Increase in Weight in All Birth Cohorts in a General Population

The Tromsø Study, 1974-1994

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Background: Obesity is a risk factor for a number of chronic diseases. Few longitudinal studies have examined changes in body mass index (BMI [calculated as weight in kilograms divided by the square of the height in meters]).

Objective: To investigate the changes in mean BMI and the prevalence of obesity in a large cohort examined several times during a 20-year period.

Methods: Mean BMI, the percentage of subjects with low BMI (<20 kg/m²), and the percentage who were obese (BMI ≥30 kg/m²) were determined in a large population of men and women who were examined up to 4 times during a 20-year period (1974-1994/1995). In a longitudinal design, we observed 3541 men who attended all 4 screenings (1974-1994/1995) and 4993 women who attended the last 3 screenings (1979/1980-1994/1995).

Results: The age- (25-49 years) and sex-adjusted mean BMI increased 1 kg/m² in men from 1974 to 1994/1995 and 0.9 kg/m² in women from 1979/1980 to 1994/1995. In the last survey, subjects aged 25 to 85 years were included. In most age groups, the mean BMI exceeded 25 kg/m² and the prevalence of obesity was 10% or higher in men and women aged 45 years or older. In the longitudinal analysis, the mean BMI in men aged 20 to 49 years increased 2.0 kg/m² during 20 years of observation and increased 2.4 kg/m² in women aged 20 to 49 years during 15 years of observation. The increase in BMI was larger in younger men than in older men.

Conclusions: Body mass index increased in every examined birth cohort (1925-1964) during the 15- to 20-year observation period. Primary prevention of further increased body weight should be a priority.

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Obesity is a significant risk factor for a number of diseases, including cardiovascular diseases, type 2 diabetes mellitus, certain types of cancer, and osteoarthritis as well as mental distress. Maintaining a lasting weight reduction is for many people an insurmountable task; therefore, the primary prevention of obesity, through a change in eating habits and/or an increase in physical activity, is an important objective for public health.

It is therefore of great concern that the prevalence of obesity is increasing in most parts of the world. We are experiencing a global epidemic; often in the nonindustrialized world obesity occurs along with widespread malnourishment. In the United States, the prevalence of being overweight in men and women aged 20 to 74 years has increased in the last 40 years. The prevalence of obesity (body mass index [BMI] ≥30 kg/m²) was 10% in men and 15% in women in 1960-1961. Between 1988 and 1994, the prevalences were 20% and 25%, respectively. The major increase in the prevalence of being overweight was observed in the last part of this 30-year period, between the second National Health and Nutrition Examination Survey (NHANES II, 1976-1980) and the third National Health and Nutrition Examination Survey (NHANES III, 1988-1994). Recent data indicate that the prevalence of obesity in the United States is still increasing.

The age-standardized (35-64 years) prevalence of obesity in the European part of the World Health Organization (WHO)-MONICA survey (1983-1986) was 15% in men and 22% in women. There were, however, large differences between the different survey centers. The highest prevalence was found among women in Kaunas, Lithuania (45%), and the lowest among men in Gothenburg, Sweden (7%).

The aim of this study was both to give longitudinal data about changes in BMI in the same persons between 1974 and 1995, using data from 4 repeated measure-
SUBJECTS, MATERIALS, AND METHODS

POPULATION

The Tromso Study was initiated in 1974 and is a single-center study of the population in the municipality of Tromso. Tromso is situated at the parallel of latitude that is 70° north of the equator (north of the Arctic Circle).10-12 With approximately 60,000 inhabitants, Tromso is the largest city in northern Norway. The aims of the Tromso Study are to investigate determinants of chronic diseases, to assess etiological significance, and to identify potentially modifiable determinants that might lead to the development of preventive strategies.

The base for this study was men and women who attended 1 or more of the 4 surveys in the Tromso Study in 1974, 1979/1980, 1986/1987, and 1994/1995. In 1974, all men aged 20 to 49 years were invited to the screening10; in 1979/1980, the invited population was expanded to all men aged 20 to 54 years (thereby including the cohort examined in the first survey) and all women aged 20 to 49 years.11 In the third screening (1986/1987), all men aged 20 to 61 years and all women aged 20 to 56 years were invited.12 All individuals older than 24 years living in the Tromso municipality were invited to the fourth survey in 1994/1995.

After excluding subjects who were not able to attend (eg, because of temporary residence outside Tromso), the attendance rate was 83% in 1974, 10 82% (men) and 88% (women) in 1979/1980,11 and 76% (men) and 83% (women) in 1986/1987.13 In 1994/1995, 74% of the invited men and 79% of the invited women attended the screening. In the analysis of data from the fourth survey in 1994/1995, we included men and women up to the age of 84 years. For older groups (≥85 years), attendance by mostly healthy persons was likely, as the 178 attendants represented only half of the population invited to the screening.

All men and nonpregnant women who had their height and weight measured were included in the cross-sectional analysis. Three percent of the attending women in 1986/1987 were pregnant. In 1974, data were available from 6579 men; in 1979/1980, from 8335 men and 7847 women; in 1986/1987, from 10,403 men and 9833 women; and finally, in 1994/1995, from 12,784 men and 13,959 women.

Two cohorts were observed in particular: the 3541 men who attended all 4 screenings and the 4993 women who attended the last 3 screenings. In addition, we included in the cohort analyses 1189 men and 779 women who were too young to be included in all the surveys but took part in the surveys to which they were invited. Thus, both cross-sectional data and longitudinal data are presented in the tables. Age- and sex-adjusted values presented in Table 1 were calculated by applying the age- and sex-specific mean BMI values to the population consisting of all the attendants of the 1986/1987 screening.

MEASUREMENTS OF WEIGHT AND HEIGHT AND COMPUTATION OF BMI

At screening, height and weight were measured. Height (without shoes) was measured to the nearest centimeter. In the first survey, weight was measured to the nearest kilogram; in the next 3 surveys, to the nearest half-kilogram. Body mass index was calculated as weight in kilograms divided by the square of the height in meters. According to the WHO,1 normal weight is a BMI between 18.5 and 25 kg/m2, overweight is a BMI between 25 and 30 kg/m2, and obesity is a BMI at 30 kg/m2 or higher. In the tables and figures, we have presented the mean BMI in different age-sex strata as well as the percentage of subjects with relatively low BMI (<20 kg/m2) and who are obese (≥30 kg/m2). A BMI lower than 20 kg/m2 was selected as the indicator of low BMI in our population because very few subjects in the Tromso population are underweight as defined by the WHO (BMI <18.5 kg/m2).1 In our presentation, we will refer to these definitions of underweight, low BMI, normal weight, overweight, and obese.

STATISTICAL METHODS AND ETHICAL APPROVAL

The statistical analyses were performed using the SAS package (SAS Institute Inc, Cary, NC, 1987). A P value less than .05 was considered statistically significant. The Regional Committee for Medical Research Ethics has approved the Tromso Study.

Table 1 gives the results from the cross-sectional analyses. In general, the age-specific BMI increased in men from one survey to the next, but in women, relatively small changes in BMI were observed between 1979/1980 and 1986/1987. The sex- and age-adjusted (25-49 years) mean BMI increased 1 kg/m2 in men during the 20-year period of observation (corresponding to a 3-kg increase in weight in a man with a height of 1.75 m) and increased 0.9 kg/m2 in women during the 15-year period of observation (approximately corresponding to a 2.5-kg increase in a woman with a height of 1.65 m).

The SD of BMI was higher in women than in men in all age groups (Table 1), and it increased with age in women.

The percentage of underweight subjects (BMI <18.5 kg/m2) was very low in men (<1% in all 4 screenings). In women, it was somewhat higher (5%, 4%, and 2% in the screenings in 1979/1980, 1986/1987, and 1994/1995, respectively). The highest prevalence of underweight subjects (6%-9%) was found in younger women aged 20 to 29 years in the 1979/1980 and 1986/1987 screenings.

In men, the prevalence of low BMI (<20 kg/m2) was less than 10% except in the group aged 20 to 24 years. In women, a reduction in the percentage of the population with low BMI occurred from 1979/1980 to 1994/1995 in relatively younger women (aged <39 years). The percentage of obese (BMI ≥30 kg/m2) men and women
increased with age and from one survey to the next, particularly from the 1986/1987 survey to the survey conducted 8 years later.

In the last survey (1986/1987), the mean BMI was 25.6 kg/m² and 24.8 kg/m² in men and women, respectively. The BMI increased with age in women. In men, the highest BMI was observed around the age of 50 years whereas the median was 23.8 kg/m². Similarly, in 1979/1980 the mean BMI in women observed for 15 years was 23.8 kg/m² (Table 3). In women, the BMI increased similarly between 1979/1980 and 1986/1987 in all birth cohorts, with a cohort effect of steeper increase in BMI with increasing age was more evident in younger vs older cohorts. Men born in the early 1950s had, when they were 42 years old, approximately the same mean BMI as men born in the late 1920s, when they were 67 years old. The prevalence of obesity (BMI \( \geq 30 \text{ kg/m}^2 \)) increased in all birth cohorts to 10% in 1994/1995 (Figure 2, Table 3).

Table 4 details a significant increase in the BMI in women during the 15 years between 1979/1980 and 1994/1995. The mean increase in BMI in women aged 20 to 49 years in 1979/1980 was 2.4 kg/m². The increase in BMI during the 15-year period between 1979/1980 and 1994/1995 was larger in women than in men in all birth cohorts. In women, the BMI increased similarly between 1979/1980 and 1986/1987 in all birth cohorts, with a steeper increase in BMI for all birth cohorts between the third and fourth survey (Table 4, Figure 1). In women born between 1955 and 1964, we found a higher BMI at a given age. The prevalence of obesity increased more in the last part of the 15-year period than in the first part (Table 4, Figure 2).

The median BMI in the population was somewhat lower than the mean BMI presented in the tables, particularly in women. For example, in 1974 the mean BMI in men observed for 20 years was 24.0 kg/m² (Table 3), whereas the median was 23.8 kg/m². Similarly, in 1979/1980 the mean BMI in women observed for 15 years was 22.7 kg/m² (Table 4) and the median was 22.1 kg/m². The median increase in BMI during the 15 and 20 years of observation, respectively, was the same as the mean increase. The pattern of the cohort-specific changes in mean and median BMI was quite similar in men, with a larger increase in the median BMI in younger men (aged 20-29 years) than in older men.
The main finding in this study is that BMI increased during the 15 to 20 years of follow-up in every examined birth cohort in this population-based study in Tromsø. In younger men, the increase in mean BMI during the 20 years following 1974 was more pronounced than in older men. The increase in BMI during the 15-year period from 1979/1980 to 1994/1995 was larger in women than in men, but the increase in BMI in women differed little among the birth cohorts. Furthermore, the increased mean BMI was not caused by an increase in BMI in a minority of the population.

Another salient finding in our study is the difference between the cross-sectional and longitudinal analyses. The former analysis indicates that the BMI in men increases with age up to age 50 years, levels off, and then slowly decreases after age 60 years. The results from the cross-sectional analysis are in accordance with other cross-sectional data. The results from the longitudinal analysis, however, show that all birth cohorts have experienced an increase in weight. The cross-sectional and longitudinal results are compatible in that younger men have higher BMIs than older men. Thus, in the 1974 survey, the mean BMI increased directly with age in men aged 20 to 49 years. Twenty years later, when the men were 40 to 69 years old, the highest BMI occurred in men aged 45 to 64 years and a somewhat lower mean BMI occurred in men aged 65 to 69 years.

When restricting the population in the 1994/1995 survey to subjects aged 35 to 64 years, we found that 10% to 11% of men and women were obese as defined by WHO. Therefore, the prevalence of obesity in Tromsø, was somewhat lower in the mid-1990s than in most Western European countries as measured 10 years before in the WHO-MONICA survey in 1983-1986, although lower prevalences of obesity have also been reported. The prevalence of obesity in our population is also lower than in the United States and in another county in Norway (the North-Trøndelag Health Surveys).

We have studied the change in BMI in a relatively large population of both sexes measured 3 or 4 times during a 15- to 20-year period. Some comparable studies have been published. Based on 2 measurements of BMI in 17000 adult Finns taken an average of 5.7 years apart, Rissanen and colleagues found that young men experienced a greater BMI increase than young women. In middle-aged and older subjects (50 years or older at baseline in 1966-1972), the BMI was unchanged or actually decreased between the 2 examinations. As their data were collected before ours, comparisons are somewhat hampered.

Williamson and colleagues analyzed changes in BMI in the United States during a 10-year period starting in 1971-1975 and included 3727 men and 6135 women. In the same age groups also considered in our analysis, Williamson and colleagues found that women experienced a greater BMI increase than men, and younger subjects experienced a greater BMI increase than older subjects. These results confirm some of ours. We found that women gained more

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<th>1986-1987, M/F</th>
<th>1994-1995, M/F</th>
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<tbody>
<tr>
<td>No.</td>
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</tr>
<tr>
<td>1159/1229</td>
<td>23.2 (2.9)/22.1 (3.2)</td>
</tr>
<tr>
<td>1317/1449</td>
<td>23.7 (2.7)/22.1 (3.1)</td>
</tr>
<tr>
<td>1583/1755</td>
<td>24.1 (2.9)/22.4 (3.1)</td>
</tr>
<tr>
<td>1709/1649</td>
<td>24.7 (3.0)/22.9 (3.1)</td>
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<tr>
<td>1484/1520</td>
<td>25.2 (2.9)/23.8 (3.6)</td>
</tr>
<tr>
<td>1074/1058</td>
<td>25.5 (2.9)/24.2 (3.6)</td>
</tr>
<tr>
<td>891/871</td>
<td>25.5 (3.1)/24.8 (3.8)</td>
</tr>
<tr>
<td>834/322</td>
<td>25.3 (3.3)/25.0 (4.1)</td>
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<td>352x</td>
<td>25.3 (3.0)/x</td>
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<td>x/x</td>
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<td>8326/8660</td>
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<tr>
<td>8059/8302</td>
<td>24.7/23.2</td>
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weight than men did from 1979/1980 to 1994/1995, but that the change in weight in women was similar in the different birth cohorts. Williamson and colleagues found in subjects aged 55 years or older at baseline (older than the persons included in our longitudinal analysis) a decrease in the mean BMI during the next 10-year period and a larger decrease in women than in men. This is similar to the findings by Rissanen and colleagues.15

Recently, Lewis and colleagues18 published a 10-year follow-up study (the Coronary Artery Risk Development in Young Adults [CARDIA] Study) of Americans aged 18 to 30 years at baseline in 1985/1986. A total of 5115 subjects were included in the baseline, 79% of whom were observed for 10 years. The mean BMI and the prevalence of obesity have increased in both white and African American men and women in the 10 years after 1985/1986. The increase in BMI was most pronounced in African American women, but the mean BMI in all 4 race-sex groups in 1995/1996 (when the sub-

Table 3. Mean Body Mass Index (BMI) of 3541 Men Observed From 1974 to 1994/1995 by Age and Percentage With Low BMI ($<20$ kg/m²) or Obesity ($\geq 30$ kg/m²): The Tromsø Study, Norway*

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<tr>
<td></td>
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<td>15-19 (500)</td>
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<tr>
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<td>8</td>
<td>1</td>
<td>23.7</td>
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<tr>
<td>25-29 (683)</td>
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<td>6</td>
<td>2</td>
<td>24.4</td>
</tr>
<tr>
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<td>3</td>
<td>1</td>
<td>24.6</td>
</tr>
<tr>
<td>35-39 (620)</td>
<td>24.5</td>
<td>1</td>
<td>3</td>
<td>24.9</td>
</tr>
<tr>
<td>40-44 (579)</td>
<td>24.6</td>
<td>3</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td>45-49 (505)</td>
<td>24.6</td>
<td>2</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td>20-49 (3541)</td>
<td>24.0</td>
<td>4</td>
<td>3</td>
<td>24.6</td>
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*BMI is calculated as weight in kilograms divided by the square of the height in meters; x indicates not applicable.

Figure 1. Mean body mass index (BMI) according to birth cohort in 3541 men observed from 1974 to 1994/1995 and 4993 women observed from 1979/1980 to 1994/1995: the Tromsø Study.

Figure 2. Prevalence of obesity (body mass index [BMI] ≥30 kg/m²) according to birth cohort in 3541 men observed from 1974 to 1994/1995 and 4993 women observed from 1979/1980 to 1994/1995: the Tromsø Study.

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Table 4. Mean Body Mass Index (BMI) in Women Observed From 1979/1980 to 1994/1995 and Percentage With Low BMI (<20 kg/m²) and Obesity (>30 kg/m²): The Tromsø Study, Norway

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<tr>
<td></td>
<td>Mean BMI</td>
<td>&lt;20, %</td>
<td>≥30, %</td>
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<tr>
<td>15-19 (779)</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>20-24 (584)</td>
<td>21.4</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>25-29 (870)</td>
<td>21.7</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>30-34 (1129)</td>
<td>23.3</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>35-39 (989)</td>
<td>22.9</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>40-44 (761)</td>
<td>23.7</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>45-49 (660)</td>
<td>24.3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>20-49 (4993)</td>
<td>22.7</td>
<td>16</td>
<td>3</td>
</tr>
</tbody>
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*BMI is calculated as weight in kilograms divided by the square of the height in meters; x indicates not applicable.

The attendance rates of the screenings were relatively high, particularly of those that formed the basis for the 2 longitudinal analyses (83% for men in 1974 and 88% in women in 1979/1980). This reduces the likelihood of major bias in the estimates of BMI in the population. As must be expected in the longitudinal analysis with birth cohorts observed for up to 20 years, a relatively high percentage (46% in men) of the initial cohort did not take part in all surveys. Reasons for not attending one of the consecutive screenings include death, emigration from Tromsø, temporary absence from Tromsø, and unwillingness to participate. In this relatively young population, a lack of motivation and emigration are the main reasons, although the percentage that died during the next 20 years was not negligible in men aged 45 to 49 years. Because the characteristics of subjects who attended all screenings may differ from those who did not, a bias may be introduced.

A total of 6579 men aged 20 to 49 years had their BMI measured in 1974, whereas 3541 of these men (54%) had their BMI measured in all 4 surveys. In the group aged 20 to 24 years in 1974, men who were observed during the next 20 years had a higher BMI by 0.5 kg/m² than men who did not participate in all 4 screenings, whereas in men aged 45 to 49 years who participated throughout, the BMI was lower by 0.4 kg/m². The implications of this for our main results, however, are not clear. Perhaps it indicates that the younger men who took part in all 4 surveys had a greater tendency to put on weight relative to the older men. We have no data to address this question formally, but found in the younger men (aged 20-24 years at baseline) who participated in all 4 screenings no correlation (r = -0.03) between the baseline BMI and the change in BMI during the next 20 years. In men aged 45 to 49 years at baseline, an inverse relationship was found (r = -0.2). Thus, there were no indications that men with high BMIs at baseline tended to put on weight. It may also be suggested that the lower mean BMI in men aged 45 to 49 years at baseline who attended all screenings reflects a higher mortality in the men who were most obese at baseline. However, the percentage of men in this age group who were obese differed little between all men in 1974 (5%; Table 1) and men who were observed for the entire 20-year period (4%; Table 3).

In 1979/1980, 7847 nonpregnant women aged 20 to 49 years had their BMI measured, whereas 4993 of these women (64%) had their BMI measured in all 3 surveys. Analysis findings of the 6 different birth cohorts revealed that the mean BMI in the women who did not attend all screenings did not differ significantly (P = 0.97) from the BMI in women who took part in all 3 screenings. Therefore, no bias with regard to the initial BMI was indicated.
In the older age groups, the effect of a height reduction due to osteoporosis may somewhat influence the results from the longitudinal analysis. At a given weight, a reduced height would result in an increase in BMI. A recent study has shown that in older age groups, the effect of height reduction on BMI, given no actual change in weight, can be substantial (an increase of 2.5 kg/m² between the ages of 20 and 80 years in women). During the 20 years from 1974 to 1994/1995, the mean height of the 505 oldest men observed (aged 45-49 years) was reduced by 14 mm. This corresponds to a 0.4-kg/m² increase in BMI, considerably less than the observed 1.1-kg/m² increase. In the 660 women aged 45 to 49 years in 1979/1980 and observed for 15 years, there occurred a 10-mm reduction in height, corresponding to a 0.3-kg/m² increase in BMI. Thus, in our study the change in body height cannot explain the change in BMI during the follow-up period. Furthermore, with increasing age, the proportion of body weight being lean body mass normally decreases. Therefore, even if the weight of fat in the body is unchanged, the total body mass and BMI are reduced. Thus, the 2 effects of aging (change in height due to osteoporosis and change in body composition) have opposing effects on BMI.

The most important implications of our findings are, of course, the effects that increased prevalence of obesity may have on the disease panorama in the years to come. It is noteworthy that this increase in body weight has taken place in age groups where BMI has the strongest relation to mortality. The mean values of BMI in 1994/1995 exceed the optimal BMI for longevity (20.0-24.9 kg/m²) found for nonsmoking Americans with no history of disease. It is, however, a paradox that although we demonstrate a significant increase in body weight in the period between 1974 and 1994/1995, the mortality rate of some of the diseases that may follow obesity (eg, cardiovascular diseases) is actually reduced. In another Norwegian county, the prevalence of self-reported diabetes mellitus increased in men younger than 90 years and in women younger than 60 years between 1984/1986 and 1995/1996. Also in our population, the prevalence of diabetes was assessed by a self-administered questionnaire. In subjects aged 40 to 49 years at baseline (the oldest age group that was examined in all surveys), we found the same incidence of diabetes from 1979/1980 to 1986/1987 as from 1986/1987 to 1995/1996. The incidence of diabetes in men from 1974 to 1979/1980 was, however, 40% lower (P = .10). We do not know the type of diabetes, but most new cases of diabetes in the group aged 40 to 49 years are of type 2 diabetes mellitus.

In conclusion, we have described a distinct increase in the mean and median BMI in all examined cohorts in Tromso from 1974 to 1994/1995 (in men) and from 1979/1980 to 1994/1995 (in women). According to our results, the prevalence of obesity has increased in both men and women and is now approximately 10% in men 45 years or older and even higher in women 50 years or older. The pattern of the increase in BMI seems to differ markedly between men and women. Our analysis also demonstrates that describing the relation between age and BMI from a cross-sectional analysis may be misleading. The increase in BMI and prevalence of obesity found in Norway and many other populations is a result of subtle changes in energy intake and energy expenditure over the years. There is a need for further insight into how BMI changes and the health consequences of the obesity epidemic.

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**Correction**

Errors in “Comment” Section. In the original investigation by Jacobsen et al titled “Increase in Weight in All Birth Cohorts in a General Population,” published in the February 12 issue of the ARCHIVES (2001;161:466-472), an error occurred in the “Comment” section on page 469. The fifth sentence in the second paragraph should have read: “The cross-sectional and longitudinal results are compatible in that younger men have a larger increase in BMIs than older men.” Also, on page 472 the reference number in the fifth sentence of the second paragraph should have been 13 (Midthjell et al) and not 11 (Jacobsen and Thelle).