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**General, but not abdominal, overweight increases odds of asthma among Norwegian adolescents: The Young-HUNT Study**

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## **Abstract**

### **Aim**

The aim of this analysis was to examine the association between asthma and general and abdominal weight status, defined by age-specific and sex-specific cut-offs for body mass index (BMI) and waist circumference (WC) in adolescents.

### **Methods**

Participants aged 12-19 years in the Young-HUNT (YH) Study (YH1 1995-1997: N=8,222; YH3 2006-2008: N=7,403) completed self-administered questionnaires in school as part of a series of cross-sectional, population-based studies conducted in Nord-Trøndelag, Norway. Weight, height, and WC were measured. Adjusted odds ratios (ORs) for asthma, defined by self-reported physician-diagnosis, were calculated. Potential effect modifiers evaluated included sex and pubertal development status (PDS).

### **Results**

Asthma was reported by 11.8% of the adolescents in YH1 and 17.0% in YH3. Asthma odds significantly increased for adolescents with general (OR=1.33), but not abdominal, overweight and increased for adolescents with general (OR=1.34) or abdominal obesity (OR=1.36). Underweight had no association with asthma regardless of weight assessment type and PDS did not meaningfully influence the associations between asthma and weight.

### **Conclusion**

Overweight and obesity both increased the odds of asthma in 12-19 year-old Norwegians. WC did not add further information to that already provided by BMI to improve our understanding of the association between asthma and weight.

**Keywords:** adolescents, asthma, body mass index, obesity, overweight, waist circumference

**Abbreviations:**

BMI – body mass index

WC – waist circumference

YH – Young-HUNT Study

WHO – World Health Organization

PDS – Pubertal Development Scale

**Key Notes**

- Abdominal weight status assessed by waist circumference, general overweight independent of obesity and underweight have rarely been assessed when evaluating associations between asthma and weight status in adolescents
- Among Norwegian adolescents, being overweight, assessed by BMI, increased odds of asthma which is important as many more adolescents are overweight than obese.
- Use of waist circumference to assess abdominal overweight was not associated with increased risk of asthma in this population.

**Introduction**

The prevalence of childhood asthma and overweight/obesity has increased worldwide. In Norwegian children, asthma increased from 8-9% in 1995 to 20.2% in 2003 (1). Similarly, 10.7% of Norwegian children were overweight in 1995 and this increased to 19% by 2010 (3).

General overweight and obesity are typically assessed by body mass index (BMI), an anthropometric measure used clinically as a proxy for general adiposity. Five systematic reviews examining the asthma and overweight or obesity association in children have found BMI to be associated with a 19-35% increased odds of subsequent asthma (4-8). In these meta-analyses, obese children in comparison to normal weight children had a 50% (6) and a 102% increased risk of subsequent asthma development (7). The use of BMI to assess the association between asthma and weight status may be limited as BMI cannot distinguish between fat and muscle mass. BMI is limited in its ability to predict abdominal fat deposition, which is associated with reduced pulmonary function (9) and other chronic diseases. Waist circumference (WC), an anthropometric measure of central adiposity used to assess abdominal weight status, may better reflect metabolic differences in subcutaneous and visceral fat deposits than BMI (10). Abdominal obesity may increase at a faster rate than general obesity. High abdominal adiposity increases asthma severity in children (11). Therefore, abdominal adiposity (WC), may be more important than general adiposity (BMI) as an asthma risk factor; however, WC is rarely used to assess overweight status in childhood asthma studies (4, 10). No published systematic reviews have identified cross-sectional or prospective studies of adolescents that used WC to assess the association between asthma and weight status (4-8).

It is unclear whether sex modifies the association between childhood asthma and weight status as conflicting sex-specific associations between general obesity and asthma have been reported for each sex (6, 7). During adolescence, the sex distribution of asthma is approximately equal as overweight males have a 41% increased risk of asthma (6) and obese males and females have a 40-147% and 53% increased risk of asthma, respectively (6, 7).

This study explored associations between general and abdominal weight status, assessed by BMI and WC, respectively, and asthma in a Norwegian adolescent population. BMI and WC were assessed separately to determine whether the potential asthma and weight status associations varied by type of weight status assessment. Underweight and overweight, independent of obesity, were estimated separately. Due to the potential for confounding by sexual maturation in this age group, sex and pubertal development are given particular attention.

## **Methods**

### ***Study Population***

The Young-HUNT (YH) Study is a school-based, adolescent component of the Nord-Trøndelag Health (HUNT) Study, which is a series of population-based cross-sectional studies conducted in Norway (12). In each YH population, all adolescents age 12-19 years concurrently enrolled in secondary or high-school were eligible to participate (12). Three groups were enrolled: 1995-1997 (YH1), 2000-2001 (YH2), and 2006-2008 (YH3). The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Data Inspectorate Board. All participants, and the parents of children under 16-years-old, signed a written consent to participate and for the data collected to be used for research.

Some YH1 participants constitute the baseline for two follow-up studies: a four-year follow-up from YH1 to YH2 and an 11-year follow-up from YH1 to YH3. To achieve two mutually exclusive groups, we only included data from participants in YH1 and YH3.

A one-hour comprehensive self-administered health questionnaire was completed by 88.1% and 78.4% of adolescents invited to participate in YH1 and YH3, respectively (Figure S1). Those not participating were either absent from school on the day of the questionnaire administration or did not consent to participate. The self-administered paper-based survey included questions about current respiratory symptoms, based on the International Study of Asthma and Allergy in Childhood questionnaire (13). For this analysis, asthma was defined as self-report of asthma diagnosis ever by a physician. In the 10-year period between assessments, asthma diagnostic criteria did not change. Questions on asthma medication use and asthma symptoms were unavailable.

Height, weight, and WC were measured within a month of questionnaire completion by specially-trained nurses using internally standardised meter measures for enrolled YH1 (84.1%) and YH3 (78.3%) participants. WC was measured with a tape measure at the umbilicus to the closest centimetre (cm). Subjects removed shoes and wore light clothing for height and weight measurements obtained using calibrated scales to the nearest cm and kilogram (kg), respectively (12). This analysis was limited to 15,625 participants from YH1 (N=8,222) and YH3 (N=7,403) with complete information on asthma diagnosis, height, weight, and WC.

Body mass index (BMI,  $\text{kg/m}^2$ ) was calculated using height (cm) and weight (kg). Internationally recognised weight status assessment tools were used to classify general weight status, assessed by BMI, into: underweight, normal weight, overweight and obese categories (Table 1) (14-16). Age-specific and sex-specific WC cut-off values proposed for Norwegian children defined abdominal weight status: underweight (<15<sup>th</sup> percentile), normal

weight (15-84<sup>th</sup> percentile), overweight (85-94<sup>th</sup> percentile), and obesity ( $\geq 95^{\text{th}}$  percentile) (17, 18).

### ***Potential Covariates Eligible for Model Inclusion***

Age (years) and dichotomous questions on bronchitis or pneumonia (past 12 months), itchy rash (past 12 months), hay fever (ever), eczema (ever), allergy (ever), active participation in sports, and chronic diseases (illness lasting  $\geq 3$  months) were analysed. Categorical questions querying current health status, doctor visits (past 12 months), and school absenteeism ( $1 \geq$  or  $1 <$  week in past 12 months) were assessed (Table S1). A smoker was someone who reported smoking occasionally or daily and environmental tobacco smoke exposure was a positive report of smoking in the home. Family socioeconomic status asked only in YH3, was defined as “about the same,” “better,” or “worse” when asked “how well off is your family compared to others?”

The pubertal development scale (PDS) classified sexual maturation (19). For males, the PDS includes questions addressing: growth spurts, pubertal hair growth, voice change, and facial hair growth. For females, the PDS includes questions addressing: growth spurts, pubertal hair growth, menstruation, and breast development (19). For each of the four sex-specific questions, responses were assigned a one to four ordinal value, values were summed, and an average PDS calculated. Adolescents were assessed by PDS age-specific and sex-specific half-year percentile categories: late maturers,  $\leq 20^{\text{th}}$  percentile; intermediate maturers,  $> 20^{\text{th}}$  and  $< 80^{\text{th}}$  percentile; and early maturers,  $\geq 80^{\text{th}}$  percentile.

### ***Statistical analysis***

T-tests and chi-square tests compared participant characteristics. Pearson's correlation coefficients assessed the association between general and abdominal overweight. A Cochran-Armitage test for trend was assessed for general and abdominal weight status. Adjusted odds ratios (OR) with 95% confidence intervals (95% CI) for asthma stratified by YH group (YH1, YH3, combined YH1/YH3) among generally or abdominally underweight, overweight or obese adolescents in comparison to normal weight adolescents were computed by multivariate logistic regression. Adjusted ORs (95% CIs) for asthma stratified by YH group were estimated for continuous BMI and WC. Stepwise logistic regression ( $p \leq 0.05$  for inclusion) starting with the full model and the likelihood ratio test were used to determine if any of the covariates listed in Table S1 significantly improved the fit of each adjusted model. Subgroup analyses were completed for the total study population and stratified by YH group, sex (male, female) and by PDS categories (late, intermediate, and early). A test for interaction determined whether the effect was homogeneous among the subgroups listed above. Data were analysed using SAS software, version 9.3 of the SAS System for Windows, SAS Institute Inc., Cary, NC, USA.

## **Results**

### ***Characteristics associated with asthma***

Asthma prevalence was 11.8% in YH1 and 17.0% in YH3 (Table S1). Asthmatics were slightly older than non-asthmatics ( $p < 0.1$ ) and less likely to report "very good" health than non-asthmatics ( $p < 0.001$ ). In YH1 only, asthmatics had a higher prevalence of bronchitis and a lower prevalence of sports competition participation. Asthma was not significantly associated with PDS in either population. Increased personal smoking was marginally associated with asthma while environmental tobacco smoke exposure was

positively associated with asthma in both groups. In YH3 only, asthmatics reported higher SES. Asthmatics were more likely to be generally or abdominally overweight or obese and less likely to be generally or abdominally underweight than non-asthmatics in each YH group (all  $p \leq 0.001$ ) (Table 2). Age-specific and sex-specific BMI and WC were moderately correlated (0.65, YH1; 0.61, YH3;  $p < 0.001$  for both). There was a significant dose-response trend for increasing asthma with both increasing general ( $p < 0.0001$ ) and abdominal ( $p = 0.0003$ ) weight status.

### ***Odds of asthma in each of the YH1 and YH3 populations***

When the asthma-weight status association was assessed in each population separately, general overweight (OR=1.40, 95%CI: 1.15, 1.71) and obesity (OR=1.69, 95%CI: 1.24, 2.31) were both significantly associated with increased odds of asthma in YH3 and modestly associated with increased odds in YH1 (data not shown). Abdominally obese adolescents were at increased odds of asthma (OR=1.43, 95%CI: 1.19, 1.73) in YH3. Interestingly, in each population, underweight was less common among asthmatics, but not significantly so, for each type of weight status assessment.

### ***Odds of asthma in the overall population***

After adjustment for covariates, the OR for asthma among generally overweight or obese adolescents when compared to normal weight adolescents were 1.33 (95%CI: 1.13, 1.56) and 1.34 (95%CI: 1.02, 1.75) using the total study population (Table 3). One unit increase in BMI was associated with a 1.05 times increased odds of asthma (95%CI 1.03, 1.07). Adolescents with abdominal underweight or overweight were not at significantly lower or higher odds of asthma in comparison to normal weight adolescents. However, abdominally obese adolescents had a 36% increased odds of asthma in comparison to their normal weight

peers (95%CI: 1.16, 1.60). One centimetre increase in WC was associated with a 1.15 times increased odds of asthma (95%CI 1.07, 1.22).

After sex stratification, general obesity in comparison to normal weight was significantly associated with increased odds of asthma in females only (OR=1.77, 95%CI: 1.14, 2.75). Sex did not mediate the association between asthma and general underweight or overweight, abdominal obesity, continuous BMI, or continuous WC.

### ***Pubertal status as a potential effect modifier***

A second *a priori* subgroup analysis by PDS assessed the effect of puberty on the asthma-weight status associations (Table S2). Adolescents who were early to mature had modestly increased odds of asthma if they were generally overweight, generally obese, or abdominally obese. Those with intermediate pubertal development were at increased odds of asthma if they were generally overweight, abdominally overweight or abdominally obese. Further stratification of PDS did not indicate effect modification by sex (data not shown).

Use of the WHO BMI-for-age standards, instead of the International Obesity Task Force criteria, did not change the general underweight, overweight or obese conclusions in any meaningful way (data not shown).

### **Discussion**

In two groups of Norwegian adolescents, assessed 11 years apart, general overweight, defined by age-specific and sex-specific BMI criteria, increased the odds of asthma. The analysis revealed no major differences in odds between general overweight and obesity indicating that being overweight, but not necessarily obese, was sufficient to increase the

odds of asthma in adolescents by 33%. These increased odds of asthma among general overweight adolescents remained after stratification by sex and by pubertal development. Clear effect modification by puberty was not observed.

Consistent with our findings, several studies have reported positive associations between general overweight/obesity and asthma in childhood (4, 6). However, inconsistent results have been reported on the association between overweight, independent of obesity, and asthma in children (4, 6). Estimating the independent effects of being overweight, as distinct from obese, on asthma is of critical public health importance as a considerably larger proportion of children are overweight than obese. We observed that overweight incurred almost the same amount of increased risk as obesity which, if replicated, has important implications for change programs.

Studies in children investigating the relationship between asthma and general overweight, as distinct from obesity, and abdominal weight status are uncommon (4-8). Of the 31 cross-sectional childhood studies examined, only five made a distinction between overweight and obesity using BMI and only one used WC to assess abdominal weight status. BMI may inadequately reflect fat distribution as wide variations in body fat distribution can occur within the same BMI group leading to under estimations or over estimations of weight status (10).

The prevalence of abdominal obesity was higher than the prevalence of general obesity yet similarly increased the odds of asthma in both YH populations. Abdominal overweight also increased the odds of asthma in both sexes despite the fact that being male was associated with decreased odds of abdominal overweight, but was still a risk factor for

general overweight. This suggests that, despite the difference in weight status outcome used and prevalence, use of BMI and WC together may not be necessary in adolescents to assess the asthma and weight status association.

Only one previous study examined the association of both general and abdominal overweight, assessed by BMI and WC, respectively, in adolescents (10). This study found that a one unit increase in WC increased odds of asthma by almost three-fold ( $OR=2.95$ ) (10). Two other studies in younger school-aged children also found WC to be associated with 1.18-1.56 times increased odds of asthma (20, 21). Our data suggest that use of WC, in addition to BMI, may only slightly reduce misclassification and whether classified as general or abdominal, overweight and obesity each increased asthma odds. WC has rarely been used to assess central adiposity in childhood asthma studies, despite its potential positive association with asthma (4, 10). The mechanical hypothesis suggests that increased adiposity may influence asthma through changes in airway compliance due to increased pressure of fat mass. However, other factors may also be responsible including: increased airway hyper-responsiveness, low-grade systemic inflammation, genetic susceptibility, or the potential for excess weight gain to trigger changes in adipose tissue-derived proteins (adipokines) (22, 23).

Obesity may also complicate the progression, diagnosis, and treatment of asthma as the conditions may have additive or synergistic pro-inflammatory effects. Obese asthmatics have more frequent asthma symptoms, activity restriction, and asthma medication use, and fewer symptom-free days than non-obese asthmatics (24). Obese children have increased bronchial hyper-responsiveness and decreased pulmonary volumes in comparison to normal weight children (25). The factors linking this association remain unclear and, due to the cross-sectional survey design, these factors were not assessed in this study.

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Abdominal obesity significantly increased odds of asthma in the total population by 36%. However, abdominal overweight did not significantly increase the odds of asthma in either YH group or after sex-stratification. Obesity-related cardiovascular complications and metabolic changes have been linked to visceral adipose tissue which is better indicated by WC than BMI (26). However, we used indirect measures of weight status and do not have gold standard measures of body fat distribution, such as DXA, available in this study which may have influenced our ability to detect differences due to abdominal adiposity.

We stratified by pubertal development (Table S2) because fat distribution, linear growth, and final height, influencing BMI, may be affected by sexual maturation changes that differ in duration, timing, and tempo. Asthma and WC studies among adolescents rarely include an age-specific and sex-specific measure of pubertal development. Obesity is a risk factor for early-onset puberty as obese children grow faster and mature earlier than normal weight children (27). In each of the YH groups, adolescents who were early to mature had a 30-63% increased odds of asthma after controlling for general overweight, general obesity, or abdominal obesity. It may be that asthma and early-onset puberty are influenced by common risk factors such as dietary and endogenous influences such as exposure to endocrine disruptors. The relationship between asthma and puberty may indicate a biological phenomenon as sex hormonal fluctuations, especially among females during the menstrual cycle, influence asthma (28). Leptin, a hormone regulating energy intake and expenditure and involved in sexual maturation, has been proposed to peripherally influence respiratory function regulation (29). Early-onset puberty may be important to assess in studying the adolescent asthma-weight status relationship due to its individual associations with both asthma and weight status.

We recognise several limitations to our study. The cross-sectional nature of these two independent study populations and a lack of information on asthma symptoms and medication use precluded us from assessing changes in asthma severity, asthma-related healthcare utilization, changes in body habitus over time, and temporality of the asthma-weight status relationship. International Obesity Task Force weight status categories provide limited ranges with no allocation for calculating standard deviations. However, use of these cut-offs is conservative and observed associations were verified using WHO criteria. As mentioned previously, both BMI and WC are indirect measures of general and abdominal weight status. Misclassification may result from use of self-reported asthma diagnosis. However, previous studies in adolescents suggest that self-reported asthma is valid and reliable (30). Despite using a detailed health survey that assessed a range of potential confounding variables, there may be residual confounding from unknown or unmeasured characteristics, such as diet, which could not be evaluated in our study.

Our study has several strengths. Use of an ethnically-homogenous Norwegian population limited potential for confounding by race/ethnicity. We used two standardised, objective anthropometric general weight measures and Norwegian age-specific and sex-specific WC cut-off values (17, 18) which may have minimised the likelihood of misclassification of weight status. This analysis is one of only a few to provide independent estimates of asthma associations for both overweight and underweight children. We controlled for environmental exposures and behaviours known to exacerbate asthma symptoms including: household smoking and physical activity. The two YH populations provided an internal source of replication and, while slight differences were observed, we were able to adjust for YH group in the total population models, which minimised the potential for a cohort effects.

### **Conflict of Interest Statement:**

The authors declare no conflicts of interest.

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**Table 1. Weight status classification by type of weight and measurement standard**

| Type of Weight | Measurement Standard   | Age (years) | Weight Status Classification                                    |                                                |                                                |                               |
|----------------|------------------------|-------------|-----------------------------------------------------------------|------------------------------------------------|------------------------------------------------|-------------------------------|
|                |                        |             | Underweight                                                     | Normal Weight                                  | Overweight                                     | Obese                         |
| General (BMI)  | IOTF <sup>1</sup>      | 12 - 17     | Age- and sex- specific cut-off values for children <sup>1</sup> |                                                |                                                |                               |
|                |                        | 18 - 19     | BMI < 18.5 kg/m <sup>2</sup>                                    | BMI ≥ 18.5 to < 25 kg/m <sup>2</sup>           | BMI ≥ 25 to < 30 kg/m <sup>2</sup>             | BMI ≥ 30 kg/m <sup>2</sup>    |
|                | WHO <sup>2</sup>       | 12 - 19     | < 15 <sup>th</sup> percentile                                   | 15 <sup>th</sup> - 84 <sup>th</sup> percentile | 85 <sup>th</sup> - 94 <sup>th</sup> percentile | ≥ 95 <sup>th</sup> percentile |
| Abdominal (WC) | Norwegian <sup>3</sup> | 12 - 19     | < 15 <sup>th</sup> percentile                                   | 15 <sup>th</sup> - 84 <sup>th</sup> percentile | 85 <sup>th</sup> - 94 <sup>th</sup> percentile | ≥ 95 <sup>th</sup> percentile |

<sup>1</sup> International Obesity Task Force (IOTF) BMI age-, by ½ year categories, and sex-specific cut-off values for weight status in children (15, 16)

<sup>2</sup> World Health Organization (WHO) BMI age-, by ½ year categories, and sex-specific cut-off values for weight status in children (17)

<sup>3</sup> Norwegian age- and sex-specific WC cut-off values for abdominal weight status in children (18, 19)

**Table 2. Weight status characteristics according to asthma status in the Young-HUNT1 and Young-HUNT3 study populations, Norway<sup>1</sup>**

| Characteristic                                            | Young-HUNT1                   |                                |                | Young-HUNT3                     |                                |                |
|-----------------------------------------------------------|-------------------------------|--------------------------------|----------------|---------------------------------|--------------------------------|----------------|
|                                                           | Asthma                        |                                | p <sup>3</sup> | Asthma                          |                                | p <sup>3</sup> |
|                                                           | Yes<br>(N = 971) <sup>2</sup> | No<br>(N = 7,251) <sup>2</sup> |                | Yes<br>(N = 1,258) <sup>2</sup> | No<br>(N = 6,145) <sup>2</sup> |                |
| Body Mass Index (BMI)                                     | 21.9 ± 3.4                    | 21.3 ± 3.3                     | <0.001         | 22.8 ± 4.3                      | 22.0 ± 3.7                     | <0.001         |
| General Weight Status (BMI) by IOTF Standard <sup>4</sup> |                               |                                | <0.001         |                                 |                                | <0.001         |
| Underweight                                               | 35 (3.6)                      | 401 (5.5)                      |                | 35 (2.8)                        | 229 (3.7)                      |                |
| Normal weight                                             | 719 (74.0)                    | 5700 (78.6)                    |                | 827 (65.7)                      | 4479 (72.9)                    |                |
| Overweight                                                | 186 (19.2)                    | 953 (13.1)                     |                | 293 (23.3)                      | 1118 (18.2)                    |                |
| Obese                                                     | 31 (3.2)                      | 197 (2.7)                      |                | 103 (8.2)                       | 319 (5.2)                      |                |
| Cochran-Armitage Trend Test                               |                               |                                | 0.006          |                                 |                                | <0.001         |

|                                                            |            |              |        |             |             |
|------------------------------------------------------------|------------|--------------|--------|-------------|-------------|
| General Weight Status (BMI) by WHO Standard <sup>5</sup>   |            | <0.001       |        | <0.001      |             |
| Underweight                                                | 60 (6.2)   | 616 (8.5)    |        | 66 (5.3)    | 372 (6.1)   |
| Normal weight                                              | 666 (68.6) | 5351 (73.8)  |        | 758 (60.3)  | 4171 (67.9) |
| Overweight                                                 | 140 (14.4) | 782 (10.8)   |        | 222 (17.7)  | 848 (13.8)  |
| Obese                                                      | 105 (10.8) | 502 (6.9)    |        | 212 (16.9)  | 754 (12.3)  |
| Cochran-Armitage Trend Test                                |            | <0.001       |        | <0.001      |             |
| Waist Circumference (WC)                                   | 74.5 ± 9.3 | 73.0 ± 8.7   | <0.001 | 80.3 ± 12.0 | 78.0 ± 10.3 |
| Abdominal Weight Status (waist circumference) <sup>6</sup> |            | <0.001       |        | <0.001      |             |
| Underweight                                                | 70 (7.2)   | 629 (8.7)    |        | 21 (1.7)    | 141 (2.3)   |
| Normal weight                                              | 572 (58.9) | 4717 (65.05) |        | 521 (41.4)  | 2859 (46.5) |
| Overweight                                                 | 164 (16.9) | 1035 (14.3)  |        | 268 (21.3)  | 1314 (21.4) |
| Obese                                                      | 165 (17.0) | 870 (12.0)   |        | 448 (35.6)  | 1831 (29.8) |
| Cochran-Armitage Trend Test                                |            | 0.003        |        | 0.018       |             |

<sup>1</sup> Table values are mean ± SD for continuous variables and n (column %) for categorical variables.

<sup>2</sup> Numbers may not sum to total due to missing data, and percentages may not sum to 100% due to rounding.

<sup>3</sup> P-value is for  $\chi^2$  test (categorical variables), t-test (continuous variables) or Cochran-Armitage Trend Test

<sup>4</sup> International Obesity Task Force age- and sex- specific overweight status (15, 16)

<sup>5</sup> World Health Organization age- and sex-specific weight percentiles (17)

<sup>6</sup> Norwegian age- and sex- specific waist circumference (WC) cut-off values (18, 19)

**Table 3: General and abdominal weight status in association with asthma, overall and stratified by sex, in the combined Young-HUNT1 and Young-HUNT3 study populations, Norway**

|                                |                               | Adjusted Odds Ratios (95% Confidence Intervals)<br>for Asthma <sup>1</sup> |                      |                      |                      |                        |                      |
|--------------------------------|-------------------------------|----------------------------------------------------------------------------|----------------------|----------------------|----------------------|------------------------|----------------------|
| Measure-<br>ment<br>Standard   | Weight<br>Classifica-<br>tion | Overall<br>(N = 15,625)                                                    |                      | Males<br>(N = 7,795) |                      | Females<br>(N = 7,830) |                      |
|                                |                               | N <sup>2</sup>                                                             | OR (95%<br>CI)       | N <sup>2</sup>       | OR (95%<br>CI)       | N <sup>2</sup>         | OR (95%<br>CI)       |
| <b>Genera<br/>l (BMI)</b>      | Underwei<br>ght               | 700                                                                        | 0.71 (0.49,<br>1.03) | 296                  | 0.72 (0.46,<br>1.14) | 404                    | 0.70 (0.37,<br>1.35) |
|                                | Normal                        | 117<br>25                                                                  | 1.00                 | 582<br>4             | 1.00                 | 590<br>1               | 1.00                 |
|                                | Overweig<br>ht                | 255<br>0                                                                   | 1.33 (1.13,<br>1.56) | 131<br>3             | 1.27 (1.04,<br>1.55) | 123<br>7               | 1.49 (1.14,<br>1.94) |
|                                | Obese                         | 650                                                                        | 1.34 (1.02,<br>1.75) | 362                  | 1.19 (0.84,<br>1.68) | 288                    | 1.77 (1.14,<br>2.75) |
| <b>Abdom<br/>inal<br/>(WC)</b> | Underwei<br>ght               | 861                                                                        | 1.02 (0.73,<br>1.42) | 421                  | 1.07 (0.75,<br>1.52) | 440                    | 0.82 (0.31,<br>2.17) |
|                                | Normal                        | 866<br>9                                                                   | 1.00                 | 481<br>4             | 1.00                 | 385<br>5               | 1.00                 |
|                                | Overweig<br>ht                | 278<br>1                                                                   | 1.09 (0.92,<br>1.29) | 132<br>9             | 1.18 (0.96,<br>1.44) | 145<br>2               | 0.92 (0.68,<br>1.25) |
|                                | Obese                         | 331                                                                        | 1.36 (1.16,<br>1.58) | 123                  | 1.38 (1.12,<br>1.69) | 208                    | 1.33 (1.04,<br>1.69) |

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|   |       |   |       |   |       |
|---|-------|---|-------|---|-------|
| 4 | 1.60) | 1 | 1.70) | 3 | 1.69) |
|---|-------|---|-------|---|-------|

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<sup>1</sup> Models were adjusted for all Young-HUNT1 and Young-HUNT3 variables in Table 1, as needed, by stepwise regression.

<sup>2</sup> Sample size for adjusted models with non-missing data only

<sup>3</sup> Calculated using age- and sex- specific body mass index cut-off values for overweight/obesity from the International Obesity Task Force for children ages 0-18 years (15, 16)

<sup>4</sup> Calculated using Norwegian age- and sex- specific waist circumference percentile cut-off values for abdominal underweight (<15<sup>th</sup>), normal weight (15-84<sup>th</sup>), overweight (85-94<sup>th</sup>) and obesity (≥95<sup>th</sup>) for children (18, 19)