Trends in overweight and obesity over 22 years in a large adult population: the HUNT Study, Norway

K. Midthjell1, C. M. Y. Lee2, A. Langhammer1, S. Krokstad1, T. L. Holmen1, K. Hveem1, S. Colagiuri2 and J. Holmen1

What is already known about this subject

- Prevalence of overweight and obesity has been increasing worldwide, but recent reports suggest the trend in some countries may be plateauing.
- Prevalence of overweight and obesity derived from body mass index can be different to that derived from waist circumference.

What this study adds

- Obesity was more prevalent and increased more when defined by waist circumference than by body mass index.
- While the increase in obesity prevalence as defined by body mass index was greater in men, the increase in obesity prevalence as defined by waist circumference was greater in women.
- The increase in prevalence for body mass index-defined overweight was significant in both sexes over the first half of the period studied, but was only significant in men over the second half.

Summary

Some reports indicate that the obesity epidemic may be slowing down or halting. We followed body mass index (BMI) and waist circumference (WC) in a large adult population in Norway (n = 90,000) from 1984–1986 (HUNT1) through 1995–1997 (HUNT2) to 2006–2008 (HUNT3) to study whether this is occurring in Norway. Height and weight were measured with standardized and identical methods in all three surveys; WC was also measured in HUNT2 and HUNT3. In the three surveys, mean BMI increased from 25.3 to 26.5 and 27.5 kg m\(^{-2}\) in men and from 25.1 to 26.2 and 26.9 kg m\(^{-2}\) in women. Increase in prevalence of obesity (BMI ≥ 30 kg m\(^{-2}\)) was greater in men (from 7.7 to 14.4 and 22.1%) compared with women (from 13.3 to 14.4 and 22.1%). In contrast, women had a greater increase in abdominal obesity (WC ≥ 102 cm for men and WC ≥ 88 cm for women). There was a continuous shift in the distribution curve of BMI and WC to the right, demonstrating that the increase in body weight was occurring in all weight groups, but the increase of obesity was greatest in the youngest age groups. Our data showed no signs of a halt in the increase of obesity in this representative Norwegian population.

Keywords: Gender differences, Norway, obesity, overweight.

Abbreviations: BMI, body mass index; HUNT, The Nord-Trøndelag Health Study (HelseUndersøkelsen i Nord-Trøndelag); WC, waist circumference.

Introduction

The prevalence of overweight and obesity is increasing worldwide (1,2); although some recent reports indicate that the obesity epidemic may be slowing down, especially in children and adolescents (3–10). We have previously reported a considerable increase in obesity in Norway between 1984–1986 and 1995–1997, coinciding with an
increase in the prevalence of diabetes (11). The health consequences of overweight and obesity are well documented, irrespective of whether it is expressed as general obesity by body mass index (BMI) (12–14) or as abdominal obesity by waist circumference (WC) (15–19). Both contribute separately to increased morbidity (20) and mortality (16).

The Nord-Trøndelag Health Study (The HUNT Study) has followed a large, non-selected adult population in central Norway through three cross-sectional surveys during a 22-year period, enabling the study of longitudinal changes in weight measures in adults aged 20–99 years.

Subjects and methods

Population

Nord-Trøndelag County is located in the middle part of Norway at 64 degrees North, with a population of 127 000 in 1984, increasing to 130 000 in 2008. The population structure of Nord-Trøndelag is stable and fairly representative of Norway, except that it has no big city (the largest town having 20 500 inhabitants), mean income and education level is slightly less than the national average, and foreign immigration is lower than in the more densely populated areas of Norway. Although immigration from other cultures increased somewhat over the years and there is a small Lappish (Sami) population, the population studied is almost exclusively Caucasian (around 97% in 2000 (21,22)).

Data collection

HUNT1

In the first HUNT survey (HUNT1, 1984–1986), all inhabitants in the county aged 20 years and over were invited, and 74 436 individuals (87%) participated in a clinical examination and had their height and weight measured (11,23). Height was measured without shoes to the nearest centimetre. Weight was measured with light clothes, without shoes, jacket or outdoor garments to the nearest half kilogram. We excluded 2354 participants who either were not able or willing to have their height or weight measured, or reported to be pregnant. Participants answered extensive health-related questionnaires.

HUNT2

The second survey (HUNT2) was conducted in 1995–1997. All inhabitants aged 13 years or more were invited (21). Of those aged 20 years and over, 64 804 individuals (70%) attended the clinical examination and had their height and weight measured by the same method as in HUNT1. After excluding 2162 participants who could not be measured or were pregnant, a total of 62 642 were included in the analysis. Nearly all participants (n = 62 513) also had their WC and hip circumference measured to the nearest centimetre by applying a non-stretchable band with the participant standing relaxed with arms on the side. WC was measured horizontally at the umbilical level, and hip circumference at the thickest part of the hips.

HUNT3

The third survey (HUNT3) was conducted from 2006 to 2008, again addressing all inhabitants aged 13 years or more (24). In all, 50 386 participants (54%) aged 20 years and over participated in the clinical examination and had their height, weight, WC and hip circumference measured using the same protocol as in HUNT2. Five hundred fifty-seven participants were excluded from the analysis because of pregnancy or because height and/or weight could not be measured. Of the 49 829 participants with valid height and weight data, 49 739 also had their WC measured.

Ethics

All participants in the three HUNT surveys consented according to Norwegian law and recommendations; in HUNT1 by informed and voluntary participation, in HUNT2 and HUNT3 by signed informed consent. Approvals were obtained from the Regional Committee for Ethics in Medical Research and the Norwegian Data Inspectorate.

Statistics

Included in the analyses were BMI measured in all three surveys and WC in HUNT2 and HUNT3. BMI was calculated as weight in kg/(height in m)². According to the World Health Organization, overweight and obesity were defined as BMI 25–29.9 kg m⁻² and BMI ≥ 30 kg m⁻², respectively (1,25). Obesity was further classified into classes I, II and III for those with BMI 30–34.9 kg m⁻², BMI 35–39.9 kg m⁻² and BMI ≥ 40 kg m⁻², respectively (1). Abdominal obesity was defined as WC ≥ 102 cm for men and WC ≥ 88 cm for women, equivalent to ‘significantly increased risk’ in a Caucasian population. Correspondingly, abdominal overweight was defined as WC 94–101.9 cm for men and WC 80–87.9 cm for women, equivalent to ‘increased risk’ in this type of population (1,25–29). The central obesity criterion for Europids used in the International Diabetes Federation’s definition for the metabolic syndrome (30,31) is equivalent to the sum of abdominal overweight and obesity (WC ≥ 94 cm for men and ≥ 80 cm for women) by the World Health Organization definition used here.

Prevalence of BMI-based overweight and obesity and abdominal overweight and obesity are reported by sex and 10-year age groups. Two-sample z-test was used to
compare mean values and two-proportion z-test was used to compare prevalence between HUNT1 and HUNT2 and between HUNT2 and HUNT3. Statistical significance was set at \( P < 0.05 \). SAS 9.1 for Windows (SAS Institute, Inc., Cary, NC, USA) was used for the analysis.

**Results**

Table 1 shows the characteristics of participants in the three surveys. More women than men participated in HUNT2 and HUNT3. HUNT3 participants were generally older and taller than HUNT1 and HUNT2 participants. In men, mean BMI increased from 25.3 kg m\(^{-2}\) in HUNT1 to 27.5 kg m\(^{-2}\) in HUNT3. The corresponding increase in women was from 25.1 to 26.9 kg m\(^{-2}\). Mean WC increased from 91.9 to 97.4 cm in men and from 81.4 to 90.3 cm in women. Hip circumference also increased significantly from HUNT2 to HUNT3.

The distribution curve for BMI in HUNT2 was broader, with a lower peak, and moved to the right of that in HUNT1 (Fig. 1). This rightward shift continued in HUNT3. The distribution curve for WC in HUNT3 was lower and shifted rightward compared with the HUNT2 curve in both sexes, but more in women than men (Fig. 1). The rightward shift in distribution was greater for WC than for BMI. The rightward shift in BMI from HUNT2 to HUNT3 was greater in men, while the rightward shift for WC was greater in women in accordance with the mean values in Table 1.

**Change in overweight**

The prevalence of BMI-defined overweight increased from 42.1% in HUNT1 to 52.4% in HUNT3 in men, and from 29.9 to 37.7% in women (Table 2). The increase was largest from HUNT1 to HUNT2 in both sexes. No significant increase from HUNT2 to HUNT3 was observed in women.

In men, the increase in overweight from HUNT1 to HUNT2 was significant in all age groups, but was largest among the youngest (Table 2). From HUNT2 to HUNT3, only age group 30–39 years showed a significant increase.

In women, the increase from HUNT1 to HUNT2 was significant in all age groups except age group 70–79 years. Even among women, the change was largest in the youngest age groups (Table 2). From HUNT2 to HUNT3 there was no significant increase of overweight in any age group (Table 2).

**Change in obesity**

In men, BMI-based obesity increased from 7.7% in HUNT1 to 22.1% in HUNT3 and in women from 13.3 to 23.1% (Table 2). From HUNT1 to HUNT2 the increase was significant in all age groups for both sexes, except age group 80+ years in men.

In men, the increase from HUNT2 to HUNT3 was of equal size as from HUNT1 to HUNT2 and was equally distributed amongst age groups. The increase was signifi-
cant in all age groups (Table 2). In women, the increase of obesity from HUNT2 to HUNT3 was largest in the youngest age groups, while the increase was not significant in those aged 60 years and over (Table 2).

Obesity class I-III

In men, the prevalence of obesity class I increased nearly threefold from 6.8% in HUNT1 to 18.5% in HUNT3 (Table 1), fairly equally distributed among age groups. The same pattern was seen in obesity class II and class III, though only 107 men were in class III.

In women, obesity class I increased from 10.1% in HUNT1 to 16.6% in HUNT3 (Table 1). The increase was largest among younger age groups, while there was no increase from HUNT2 to HUNT3 in the oldest age groups. More women than men were classified as having obesity.
class II and III, and in women the increase was especially large from HUNT2 to HUNT3 in the youngest age groups.

**Abdominal overweight and obesity**

The prevalence of abdominal overweight was higher in men than in women in all age groups except age group 20–29 years, but the prevalence did not change significantly from HUNT2 to HUNT3 (Table 3). In contrast, the prevalence of abdominal obesity increased by 117% over the 11-year period, and the prevalence was substantially higher in women than in men in all age groups. The prevalence of abdominal obesity nearly tripled in women below age 50 years (Table 3).

### Table 2
Prevalence (%) of overweight (BMI 25–29.9 kg m\(^{-2}\)) and obesity (BMI ≥ 30 kg m\(^{-2}\)) by sex and age group

| Age group | HUNT1 | | | HUNT2 | | | HUNT3 | | |
|-----------|-------|---|---|------|---|---|------|---|---|
| n         | Overweight | Obese | n         | Overweight | Obese | n         | Overweight | Obese | n         | Overweight | Obese |
| Men       |       |     |       |     |     |       |     |     |       |     |     |
| 20–29     | 5853  | 25.0 | 3.7 | 3905 | 37.0* | 8.4* | 1739  | 35.4 | 13.3 |
| 30–39     | 7941  | 38.5 | 5.5 | 5360 | 49.1* | 12.7* | 2837  | 51.5^ | 21.3^ |
| 40–49     | 5917  | 46.0 | 8.0 | 6461 | 53.1* | 14.4* | 4534  | 54.2 | 23.5^ |
| 50–59     | 5517  | 49.7 | 9.7 | 5332 | 54.6* | 17.8* | 5384  | 55.2 | 23.5^ |
| 60–69     | 5862  | 49.2 | 10.7 | 4241 | 54.0* | 17.4* | 4625  | 54.7 | 24.6^ |
| 70–79     | 3469  | 48.4 | 10.6 | 3436 | 52.2* | 15.9* | 2604  | 53.3 | 21.3^ |
| 80+       | 881   | 42.1 | 8.9 | 911  | 51.6* | 10.7 | 935   | 48.5 | 15.2^ |
| 20+       | 35440 | 42.1 | 7.7 | 29646 | 50.5* | 14.4* | 22658 | 52.4^ | 22.1^ |

*P < 0.05 between HUNT1 and HUNT2.  
^P < 0.05 between HUNT2 and HUNT3.

### Table 3
Prevalence (%) of abdominal overweight (WC 94.0–101.9 cm for men and 80.0–87.9 cm for women) and obesity (WC ≥ 102.0 cm for men and ≥88 cm for women) by sex and age group

| Age group | HUNT2 | | | HUNT3 | | |
|-----------|-------|---|---|------|---|---|
| n         | Overweight | Obese | n         | Overweight | Obese |
| Men       |       |     |       |     |     |
| 20–29     | 3902  | 12.5 | 5.5 | 1738 | 18.2* | 13.9^ |
| 30–39     | 5352  | 22.2 | 8.4 | 2834 | 29.6* | 25.1^ |
| 40–49     | 6453  | 25.5 | 11.0 | 4532 | 32.6* | 29.6^ |
| 50–59     | 5325  | 30.5 | 15.3 | 5378 | 34.8* | 33.4^ |
| 60–69     | 4234  | 30.7 | 20.2 | 4623 | 33.0* | 38.5^ |
| 70–79     | 3428  | 32.4 | 23.0 | 2601 | 33.8 | 38.2^ |
| 80+       | 904   | 32.9 | 24.8 | 932  | 32.5 | 38.5^ |
| 20+       | 29598 | 25.8 | 13.7 | 22638 | 31.9* | 31.9^ |

Women

| Age group | HUNT2 | | | HUNT3 | | |
|-----------|-------|---|---|------|---|---|
| n         | Overweight | Obese | n         | Overweight | Obese |
| Men       |       |     |       |     |     |
| 20–29     | 4418  | 16.6 | 12.1 | 2388 | 25.0* | 32.6^ |
| 30–39     | 5864  | 20.7 | 16.1 | 3903 | 26.1* | 46.3^ |
| 40–49     | 6985  | 24.0 | 21.2 | 5422 | 26.4* | 51.5^ |
| 50–59     | 5702  | 26.5 | 30.4 | 5960 | 24.9 | 58.7^ |
| 60–69     | 4576  | 29.4 | 38.5 | 5079 | 21.1* | 64.6^ |
| 70–79     | 4058  | 29.2 | 45.1 | 3020 | 18.4* | 69.1^ |
| 80+       | 1312  | 30.6 | 44.3 | 1329 | 20.1* | 68.0^ |
| 20+       | 32915 | 24.5 | 26.9 | 27101 | 23.7* | 55.9^ |

^P < 0.05 between HUNT2 and HUNT3.
The greatest increase in nearly all grades of obesity was observed in the 30–39 years age group in both sexes for BMI- and WC-defined obesity.

Additional tables and figures are available at the publisher’s web-site (see Supporting Information).

Discussion

Main results

Our data demonstrate that the obesity epidemic continued in this fairly representative, almost exclusively Caucasian population in Norway. It is worrying that the greatest increase was seen in the younger adult groups, as the risk of obesity complications increases with duration of obesity (32). An important finding is, however, that the increase in overweight was significantly smaller in the second period (between HUNT2 and HUNT3); 1.9% (from 50.5 to 52.4% in men) and 0.6% correspondingly in women compared with 8.4% in men and 7.2% in women, respectively, in the first period (between HUNT1 and HUNT2). This considerably smaller increase in overweight may give hope of a future reduction in the increase of obesity in Norway in line with studies indicating that the obesity epidemic is already slowing down (3–5), in the United States most pronounced in women (6), but recently also in men (9).

Nevertheless, we observed a shift in the distribution curves of BMI and WC to the right, indicating that the change was not only due to fat people getting fatter. The shift in BMI was considerably greater than that observed for American adults between 1999/2000 and 2007/2008 (6). Similar patterns were observed in 40–42-year-old Norwegians from three other counties (33). Additionally, both self-reported (34) and measured (35) data demonstrated that overweight and obesity also increased in children in Norway. In addition to this general shift towards higher body weight in all weight categories, there was an especially large increase in obesity classes II and III even between HUNT2 and HUNT3 in most age groups of men and younger age groups of women.

In the US National Health and Nutrition Examination Surveys (6), which also used measured data, the prevalence of obesity in non-Hispanic white men aged ≥20 years increased from 27.3% in 1999–2000 to 33.1% in 2005–2006 and 31.9% in 2007–2008. In our study, the obesity prevalence in the same age and sex group increased from 14% in 1995–1997 to 22.1% in 2006–2008. Although our study showed lower obesity prevalence than the US comparable group, the sum of overweight and obesity groups in the latest surveys (BMI ≥ 25 kg m⁻²) was similar (HUNT 67.0% vs. the United States 67.5%). In a recent worldwide review, Finucane et al. (2) estimated a global increase in mean BMI of 0.4 kg m⁻² per decade. The corresponding HUNT figures for the 22-year period covered was 1.0 kg m⁻² per decade compared with 1.1 kg m⁻² per decade for the United States.

Different measures

BMI is the most widely applied measure in epidemiological studies, but it has well-known limitations as a surrogate measure for body fat, especially in those with high muscle mass. Furthermore, it has recently been shown that many people identified with obesity based on body fat measurements had BMI in the normal range (36). WC, reflecting central or visceral obesity, has gained increasing attention. Both BMI and WC are independently associated with cardiovascular risk and risk of death (16), but their relative importance may differ depending on the end point (37) or sex (38). Future health costs may be predicted better by WC than by BMI (39), and WC may precede other cardiovascular risk factors (40). The distribution curves of BMI and WC were comparable in our study. Obesity was more prevalent and increased to a greater extent when defined by WC than by BMI, indicating a considerable increase in abdominal fat. WC is a strong and additional risk factor for type 2 diabetes and all-cause mortality (41), and is more strongly related to mortality than BMI in persons with diabetes (42), raising health-related concerns in our population. The reason for this distinct increase in WC is difficult to establish. Compared with HUNT2, the proportion of HUNT participants reporting at least 30 min of daily physical activity was greater for HUNT3 in all age groups (data not shown). The amount of sitting time has, however, increased between HUNT2 and HUNT3. Sitting time is positively associated with cardiovascular risk factors (Chau J et al. personal communication), and one could speculate that sitting time might affect WC more than BMI. Further research is needed to examine this against more precise measures of body and abdominal fat.

Gender differences

Although BMI-defined obesity prevalence increased more in men than in women between HUNT2 and HUNT3, the reverse was observed for WC-defined obesity prevalence. Mean WC increased by 8.9 cm in women and 6.5 cm in men over the same period. A similar increase was observed in both sexes in Canada (10.6 and 6.5 cm, respectively) (43), but over a longer period (1981–2007/2009). A greater increase in women is also reported in Finland (44). In the United States, a much smaller increase, with similar increases between the sexes (2.9 cm in men and 3.2 cm in women), was observed between 1988/1994 and 1999/2000 (45).

The same gender differences were found in a recent study from Young-HUNT (the adolescent part of the HUNT Study), following changes in BMI and WC in 13–19-year-old participants with normal weight prospectively for 11
years (46). While 8% of girls and 9% of boys developed BMI-defined obesity, 34% of girls and 9% of boys developed WC-defined obesity.

WC is reported to predict all-cause mortality better in women than in men (37), which make the observed change in WC in women a worry. The substantial increase in WC in women could, at least partly, be related to changes in androgen levels in women (47,48) because total fat mass in women correlates with circulating testosterone levels (49). It is well known that abdominal obesity increases among women after menopause, associated with an increased amount of bioavailable testosterone (50), although this would not explain the increase in pre-menopausal women. Testosterone levels were not measured in our study.

Strengths and limitations
In contrast to most other studies, the present study includes a large population with wide age span and long follow-up period. Objective standardised measurements of height and weight were performed by trained personnel, and are more reliable than self-reported data used in many studies. Self-report has been shown to overestimate height and underestimate weight (especially in women), both resulting in lower than actual BMI (51,52), although the degree of underestimation varies (53).

A limitation of the study might be the declining participation rate from HUNT1 to HUNT3, introducing a potential selection bias, especially in the younger age groups. Overweight people might be more inclined to participate in the later surveys, but the opposite could also occur because of fear of unwanted comments on their body weight. Non-participation studies in HUNT1 and HUNT2 demonstrated that young people mostly attributed non-attendance to forgetfulness or practical difficulties like being away for school or work. After HUNT3, a two-page questionnaire was sent to all non-attendees and 6923 persons (16%) answered. BMI based on self-reported height and weight in this group was, in all age and sex groups, slightly lower than the measured values in those who attended (54). The mean difference in BMI (0.6 kg m\(^{-2}\) in men and 1.1 kg m\(^{-2}\) in women) was similar in men, but higher in women to that reported in an Australian study, also performed in 2007–2008 (0.6 vs. 0.7 kg m\(^{-2}\) in men and women, respectively) (53). This might imply that the high prevalence of obesity in men in HUNT3 is not due to the lower attendance, particularly in men, observed in HUNT3.

As the Nord-Trøndelag County is mainly rural with mean income and education levels slightly lower than the national average, the comparability to the Norwegian population might be attenuated. The obesity prevalence in the city of Tromsø in 1994–1995 was 9.5% in men and 11.5% in women compared with 14.4 and 18.3%, respectively, in those of similar age group in HUNT2 (1995–1997) (55). Accordingly, less densely populated areas in Nord-Trøndelag County had more obesity than the county’s towns (data not shown). Because overweight is inversely related to socioeconomic status (56), this might also have contributed to some overestimation of obesity prevalence in the present study. However, the increasing non-western immigrant population in the major cities, acknowledged to be more prone to obesity, might have led to an underestimation. Obesity in certain age groups in Tromsø nearly doubled, especially in men, from 1994–1995 to 2001 (33). Altogether, we have no evidence that these factors in Nord-Trøndelag have changed significantly over the period of time studied. We, therefore, consider that the observed changes in this study are generally relevant to the Norwegian population.

A third potential limitation might be the 11-year span between the surveys; therefore, we cannot be certain about what has happened in-between. Other Norwegian studies indicate that there has been a continuous increase in body weight in both 40–42-year-olds (11,33) and children (35). However, we cannot completely rule out an initial increase between HUNT2 and HUNT3 followed by a plateau in weight increase.

Our study showed that the increase in obesity in this relatively representative Norwegian adult population continued to increase up to 2008. Of particular concern is the considerable increase in young adults. The increase in BMI-defined obesity was greater in men than in women. The increase in abdominal obesity was even greater and present in all age and sex groups, but the increase was greater in women than in men for almost all age groups. A slower increase in the overweight group may indicate a future plateauing of the increase in obesity. Because of the increase in obesity in this Caucasian population, there is concern that the decreasing cardiovascular morbidity and mortality observed in Norway may reverse when the full effect of smoking cessation is achieved, unmasking consequences of the increasing obesity. More extensive and effective prevention strategies are recommended to avoid a future reduction in the public’s health.

Conflict of Interest
All authors declare no conflict of interest.

Author contributions
KM, AL, SK, TLH, KH and JH collected the data. KM wrote the manuscript. CMYL analysed the data; AL, SK, TLH, KH, SC, and JH contributed to the interpretation of the findings. All authors contributed to the writing of the paper and approved the final paper.

Acknowledgements
The Nord-Trøndelag Health Study (The HUNT Study) is a collaboration between HUNT Research Centre (Faculty of
References

1. WHO Consultation on Obesity. Obesity: Preventing and Managing the Global Epidemic. Report of A WHO Consultation. World Health Organization: Geneva, 2000, WHO Technical Report Series 894.

2. Finucane MM, Stevens GA, Cowan MJ et al. on behalf of the Global Burden of Metabolic Risk Factors of Chronic Diseases Collaborating Group (Body Mass Index). National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants. Lancet 2011; 377: 557–567.

3. Lissner L, Sohlström A, Sundblom E, Sjöberg A. Trends in overweight and obesity in Swedish schoolchildren 1999–2005: has the epidemic reached a plateau? Obes Rev 2009; 11: 553–559.

4. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007–2008. JAMA 2010; 303: 335–341.

5. Roholm B, Baker JL, Sørensen TIA. The leveling off of the obesity epidemic since the year 1999 – a review of evidence and perspectives. Obes Rev 2010; 11: 835–846.

6. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999–2008. JAMA 2010; 303: 235–241.

7. Salopuro TM, Saaristo T, Oksa H et al. Population-level effects of the national diabetes prevention programme (FIN-D2D) on the body weight, the waist circumference, and the prevalence of the national diabetes prevention programme (FIN-D2D) on the body weight, the waist circumference, and the prevalence of obesity among children, adolescents and children, adolescents, 1999–2008. JAMA 2010; 303: 335–341.

8. Griffiths C, Gately P, Marchant PR, Cooke CB. Cross-sectional comparisons of BMI and waist circumference in British children: mixed public health messages. Obesity 2012; 20: 1258–1260.

9. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999–2010. JAMA 2012; 307: 491–497.

10. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999–2010. JAMA 2012; 307: 483–490.

11. Midthjell K, Krüger O, Holmen J et al. Rapid changes in the prevalence of obesity and known diabetes mellitus in an adult Norwegian population. The Nord-Trøndelag Health Surveys: 1984–1986 and 1995–1997. Diabetes Care 1999; 22: 1813–1820.

12. Malnick SDH, Knobler H. The medical complications of obesity. Q J Med 2006; 99: 565–579.

13. Prospective Studies Collaboration. Body mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. Lancet 2009; 373: 1083–1096.

14. Preston SH, Stokes A. Contribution of obesity to international differences in life expectancy. Am J Public Health 2011; 101: 2137–2143.

15. Wang Y, Rimm EB, Stampfer MJ, Willett WC, Hu FB. Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. Am J Clin Nutr 2005; 81: 555–563.
33. Meyer HE, Tverdal A. Development of body weight in the Norwegian population. Prostaglandins Leukot Essent Fatty Acids 2005; 73: 3–7.
34. Andersen LF, Lillegaard ITL, Overby N et al. Overweight and obesity among Norwegian schoolchildren: changes from 1993 to 2000. Scand J Public Health 2005; 33: 99–106.
35. Bjørnelv S, Lydersen S, Holmen J, Nilsen TIL, Holmen TL. Sex differences in time trends for overweight and obesity in adolescents: the Young-HUNT Study. Scand J Public Health 2009; 37: 881–889.
36. Gómez-Ambrosi J, Silva C, Galofré JC et al. Body mass index classification misses subjects with increased cardiometabolic risk factors related to elevated adiposity. Int J Obes 2012; 36: 286–294.
37. Huxley R, Mendis S, Zheleznyakov E, Reddy S, Chan J. Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk – a review of the literature. Eur J Clin Nutr 2010; 64: 16–22.
38. Belluco R, Jia C, Ye W, Lagerros YT. Effects of physical activity, body mass index, waist-to-hip ratio and waist circumference on total mortality risk in the Swedish National March Cohort. Eur J Epidemiol 2010; 25: 777–788.
39. Haigard B, Gyrd-Hansen D, Olsen KR, Søgaard J, Sørensen TIA. Waist circumference and body mass index as predictors of health care costs. PLoS ONE 2008; 3: e2619. doi:10.1371/journal.pone.0002619.
40. Cameron AJ, Boyko EJ, Sircree RA et al. Central obesity as a precursor to the metabolic syndrome in the AusDiab Study and Mauritius. Obesity 2008; 16: 2707–2716.
41. Berentzen TL, Jakobsen MU, Halkjær J et al. Changes in waist circumference and mortality in middle-aged men and women. PLoS ONE 2010; 5: e13097. doi:10.1371/journal.pone.0013097.
42. Sluik D, Boeing H, Montonen J et al. Associations between general and abdominal obesity and mortality in individuals with diabetes mellitus. Am J Epidemiol 2011; 174: 22–34.
43. Janssen I, Shields M, Craig CL, Tremblay MS. Prevalence and secular changes in abdominal obesity in Canadian adolescents and adults, 1981 to 2007–2009. Obes Rev 2011; 12: 397–405.
44. Lahti-Koski M, Harald K, Männistö S, Laatikainen T, Jousilahti P. Fifteen-year changes in body mass index and waist circumference in Finnish adults. Eur J Cardiovasc Prev Rehabil 2007; 14: 398–404.
45. Ford ES, Mokdad AH, Giles WH. Trends in waist circumference among U.S. adults. Obes Res 2003; 11: 1223–1231.
46. Cuypers K, Kvaløy K, Bratberg G et al. Being normal weight but feeling overweight in adolescence may affect weight development into young adulthood – An 11-year followup: the HUNT Study, Norway. J Obes 2012; 2012: 601872. doi: 10.1155/2012/601872. Epub 2012 May 16.
47. Rosmond R. Androgen excess in women – a health hazard? Med Hypotheses 2006; 67: 229–234.
48. Baghaei F, Rosmond R, Westberg I et al. The CYP19 gene and associations with androgens and abdominal obesity in premenopausal women. Obes Res 2003; 11: 578–585.
49. Sowers MF, Beebe JL, McDonnell D, Randolph J, Jannausch M. Testosterone concentrations in women aged 25–50 years: associations with lifestyle, body composition, and ovarian status. Am J Epidemiol 2001; 153: 256–264.
50. Janssen I, Powell LH, Kazlauskaitė R, Dugan SA. Testosterone and visceral fat in midlife women: the Study of Women’s Health Across the Nation (SWAN) Fat Patterning Study. Obesity 2010; 18: 604–610.
51. Gorber SC, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. Obes Rev 2007; 8: 307–326.
52. Krul AJ, Daanen HAM, Choi H. Self-reported and measured weight, height and body mass index (BMI) in Italy, the Netherlands and North America. Eur J Public Health 2011; 21: 414–419.
53. Hayes AJ, Clarke PM, Lung TWC. Change in bias in self-reported body mass index in Australia between 1995 and 2008 and the evaluation of correction equations. Popul Health Metr 2011; 9: 53. doi:10.1186/1478-7954-9-53.
54. Langhammer A, Kroksstad S, Romundstad P, Heggland J, Holmen J. The HUNT study: participation is associated with survival and depends on socioeconomic status, diseases and symptoms. BMC Med Res Methodol 2012; 12: 143.
55. Jacobsen BK, Njoilstad I, Thune I et al. Increase in weight in all birth cohorts in a general population. The Tromsø Study 1974–1994. Arch Intern Med 2001; 161: 466–473.
56. Faeh D, Braun J, Bopp M. Prevalence of obesity in Switzerland 1992–2007: the impact of education, income and occupational class. Obes Rev 2011; 12: 151–166.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher’s web-site:

Figure S1. Prevalence of BMI defined (A) overweight (BMI 25–29.9 kg m⁻²) and (B) obesity (BMI ≥ 30 kg m⁻²) in men

Figure S2. Prevalence of BMI defined (A) overweight (BMI 25–29.9 kg m⁻²) and (B) obesity (BMI ≥ 30 kg m⁻²) in women

Figure S3. Prevalence of obesity (A) class I (BMI 30.0–34.9 kg m⁻²), (B) class II (BMI 35.0–39.9 kg m⁻²) and (C) class III (BMI ≥ 40.0 kg m⁻²) in men

Figure S4. Prevalence of obesity (A) class I (BMI 30.0–34.9 kg m⁻²), (B) class II (BMI 35.0–39.9 kg m⁻²) and (C) class III (BMI ≥ 40.0 kg m⁻²) in women

Figure S5. Prevalence of (A) abdominal overweight (WC 94.0–101.9 cm) and (B) abdominal obesity (WC ≥ 102.0 cm) in men

Figure S6. Prevalence of (A) abdominal overweight (WC 80.0–82.9 cm) and (B) abdominal obesity (WC ≥ 88 cm) in women.

Table S1. Number of participants with obese class II (BMI 35–39.9 kg m⁻²) and obese class III (BMI ≥ 40 kg m⁻²) by sex and age group.