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Prevalence of general and abdominal obesity in 2015–2016 and 8-year longitudinal weight and waist circumference changes in adults and elderly: the Tromsø Study

Ola Løvsletten ,[1] Bjarne K Jacobsen,[1,2] Sameline Grimsgaard,[1] Inger Njølstad,[1] Tom Wilsgaard ,[1] Maja-Lisa Løchen,[1] Anne Elise Eggen,[1] Laila Arnesdatter Hopstock[1]

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[1]Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Norway
[2]Centre for Sami Health Research, Department of Community Medicine, UiT The Arctic University of Norway, Tromsø, Norway

Correspondence to
Dr Ola Løvsletten;
ola.lovsletten@uit.no

ABSTRACT

Objectives To describe the prevalence of general (body mass index (BMI) ≥30 kg/m^2) and abdominal (waist circumference women >88 cm, men >102 cm) obesity in Tromsø 7 (2015–2016), and the secular change from Tromsø 6 (2007–2008). Furthermore, to study longitudinal changes in body weight and waist circumference from Tromsø 6 to Tromsø 7.

Setting A population study in Tromsø, Norway.

Participants The cross-sectional analyses included 20 855 participants in Tromsø 7 (aged ≥40 years) and 12 868 in Tromsø 6 (aged ≥30 years). The longitudinal analyses included 8592 participants with repeated measurements, aged 35–79 in Tromsø 6.

Outcome measures Mean age-specific and sex-specific BMI, waist circumference, prevalence of general and abdominal overweight and obesity, as well as longitudinal changes in body weight and waist circumference according to sex and birth cohort.

Results Over 8 years, the age-adjusted prevalence of general obesity increased (p<0.0001) from 20.1% to 23.0% in women and from 20.7% to 25.2% in men. The age-adjusted prevalence of abdominal obesity did not increase in women (from 54.7% to 53.4%), and the increase in men was modest (from 36.8% to 38.6%, p=0.003). Longitudinal analyses showed an increase in body weight, by 1.1 kg (95% CI 0.9 to 1.2) in women and 0.7 kg (95% CI 0.6 to 0.9) in men, and also waist circumference, by 1.3 cm (95% CI 1.0 to 1.5) in women and 1.4 cm (95% CI 1.2 to 1.6) in men. There were inverse relationships (p<0.001) between age at baseline and change in weight and waist circumference.

Conclusions Repeated cross-sectional analyses showed that the prevalence of general obesity increased, whereas the increase in abdominal obesity was less marked. Longitudinal analyses showed increases in both body weight and waist circumference. The youngest age groups have the largest increase.

Strengths and limitations of this study

- Waist, weight and height were measured, not self-reported.
- Population-based study with a relative large number of participants; 21 083 in the seventh survey of the Tromsø Study (Tromsø 7) and 12 984 in Tromsø 6. A subset of participants, n=8906, attended both surveys.
- High attendance; 66% in Tromsø 6% and 65% in Tromsø 7.
- Among the elderly there may be a selection bias due to healthy individuals who participate in the study.

INTRODUCTION

There is an increasing prevalence of general obesity (body mass index (BMI) ≥30 kg/m^2) in most parts of the world, also in high-income countries,[1 2] and probably more in rural than in urban areas.[3] General obesity is an important risk factor for several non-communicable diseases[1] (NCDs), and halting the rise in obesity is part of WHO's global action plan to prevent and reduce NCDs.[4]

Abdominal obesity (waist circumference >88 cm in women and >102 cm in men) is a significant predictor of obesity-related diseases[5 6] and all-cause mortality.[7–9] Information about the prevalence of abdominal obesity is therefore of major interest.

We have previously reported secular trends in mean BMI as well as the prevalence of general obesity in a large population in Norway from 1974 to 2008[10 11] and corresponding figures for waist circumference and abdominal obesity from 1994 to 2008.[12] Furthermore, we have published longitudinal changes in the same obesity-related measures.[10–12]

The aim of this study was to describe the obesity epidemic in Norway with cross-sectional data from the last survey of the Tromsø Study in 2015–2016 (Tromsø 7), and

to study the longitudinal changes in body weight and waist circumference from the sixth survey of Tromsø Study in 2007–2008 (Tromsø 6).

MATERIAL AND METHODS

The Tromsø study

The Tromsø Study is an ongoing population-based cohort study, based in Tromsø.[13 14] The study includes seven surveys (Tromsø 1–Tromsø 7) between 1974 and 2015–2016, to which total birth cohorts and representative samples from Tromsø municipality are invited. Tromsø is the largest populated municipality in Northern Norway with ~65 000 inhabitants in 2008 and ~73 000 inhabitants in 2016, including both urban and rural living areas. The present analyses are based on data from the sixth (Tromsø 6) and seventh survey (Tromsø 7), conducted in 2007–2008 and 2015–2016, respectively.

In Tromsø 6, four different groups were invited; participants who took part in a comprehensive examination in Tromsø 4 (conducted in 1994–1995), a 10% random sample of the age group 30–39, everyone in the age groups 40–42 and 60–87, and a 40% random sample of people aged 43–49 years (n=19 762), and 12 984 men and women aged 30–87 years attended (66%). In Tromsø 7, all inhabitants of Tromsø municipality aged 40 and older were invited (n=32 591), and 21 083 men and women aged 40–99 years attended (65%). A total of 8906 attended both Tromsø 6 and Tromsø 7.

The participants gave written informed consent.

Public involvement

The Norwegian Health Association (https://nasjonalforeningen.no/) was member of the steering group for Tromsø 7. There is an ongoing research communication between the Tromsø Study and the community.

Measurements

Body height and weight were measured to the nearest 0.1 cm and 100 g, respectively. Waist circumference was measured at the umbilical level by a tape measure, to the nearest centimetre. All measurements were performed by trained staff with the participant standing and breathing normally, with light clothing and no footwear.

BMI was calculated as weight divided by the square of height (kg/m^2) categorised into underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25–29.9 kg/m^2), obese class 1 (30.0–34.9 kg/m^2), class 2 (35.0–39.9 kg/m^2) or class 3 (≥40.0 kg/m^2).[15]

The age group 75–79 (age in 2007) experienced a height reduction of 1.4 cm in women and 1.2 cm in men, from Tromsø 6 to Tromsø 7. Height loss increases BMI and also waist/height ratio (under the assumption of no change in weight and waist circumference).

For instance, a height reduction of 3 cm, from 1.80 to 1.77 cm in a person with body weight 70 kg, gives a 0.7 kg/m^2 higher BMI. Therefore, weight and waist circumference are the dependent variables in the longitudinal analyses. Thus, we avoid a potential masking of weight loss in the elderly, which can be a problem for BMI.[16]

Sample

After exclusions, the cross-sectional analyses of BMI in Tromsø 7 include data from 20 855 participants (10 932 women and 9923 men), whereas for waist circumference the sample size was 20 953 participants (10 991 women and 9962 men). Pregnant women and participants with other remarks concerning the waist, height or weight

Table 1 Mean body mass index (BMI, kg/m^2), and prevalence of overweight and obesity by gender and age groups in Tromsø 7 (2015–2016)*

	Women (n=10 932)				Men (n=9923)			
Age	n	Mean (SD) BMI	% overweight (95% CI†)	% obese (95% CI†)	n	Mean (SD) BMI	% overweight (95% CI†)	% obese (95% CI†)
40–44	1656	26.6 (5.1)	33.6 (31.3 to 35.9)	21.1 (19.2 to 23.2)	1468	28.0 (4.2)	50.5 (47.9 to 53.1)	26.3 (24.1 to 28.6)
45–49	1686	27.0 (5.3)	31.9 (29.6 to 34.1)	24.8 (22.7 to 26.9)	1574	28.1 (4.2)	50.1 (47.6 to 52.6)	27.3 (25.1 to 29.6)
50–54	1690	26.6 (4.9)	34.7 (32.4 to 37.0)	20.9 (19.0 to 22.9)	1429	27.9 (4.1)	50.9 (48.3 to 53.6)	25.5 (23.3 to 27.9)
55–59	1532	26.9 (4.8)	39.4 (37.0 to 41.9)	21.4 (19.4 to 23.6)	1348	27.9 (3.8)	52.5 (49.8 to 55.2)	24.9 (22.6 to 27.3)
60–64	1404	26.8 (4.6)	39.7 (37.2 to 42.4)	21.2 (19.1 to 23.5)	1318	27.8 (4.0)	49.2 (46.4 to 51.9)	25.3 (22.9 to 27.7)
65–69	1245	27.0 (4.7)	40.5 (37.7 to 43.3)	22.5 (20.2 to 24.9)	1165	27.8 (3.8)	52.6 (49.7 to 55.5)	24.1 (21.7 to 26.7)
70–74	840	27.8 (5.0)	40.2 (36.9 to 43.6)	28.6 (25.5 to 31.8)	845	27.8 (3.9)	50.8 (47.3 to 54.2)	25.2 (22.3 to 28.3)
75–79	488	27.0 (4.8)	42.8 (38.4 to 47.4)	22.5 (18.9 to 26.5)	453	27.4 (3.8)	50.8 (46.1 to 55.5)	21.0 (17.3 to 25.0)
80–84	257	26.7 (4.4)	45.1 (38.9 to 51.4)	20.6 (15.8 to 26.1)	237	26.9 (3.5)	47.3 (40.8 to 53.8)	18.1 (13.5 to 23.7)
85+	134	27.1 (4.7)	44.8 (36.2 to 53.6)	23.9 (16.9 to 32.0)	86	25.9 (3.4)	52.3 (41.3 to 63.2)	8.1 (3.3 to 16.1)
All	10 932	26.9 (4.9)	37.2 (36.3 to 38.1)	22.5 (21.7 to 23.3)	9923	27.8 (4.0)	50.8 (49.8 to 51.8)	25.1 (24.2 to 25.9)

The Tromsø study.
*Overweight, BMI 25–29.9; obesity, BMI ≥30.
†Exact (Clopper-Pearson) CI from the binomial distribution.

Table 2 Distribution of body mass index (BMI, kg/m^2), and age-adjusted prevalence of overweight and obesity, in Tromsø 6 (2007–2008) and Tromsø 7 (2015–2016)

	Women			Men		
	Tromsø 6	Tromsø 7		Tromsø 6	Tromsø 7	
BMI						
<18.5	1.0	0.9		0.3	0.2	
18.50–19.99	3.0	2.7		0.7	0.6	
20.00–24.99	37.5	36.6		27.4	23.3	
25.00–29.99	38.3	37.2		51.2	50.8	
30.00–34.99	14.9	16.0		17.3	20.0	
35–39.99	4.2	4.8		2.6	4.2	
≥40.00	1.1	1.7		0.5	1.0	
Participants aged 40–84						
Mean age (SD)	58.2 (12.0)	56.8 (10.9)		58.1 (11.5)	57.1 (11.0)	
Mean BMI (95% CI)	26.6 (26.5 to 26.7)	26.9 (26.8 to 27.0)		27.3 (27.1 to 27.4)	27.9 (27.8 to 27.9)	
Mean BMI age adjusted (95% CI)	26.6 (26.5 to 26.7)	26.9 (26.8 to 27.0)	P<0.0001†	27.3 (27.2 to 27.4)	27.8 (27.8 to 27.9)	P<0.0001†
% obese (95% CI)	20.4 (19.4 to 21.4)	22.5 (21.7 to 23.3)		20.4 (19.4 to 21.5)	25.2 (24.4 to 26.1)	
% obese, age adjusted (95% CI)	20.1 (19.3 to 21.0)	23.0 (22.2 to 23.7)	OR=1.18 (1.12 to 1.25)†	20.7 (19.8 to 21.6)	25.2 (24.3 to 26.0)	OR=1.29 (1.22 to 1.36)†

The Tromsø study.
*Distribution in %. Obesity, BMI ≥30.
†From generalised estimation equation.

measurement (eg, scoliosis, measured with shoes) were excluded from the analyses (n=165 for BMI and n=38 for waist). In Tromsø 6, after exclusions, 12 868 had a measurement of BMI and 12 493 a measurement of waist.[11 12]

Altogether 4580 women and 4012 men were included in the longitudinal analysis of body weight. The corresponding analysis of waist circumference included 4506 women and 3916 men. We included subjects aged 35–79 in Tromsø 6 (born 1928–1972) with valid measurements in both Tromsø 6 and Tromsø 7. Participants aged ≥80 years in 2007 were not included because only 78 individuals (15 %) of them also participated in Tromsø 7.

A total of 5737 men and 6410 women aged 35–79 in Tromsø 6 had a valid measurement of body weight, and 71% of them also had a valid measurement of weight in Tromsø 7. The main reasons for not attending the survey in 2015–2016 included death or moving out of Tromsø (1261 subjects) or non-attendance without justification despite being invited (2107 subjects). Comparing mean body weight in Tromsø 6 among men and women who attended both Tromsø 6 and Tromsø 7 (n=8592), to those who attended Tromsø 6 only (n=3555), showed no significant difference (age-adjusted 0.63 kg higher (p=0.10) in men and 0.39 kg lower (p=0.29) in women in subjects who attended both surveys). Similar results were found for difference in waist circumference, though women who attended Tromsø 6 only had a 0.7 cm (p=0.04) higher waist circumference. In men, the difference was a non-significant 0.5 cm (p=0.13).

Statistical analyses

We present results from cross-sectional analyses of data from Tromsø 7 according to age groups in Tromsø 7, whereas the longitudinal analyses are presented according to age groups in Tromsø 6. Age is given in years, per 31.12.2007 in Tromsø 6, and per 31.12.2015 in Tromsø 7. We computed age-adjusted mean BMI and waist circumference, as well as the age-adjusted prevalence of general obesity and abdominal obesity, for participants aged 40–84. Herein, to take into account the dependence caused by some participants attending both surveys we applied generalised estimation equations (GEE) with a non-zero correlation, and age adjusted by setting the covariate age equal to the mean value (57.4 years).

In the longitudinal analysis, we examined whether the change in waist circumference was larger than expected based on the difference in body weight and age from Tromsø 6 to Tromsø 7, as described previously.[12] We assumed that weight and age together predicted waist circumference in the same way in Tromsø 6 as in Tromsø 7. Based on the linear relationship in Tromsø 6, we predicted the waist circumference in Tromsø 7. The expected waist circumference was compared with that observed in Tromsø 7.

All analyses were conducted using SAS V.9.4.[17] The figures were made in R[18] using the R-package ggplot2.[19] The statistical analyses included descriptive statistics, GEE, paired t-tests and linear regression. Assumptions in the statistical models were assessed graphically by residual analyses. A p<0.05 was considered statistically significant.

RESULTS

Cross-sectional analyses

Table 1 and (online supplemental figure S1) gives the cross-sectional findings regarding BMI in Tromsø 7. A larger proportion of men than women were classified as being overweight.

The prevalence of underweight was low (≤1 %) in both women and men in both surveys. Age-adjusted mean BMI increased in both genders from Tromsø 6 to Tromsø 7 (p<0.0001). The age-adjusted OR for being obese in Tromsø 7, relative to Tromsø 6, was 1.18 (95% CI 1.12 to 1.25) in women and 1.29 (95% CI 1.22 to 1.36) in men (table 2). Cross-sectional results for waist circumference in Tromsø 7 are given in table 3 and online supplemental figure S2. The mean waist circumference was higher than the overweight lower limit in men, and higher than the obese lower limit in women.

Table 4 displays the crude and age-adjusted mean waist circumference and prevalence of abdominal obesity in participants aged 40–84 in Tromsø 7, and results for Tromsø 6 for comparison. The change in age-adjusted mean waist circumference was not statistically significant in women (0.1 cm, p=0.41), whereas men had a 0.7 cm increase (p<0.0001). The age-adjusted OR for being abdominal obese in Tromsø 7, relative to Tromsø 6, was 0.95 (95% CI 0.91 to 1.00) in women and 1.08 (95% CI 1.03 to 1.14) in men.

Longitudinal analyses

Table 5 displays the longitudinal changes in body weight between Tromsø 6 and Tromsø 7. Mean weight increased by 1.1 kg and 0.7 kg, in women and men, respectively. An inverse, approximately linear, relationship was found between age in Tromsø 6 and the change in weight over the next 8 years (online supplemental figure S3). We observed a statistically significant increase in body weight in men and women aged 35–59 years, while there was a statistically significant decrease in weight in participants aged 65–79 years.

Change in waist circumference from Tromsø 6 to Tromsø 7 is displayed in table 6 (and online supplemental figure S4). We observed statistically significant increases in waist circumference in both men and women. An inverse relationship was found between age at baseline and the change in waist circumference the next 8 years. We observed a statistically significant increase in waist circumference in subjects aged <70 years, whereas there was no significant changes in subjects in their 70s.

Comparing the estimated waist circumference in Tromsø 7 with that expected based on the relationship between waist circumference, weight and age in Tromsø 6, revealed a larger-than-expected increase in waist

Table 3 Mean waist circumference (WC, cm), and prevalence of abdominal overweight and abdominal obesity in Tromsø 7 (2015–2016)*

	Women (n=10991)					Men (n=9962)				
Age	n	Mean WC	SD	% abdominal overweight (95% CI†)	% abdominal obese (95% CI†)	n	Mean WC	SD	% abdominal overweight (95% CI†)	% abdominal obese (95% CI†)
40–44	1655	88.4	12.8	24.8 (22.7 to 26.9)	43.9 (41.5 to 46.4)	1463	98.6	11.8	30.0 (27.7 to 32.4)	31.5 (29.1 to 34.0)
45–49	1690	90.0	13.7	24.3 (22.3 to 26.4)	48.5 (46.1 to 50.9)	1575	99.9	11.8	29.7 (27.5 to 32.0)	36.6 (34.2 to 39.0)
50–54	1696	89.5	12.8	25.5 (23.5 to 27.7)	47.8 (45.4 to 50.2)	1429	99.6	11.2	29.3 (27.0 to 31.8)	36.5 (34.0 to 39.1)
55–59	1530	91.3	12.4	25.9 (23.7 to 28.2)	55.2 (52.7 to 57.7)	1350	100.3	10.6	30.1 (27.7 to 32.7)	39.9 (37.2 to 42.5)
60–64	1408	91.2	12.4	24.2 (22.0 to 26.5)	55.5 (52.9 to 58.2)	1319	100.4	11.1	31.0 (28.5 to 33.6)	38.7 (36.0 to 41.4)
65–69	1249	92.2	12.6	22.6 (20.3 to 25.0)	59.1 (56.3 to 61.8)	1174	101.1	11.4	30.4 (27.8 to 33.1)	42.0 (39.2 to 44.9)
70–74	854	94.3	13.0	20.8 (18.2 to 23.7)	64.9 (61.6 to 68.1)	849	102.2	11.0	28.5 (25.5 to 31.7)	47.3 (43.9 to 50.8)
75–79	498	92.8	12.8	22.5 (18.9 to 26.4)	62.0 (57.6 to 66.3)	461	101.3	10.7	34.7 (30.4 to 39.2)	40.1 (35.6 to 44.8)
80–84	267	91.2	11.5	21.7 (16.9 to 27.2)	59.9 (53.8 to 65.9)	247	101.2	9.9	29.1 (23.6 to 35.2)	43.7 (37.4 to 50.2)
85+	144	93.0	12.3	16.0 (10.4 to 23.0)	68.1 (59.8 to 75.6)	95	99.5	10.1	37.9 (28.1 to 48.4)	31.6 (22.4 to 41.9)
All	10991	90.8	12.9	24.1 (23.3 to 24.9)	53.2 (52.2 to 54.1)	9962	100.2	11.3	30.2 (29.3 to 31.1)	38.4 (37.4 to 39.4)

The Tromsø study.
*Abdominal overweight: WC 81–88 cm (women), 95–102 cm (men). Abdominal obesity: WC >88 cm (women), >102 cm (men).
†Exact (Clopper-Pearson) CI from the binomial distribution.

Table 4 Mean waist circumference and age-adjusted waist circumference (cm) and prevalence of abdominal obesity in participants aged 40–84 in Tromsø 6 (2007–2008) and Tromsø 7 (2015–2016)*

	Women			Men		
	Tromsø 6	Tromsø 7		Tromsø 6	Tromsø 7	
Mean age (SD), years	58.3 (12.0)	56.8 (11.0)		58.2 (11.5)	57.1 (11.0)	
Mean waist circumference	91.0 (90.8 to 91.3)	90.8 (90.5 to 91.0)		99.6 (99.3 to 99.8)	100.2 (100.0 to 100.4)	
Age-adjusted mean waist circumference	90.8 (90.6 to 91.1)	90.9 (90.7 to 91.2)	P=0.41†	99.5 (99.3 to 99.8)	100.3 (100.0 to 100.5)	P<0.0001†
% abdominal obese	55.3 (54.1 to 56.5)	53.0 (52.0 to 53.9)		37.1 (35.8 to 38.3)	38.5 (37.5 to 39.4)	
% abdominal obese, age-adjusted	54.7 (53.6 to 55.9)	53.4 (52.5 to 54.4)	OR=0.95 (0.91 to 1.00)†	36.8 (35.6 to 38.0)	38.6 (37.7 to 39.6)	OR=1.08 (1.03 to 1.14)†

The Tromsø study.
*Abdominal obesity: waist circumference >88 cm (women), >102 cm (men).
†From generalised estimation equation.

circumference in both women, 0.7 cm (95% CI 0.6 to 0.9), and men, 0.8 cm (95% CI 0.6 to 0.9).

DISCUSSION

Repeated cross-sectional analyses of BMI in a large population in Norway showed an increase in mean BMI and prevalence of obesity from 2007 to 2008 to 2015–2016. Secular changes in waist circumference and abdominal obesity were less marked. Longitudinal results among a subset of participants showed an overall increase in both weight and waist circumference from 2007–2008 to 2015–2016. However, age-related differences were observed; weight and waist circumference increased most in the youngest, whereas the oldest participants had no significant change in waist circumference and lost weight.

The prevalence of general obesity was 25% for men and 23% for women in Tromsø 7, higher than any of the six previous surveys of the Tromsø Study.[10 11] Moreover, 6.5% of the women and 6.2% of the men have BMI ≥35 kg/m^2. An increase in obesity has also been found in the National Health and Nutrition Examination Survey, for the same time period, 2007–2008 to 2015–2016.[20] A population-based study in mid-Sweden, where height and weight were self-reported, also showed an increase in obesity between 2000 and 2012, although at a lower rate from 2008.[21]

Previous analyses from the Tromsø Study have shown that the prevalence of abdominal obesity nearly doubled between 1994 and 2007.[12] In women, we found no change in age-adjusted mean waist circumference from Tromsø 6 to Tromsø 7, in contrast to the increase in BMI. This result could reflect a small secular change in body composition, but we cannot exclude a measurement error in waist circumference since it is difficult to measure accurately.[9 22] While cross-sectional comparisons showed no change in waist circumference in women, there was a significant increase longitudinally. In the cross-sectional analyses, we found that the age-specific mean waist circumference figures were similar in Tromsø 6 and Tromsø 7, and that there were a modest increase in waist circumference with advancing age (table 3) at least to the age of 70. Therefore, the age-adjusted figures in Tromsø 6 and Tromsø 7 were similar (table 4). However, in the longitudinal analyses, we assessed the 8-year change in waist circumference in the subjects that attended both surveys. In subjects aged less than 70, we found an increase in waist circumference (table 6), in concordance with the cross-sectional findings of a modest increase in waist circumference with advancing age.

There is a large difference in the prevalence of general and abdominal obesity. For women, where the difference is most pronounced, 53% are classified as abdominal obese whereas 23% have BMI ≥30 kg/m^2. Similar discrepancies have also been found earlier, and it has been suggested that these two measures of obesity need to be harmonised.[12] However, as pointed out by Midthjell *et al*,[23] BMI

Table 5 Mean body weight (kg) in Tromsø 6 (2007–2008), Tromsø 7 (2015–2016) and change in weight

		Tromsø 6		Tromsø 7		Change between Tromsø 6 and Tromsø 7	
Age 2007, years	N	Mean weight	SD	Mean weight	SD	Mean weight	95% CI*
Women							
35–39	123	70.8	12.5	73.9	12.9	3.1	1.9 to 4.4
40–44	955	70.6	13.2	73.6	14.2	3.0	2.6 to 3.4
45–49	502	71.8	13.6	74.0	14.3	2.2	1.7 to 2.8
50–54	533	69.5	11.4	71.2	12.3	1.7	1.3 to 2.1
55–59	486	70.9	12.8	71.6	13.3	0.7	0.3 to 1.2
60–64	953	72.4	12.4	72.7	13.0	0.3	–0.0 to 0.6
65–69	562	71.0	13.1	70.3	13.0	–0.6	–1.1 to 0.2
70–74	301	69.8	12.0	68.7	12.4	–1.1	–1.7 to 0.5
75–79	165	69.7	12.3	67.9	12.9	–1.8	–2.6 to 1.0
All women	4580	71.0	12.7	72.1	13.4	1.1	0.9 to 1.2
Men							
35–39	92	90.4	13.3	93.2	15.5	2.9	1.6 to 4.1
40–44	774	87.4	13.5	89.7	14.6	2.3	1.8 to 2.7
45–49	452	86.9	12.8	88.9	13.8	2.0	1.5 to 2.5
50–54	412	86.8	12.1	87.7	13.1	0.9	0.4 to 1.4
55–59	467	86.2	13.1	86.8	13.1	0.5	0.0 to 1.0
60–64	848	86.4	12.6	86.6	12.8	0.1	–0.2 to 0.5
65–69	571	84.5	12.1	84.1	13.0	–0.4	–0.9 to 0.0
70–74	291	81.6	11.5	80.5	11.8	–1.1	–1.7 to 0.6
75–79	105	79.8	10.3	78.5	12.2	–1.3	–2.4 to 0.2
All men	4012	86.0	12.8	86.7	13.7	0.7	0.6 to 0.9

The Tromsø study.
*CI based on the paired t-statistic.

and waist circumference are different measures. Gaining muscle mass will increase BMI, and thus waist circumference may be a better measure of body fat. On the other hand, weight and height are less prone to measurement error.

Weight and waist circumference increased most in the youngest, which seems to be a consistent finding from many studies.[10–12 24–32] The waist circumference increased relatively more than weight, confirming previous findings in the Tromsø Study and other cohorts.[12 32–37]

It has been found that the probability of an obese person attaining normal weight is low, and also that maintaining weight loss is difficult.[38] Thus, prevention of obesity is important, in particular for the youngest who have the largest weight gain. There is also a need for public health interventions to help obese people attaining normal- or overweight. Target 7 in WHO's action plan is a halt in prevalence of obesity and diabetes by 2025 against a baseline in 2010.[4] The results presented in this paper show that Norway is not on track to reach this goal in 2015–2016.

Change in food supply has been found to be sufficient to explain the mean body weight gain.[39] Thus, the most likely cause for the increase in obesity is higher intake of energy. In the Tromsø Study, studying change in food habits are currently not possible as an extensive food frequency questionnaire was used for the first time in Tromsø 7.[40] However, this study population have self-reported physical activity in all surveys and there has been an increase in sedentary occupational activity though it may be counteracted by increased physical activity during leisure time.[41] Thus, it is currently unclear whether this change in physical activity in the Tromsø population can explain part of the increase in the prevalence of obesity.

With the exception of some of the cross-sectional results from Tromsø 6,[11 12] which we included in this paper for comparison, and some selected results published on the web site of the Norwegian Institute of Public Health as part of the Norwegian NCD collaboration,[42] the results in this paper have not been published before.

Table 6 Mean waist circumference in Tromsø 6 (2007–2008), Tromsø 7 (2015–2016) and change in waist circumference

		Tromsø 6 (2007–2008)		Tromsø 7 (2015–2016)		Change between Tromsø 6 and Tromsø 7	
Age 2007, years	N	Mean, cm	SD	Mean, cm	SD	Mean, cm	95% CI*
Women							
35–39	118	89.3	12.8	89.8	13.1	0.5	−1.2 to 2.1
40–44	917	88.1	11.7	89.9	12.9	1.8	1.3 to 2.4
45–49	484	90.2	12.8	91.9	13.2	1.8	1.0 to 2.5
50–54	523	88.4	10.6	90.0	11.3	1.6	0.9 to 2.2
55–59	482	90.5	12.1	91.6	12.7	1.1	0.4 to 1.7
60–64	943	92.8	11.8	94.0	12.7	1.1	0.7 to 1.6
65–69	568	92.0	11.3	93.0	12.0	1.0	0.4 to 1.6
70–74	302	91.8	12.1	92.1	12.3	0.4	−0.5 to 1.3
75–79	169	92.8	11.3	92.6	12.4	−0.2	−1.4 to 1.0
All women	4506	90.5	11.9	91.8	12.6	1.3	1.0 to 1.5
Men							
35–39	86	98.8	10.1	100.7	12.5	1.8	0.5 to 3.2
40–44	738	97.5	10.4	99.3	11.8	1.8	1.2 to 2.3
45–49	417	97.2	10.0	99.8	10.9	2.6	1.9 to 3.2
50–54	404	98.6	10.2	100.0	11.1	1.4	0.8 to 2.1
55–59	460	99.4	10.4	100.9	11.2	1.5	0.9 to 2.1
60–64	836	100.8	10.2	102.1	10.6	1.3	0.8 to 1.7
65–69	571	100.8	9.8	101.6	11.0	0.9	0.3 to 1.4
70–74	295	100.0	9.9	100.5	9.9	0.5	−0.2 to 1.2
75–79	109	99.9	9.9	100.6	10.1	0.7	−0.6 to 1.9
All men	3916	99.3	10.2	100.7	11.1	1.4	1.2 to 1.6

The Tromsø study
*CI based on the paired t-statistic.

Strengths and limitations

Waist circumference, weight and height were measured by trained personnel using standardised procedures. Compared with self-reported height and weight, which tend to be biased,[43] this is a significant strength. Another strength is that the data are from a population-based study with a high attendance, 66% in Tromsø 6% and 65% in Tromsø 7. Still, a significant proportion of those invited did not participate. The attendance is lower among men than women, and the youngest and oldest have a lower attendance (www.tromsostudy.com).

A comparison between participants who attended both Tromsø 6 and Tromsø 7, and those who attended Tromsø 6 only, showed small, and mostly non-significant, differences in mean weight, and also mean waist circumference. This is an indication that there is no substantial attrition bias in the longitudinal analysis. Among the elderly, there may be a bias caused by death or severe illness. For instance, in the oldest age group, that is, those aged 75–79 years in 2007, the attendance in Tromsø 7 were 38% in women and 33% in men. For all other age groups the attendance was above 50%.

CONCLUSION

We found a high proportion of general and abdominal obesity in both men and women, and a continuation of the increase in obesity during a follow-up of 8 years.

Longitudinal analyses with 8-year follow-up of participants aged 35–79 in 2007 showed statistically significant increases in both body weight and waist circumference in participants below the age of approximately 60 years for weight and 70 years for waist circumference. The youngest age groups have the largest increase.

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ORCID iDs
Ola Løvsletten http://orcid.org/0000-0001-9483-9621
Tom Wilsgaard http://orcid.org/0000-0002-2709-9472

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