelag Health Study (HUNT), Norway.

	No.	**Cases.**	**%**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)***
Women (n=12784)					
Normal BMI (<25.0 kg/m^2)	6,958	224	3.2	1.00	1.00
General overweight (25.0-29.9 kg/m^2)	4,292	195	4.5	1.43 (1.18-1.74)	1.44 (1.18-1.76)
General obesity (≥30.0 kg/m^2)	1,534	100	6.5	2.10 (1.64-2.67)	1.96 (1.52-2.52)
P value for trend				0.001	0.001
BMI continuous**	12,784	519	4.1	1.36 (1.23-1.49)	1.32 (1.19-1.45)
Men (n=10461)					
Normal BMI (<25.0 kg/m^2)	3,859	92	2.4	1.00	1.00
General overweight (25.0-29.9 kg/m^2)	5,344	149	2.8	1.17 (0.90-1.53)	1.21 (0.93-1.58)
General obesity (≥30.0 kg/m^2)	1,258	58	4.6	1.98 (1.42-2.77)	1.84 (1.30-2.59)
P value for trend				0.001	0.001
BMI continuous**	10,461	299	2.9	1.44 (1.23-1.70)	1.38 (1.17-1.62)

BMI: body mass index. CI: confidence interval. OR: odds ratio.

*Adjusted for age, smoking, physical activity, education, family history of asthma, social benefit and economic difficulties at baseline.

** BMI per 5 unit increase.

Table 3. Abdominal overweight and obesity at baseline in association with incident asthma in the Nord-Trøndelag Health Study (HUNT), Norway.

	No.	**Cases.**	**%**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)***	**Additionally adjusted for BMI continuous OR (95% CI)**
Women (n=12,784)						
Normal WC (<80.0 cm)	7,666	253	3.3	1.00	1.00	1.00
Abdominal overweight (80.0-87.9 cm)	2,877	122	4.2	1.30 (1.04-1.62)	1.30 (1.04-1.62)	1.17 (0.91-1.50)
Abdominal obesity (≥88.0 cm)	2,241	144	6.4	2.01 (1.63-2.48)	1.88 (1.51-2.34)	1.46 (1.04-2.05)
P value for trend				0.001	0.001	0.03
WC continuous**	12,784	519	4.1	1.31 (1.22-1.42)	1.28 (1.18-1.38)	1.23 (1.04-1.44)
Men (n=10,461)						
Normal WC (<94.0 cm)	7,073	184	2.6	1.00	1.00	1.00
Abdominal overweight (94.0-101.9 cm)	2,459	74	3.0	1.16 (0.88-1.53)	1.15 (0.87-1.52)	0.89 (0.65-1.23)
Abdominal obesity (≥102.0 cm)	929	41	4.4	1.73 (1.22-2.44)	1.55 (1.08-2.21)	0.88 (0.53-1.47)
P value for trend				0.003	0.02	0.53
WC continuous**	10,461	299	2.9	1.26 (1.11-1.44)	1.23 (1.08-1.41)	0.97 (0.76-1.23)

BMI: body mass index. CI: confidence interval. OR: odds ratio. WC: waist circumference.

*Adjusted for age, smoking, physical activity, education, family history of asthma, social benefit and economic difficulties at baseline.

**Waist circumference per 10 cm increase.

Table 4. General overweight and obesity at baseline in association with incident asthma among men stratified by age (<40, ≥40 years), in the Nord-Trøndelag Health Study (HUNT), Norway.

	Age <40 (n=4,495)				**Age ≥40 (n=5,966)**			
	No.	**Cases.**	**%**	**Adjusted OR (95% CI)***	**No.**	**Cases.**	**%**	**Adjusted OR (95% CI)***
BMI								
Normal BMI (<25.0 kg/m^2)	1,989	52	2.6	1.00	1,870	40	2.1	1.00
General overweight (25.0-29.9 kg/m^2)	2,067	53	2.6	1.00 (0.67-1.47)	3,277	96	2.9	1.45 (0.99-2.11)
General obesity (≥30.0 kg/m^2)	439	15	3.4	1.28 (0.71-2.32)	8119	43	5.3	2.35 (1.50-3.68)
P value for trend				0.55				0.001
BMI continuous**	4,495	120	2.7	1.18 (0.90-1.53)	5,966	179	3.0	1.54 (1.25-1.90)

BMI: body mass index. CI: confidence interval. OR: odds ratio.

*Adjusted for smoking, physical activity, education, family history of asthma, social benefit and economic difficulties at baseline.

** BMI per 5 unit increase.

Figure 1. Flow chart of the analysis cohort.

BMI: body mass index. HUNT: Nord-Trøndelag Health Study. WC: waist circumference.

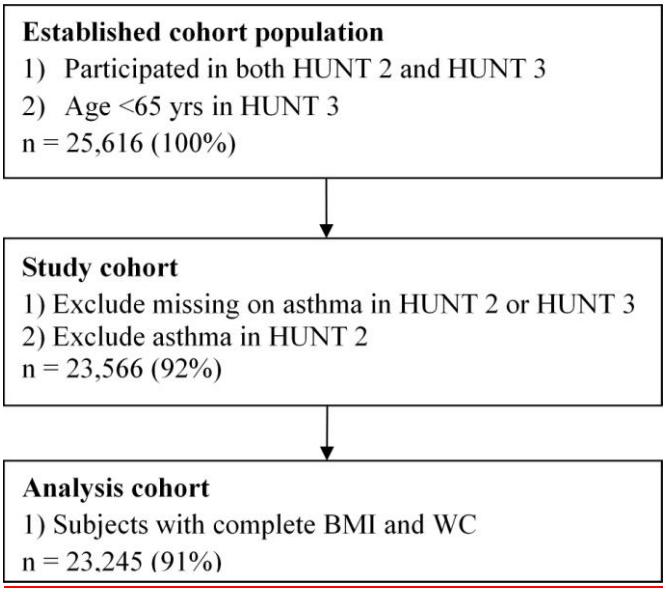
Figure 2. Waist circumference at baseline in association with incident asthma in the Nord-Trøndelag Health Study (HUNT), Norway.

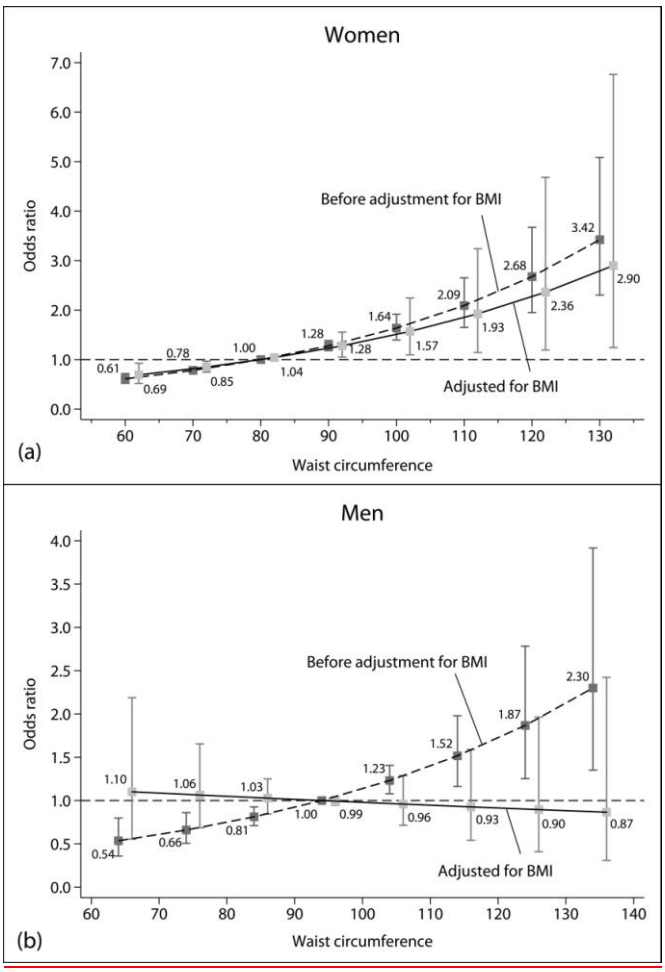
BMI: body mass index.

---- Adjusted for age, smoking, physical activity, education, family history of asthma, social benefit and economic difficulties at baseline.

___ Additionally adjusted for BMI as a continuous variable.

The reference value for (a) women is 80 cm and (b) men is 94 cm. Odds ratios for incident asthma before adjustment for BMI are at 10cm intervals from the reference values. Odds ratios for the BMI adjusted models are 2 cm above the unadjusted models to avoid overlapping the confidence intervals. Vertical capped lines indicate 95% confidence intervals.




Women
Odds ratio
Before adjustment for BMI
Adjusted for BMI
0.61
0.69
0.78
0.85
1.00
1.04
1.28
1.28
1.64
1.57
2.09
1.93
2.68
2.36
3.42
2.90
(a)
Waist circumference
Men
Odds ratio
Before adjustment for BMI
Adjusted for BMI
1.10
0.54
1.06
0.66
1.03
0.81
1.00
0.99
1.23
0.96
1.52
0.93
1.87
0.90
2.30
0.87
(b)
Waist circumference