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A longitudinal study of the changes in BMI, waist circumference, waist-to-height-ratio and desired BMI of the participants in the 4th, 5th and 6th survey of the Tromsø study.

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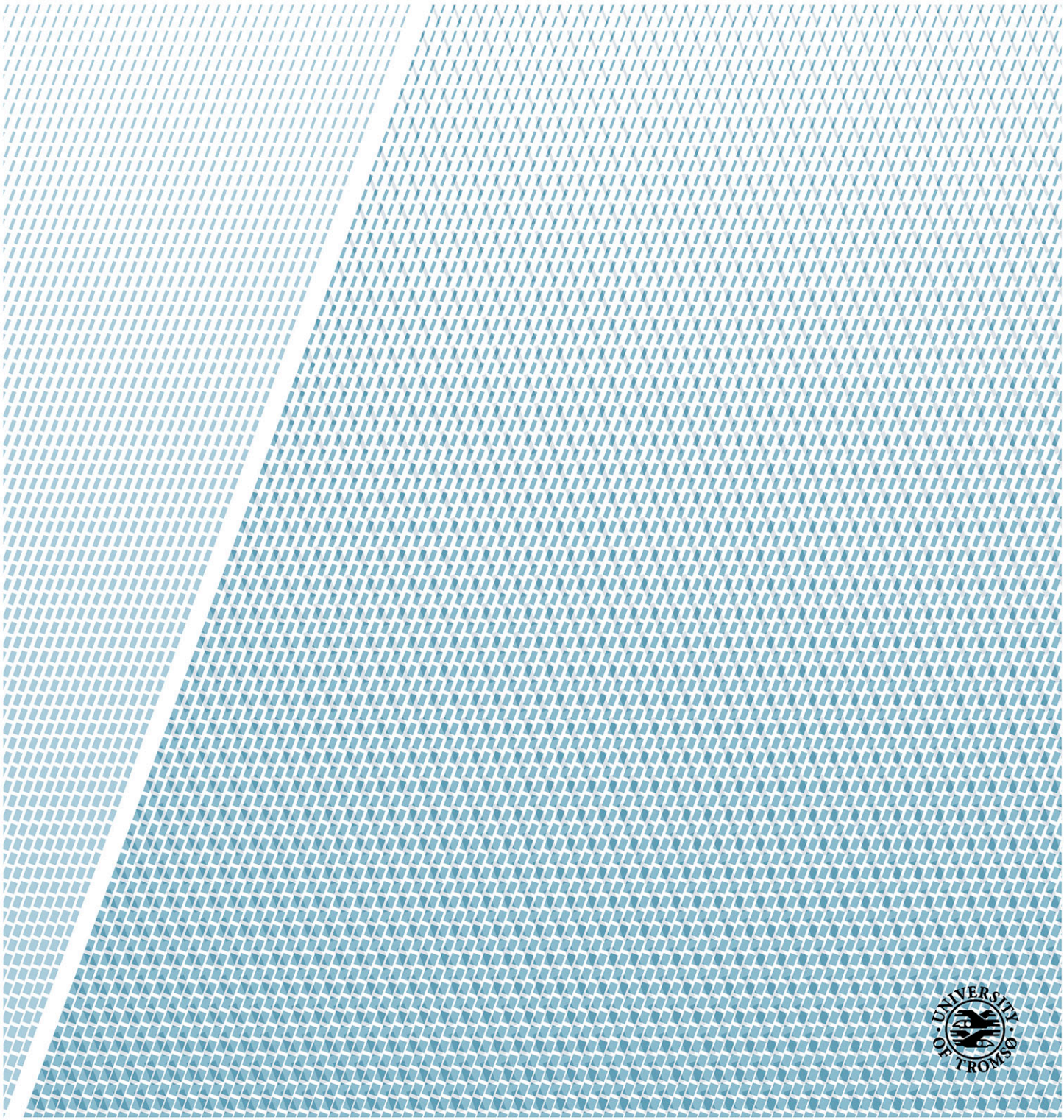

Acknowledgements.

This master thesis marks the end of a two-year study period. When I first began in the fall of 2012, I did not anticipate finding the courses as inspiring and interesting as I indeed have. During this period I have gained knowledge in the fields of public health, research in the health disciplines and in scientific writing, and for the most part it has been a fascinating journey for which I am very grateful.

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List of Abbreviations.

BMI	Body Mass Index
DBMI	Desired Body Mass Index
T4	Tromsø Survey no. 4 (1994 – 1995)
T5	Tromsø Survey no. 5 (2001 – 2002)
T6	Tromsø Survey no. 6 (2007 – 2008)
WC	Waist Circumference
WHO	World Health Organization
WHtR	Waist to Height Ratio

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Abstract.

Background: prevalence of obesity and overweight continues to increase in Norway, and more in young than old. Some researchers advocate the use of other measures of bodily composition than BMI, notably waist circumference (WC) and waist-to-height-ratio (WHtR), as predictors of morbidity and mortality and indicators of obesity and overweight. This thesis has sought to describe the changes in BMI, with supplementary analyses of WC and WHtR, over a 13-year period. Furthermore, desired BMI (DBMI) was computed based on subjectively assessed desired weight, and was analysed to assess whether the discrepancy between weight and desired weight is dependent on BMI categories of normal weight, overweight or obese.

Methods and materials: The data material used stems from the Tromsø Study, specifically surveys 4 (T4), 5 (T5) and 6 (T6). The material has been analysed both cross-sectionally and longitudinally, and so the population available for analyses depends upon participation in the different surveys. A total of 26602, 7954 and 12933 men and women were included in the cross-sectional analysis of data from T4, T5 and T6, respectively. In the longitudinal analyses of T4, T5 and T6, a total of 4285 men and women under the age of 70 in T4 (in 1994-95) were included, while the analyses of BMI in T4 and T6 alone included 10167 men and non-pregnant women under the age of 75. For WC and WHtR the longitudinal analyses were conducted on those that participated in T4 and T6, but not necessarily in T5.

Results: The results show that BMI increased over the 13-year study period in both genders and all age groups but those aged 70-74 in T4. Increase was significantly associated with age at baseline, with a negative trend of BMI-increase with increasing age. A similar pattern applies for WC and WHtR. DBMI increased in all age groups of both genders, but the increase of DBMI was less than that of BMI during the period.

Conclusion: Between T4 and T6, BMI increased in all age groups of both genders, an increase which is also evident in WC and WHtR. The analyses of BMI from the longitudinal cohort of T4, T5 and T6 indicate that the best part of the increase occurred between T4 and T5. The difference between BMI and DBMI is different between BMI categories, with normal weight people expressing low discrepancy between BMI and DBMI. The results confirm and extend previous knowledge on development of BMI in the Norwegian population.

Chapter 1. Introduction

1.1 Background

Obesity and overweight are well-known risk factors for numerous health problems such as cardiovascular disease, cancer and diabetes, and the prevalence continues to increase worldwide (1-4). The population of Norway is no exception with recent studies suggesting prevalence of obesity in the region of 20% in the adult population (5, 6). However, some studies have found a plateauing of BMI, indicating that BMI does not increase as rapid as previously (7-9). WC is increasingly used as a measure of body composition, often in combination with BMI, and both cross-sectional and longitudinal studies have found WC to increase with age throughout life (17, 18). A study based on the Framingham Heart Study explored how obesity may spread through a social network, perhaps through increased acceptance of obesity by comparison with ones social peers (10). If this is in fact the case, then a rise in prevalence of obesity might accelerate the epidemic even further. Obesity is therefore an issue of major public health concern.

Studies have indicated that a small difference between actual and desired weight is associated with improved health status (11-13). In a longitudinal perspective it is of interest to investigate whether the difference between actual and desired weight remains consistent over time, especially with regards to motivation for lifestyle change.

Numerous studies of BMI have been conducted in Norway and many using data from the Tromsø Study, but none have described the longitudinal changes in BMI from the 4th and 6th Tromsø Survey. With a 7th Tromsø Survey due next year, analyses of BMI in this population should be of interest to researchers and health professionals in the field.

1.2 Conceptual clarifications and theory

1.2.1 Body Mass Index

Body Mass Index is a widely used tool for classification of weight within the field of epidemiological research. The World Health Organization operates with a four-level classification system, where BMI is categorized as underweight (BMI < 18,5 kg/m^2), normal (BMI 18,5 – 24,99 kg/m^2), overweight (BMI 25-29,99 kg/m^2) and obese (BMI ≥ 30 kg/m^2 (14). Body mass index is a proven predictor for mortality and morbidity (2).

In study similar to this thesis, Jacobsen et. al. found an increase in BMI in all age groups over a 15-20 year observation period, with the highest increase taking place among young men (15). Recent research has indeed confirmed that the highest weight increase takes place in the younger age groups (5, 16-18). In cross-sectional studies it appears that BMI levels off with time, meaning that people continue to gain weight up to a certain point, after which weight remains stable. There is also evidence to support the claim that BMI starts to decline after a certain age is reached (19).

1.2.2 Desired weight

Desired weight is of relevance to obesity and weight research, since the discrepancy between measured weight and desired weight is an indication of weight satisfaction (12). Blake et.al. found that low difference between measured weight and desired weight was associated with positive health behaviour and health status (11), while Wilsgaard and colleagues, using data from the Tromsø Study, found that desired weight in one survey (T4) was a significant predictor of BMI 7 years later (in T5) (20). Desired weight does not contain any comparative measure of obesity, and therefore Desired Body Mass Index (DBMI) is used in the analyses to assess the difference in DBMI between classes of BMI. An argument to support this is the fact that obese and overweight people are less satisfied with their body weight than normal-

weight are, and women generally are less satisfied with their weight than men, irrespective of weight classes (11, 12, 21). Interestingly, one study has found the difference between actual and desired weight, rather than BMI, to be the stronger predictor for mental and physical health (13).

1.2.3 Waist Circumference

Waist circumference above 102 centimetres for men and 88 centimetres for women are cut-off levels above which individuals should seek to loose weight, and these values correlate with BMI as predictors of mortality and morbidity (22). High WC is associated with all cause mortality (23), and longitudinal studies indicate an increase in WC similar to that we have seen in BMI (5, 24).

1.2.4 Waist to height ratio

Waist-to-height-ratio (WHtR) is increasingly being presented as a better predictor for mortality and morbidity than BMI (25). A cut-off of 0.5 is frequently cited as a marker for whether a person is overweight or has normal weight: a WHtR of less than 0.5 indicates normal weight, while a WHtR of 0.5 or more indicated overweight or obesity (26).

1.2.5 Age

The effect of age on overweight and obesity is well known. In cross-sectional studies BMI appears to be highest at around 45-60 years of age for men, and around 60-70 years of age for women. Longitudinal studies however, indicate that BMI continues to increase throughout life for both men and women (16-19).

1.2.6 Gender

In many epidemiological studies it is common practice, where possible, to investigate gender differences in BMI development. Although gender differences are present, the overall pattern of increasing BMI with age is apparent among both men and women (15, 16).

1.2.7 Smoking

Smokers are known to have a different development in bodyweight than non-smokers (17), and furthermore is smoking cessation associated with an increase in body weight (27). Smoking is not the primary variable under investigation, but it is of interest to assess whether consistent smokers differ with regards to development in BMI from that of non-smokers or those that have quit smoking, especially since smoking prevalence in Norway has been declining steadily for both men and women in the last 15 years (28).

1.3 Aims of the study

This thesis aims to extend the knowledge on the longitudinal changes in Body Mass Index (BMI), Waist Circumference (WC), Waist-to-Height-Ratio (WHtR) and Desired Body Mass Index (DBMI) among the participants in the Tromsø Study, Tromsø Survey 4 (1994-1995), Tromsø Survey 5 (2001) and Tromsø Survey 6 (2007-8). The specific aim is to perform cross-sectional and longitudinal analyses of these variables, and to describe changes over the 13-year period. Lastly, the thesis seeks to establish whether consistent smokers have a different development in BMI than never-smokers.

1.4 Hypothesis

My hypothesis is that the participants in the T4, T5 and T6 studies have had an increasing mean BMI, waist circumference and waist-to-height-ratio, and that a similar increase in desired BMI has taken place. Furthermore, that daily smoking alters the longitudinal BMI change.

Chapter 2. Methods and materials

2.1 Design

This thesis seeks to describe the cross-sectional distribution of BMI in each of the three Tromsø Surveys in the period 1994 to 2007, as well as the longitudinal change in BMI between them for those that participated in all three. A cross-sectional design provides the researcher with a "status quo" with regards to the variable under analysis, in this case BMI, and is therefore a useful design for describing a health state in a defined population at a single point in time (29). Different cross-sectional surveys, however, are not directly comparable since the age-distribution and other confounding factors may vary between them.

Although the three surveys which form the basis for this thesis is quite similar in design and study population, it would be improper to assume that a higher mean BMI in T5 compared to T4 implies that participants in all age-groups in T4 have experienced a weight increase. This is the argument for a cohort design, wherein participants from either two- or three of the surveys in question are studied and compared with regards to the variables under analysis. A longitudinal design enables the researcher to compare data collected from the same study population at two or more different points in time, and temporal changes in the variables under study can therefore be accurately assessed. The thesis does not seek to identify causes for increased- or decreased BMI, but to describe the changes according to birth cohort and gender.

2.2 Sample: the Tromsø Study.

The Tromsø study is a large health survey, based on the population of Tromsø in the north of Norway. It was conducted for the first time in 1974 (Tromsø 1), and its original aim was to map cardiovascular risk factors among the male population. The first survey included 6595 men between the age of 20 and 49 (30). Since then the survey has been repeated five times,

with a 7th survey scheduled to be undertaken in 2015. This particular thesis is based on the 4th, 5th and 6th Tromsø surveys. The reader is referred to Jacobsen et. al. for a summary of the entire Tromsø Study (30).

The 4th Tromsø Survey (T4) took place in 1994-1995 and the entire population of Tromsø born before 1970 was invited, which numbered to 37 558 men and women. Response rate was 69.6% for men and 74.9% for women. All the participants received a questionnaire with the invitation, which they delivered at the health screening. The clinical examination included several health- and bodily measurements, of which measurements of height and weight is most important for this thesis (31). At the clinical examination participants received a more comprehensive questionnaire, which differed for those under or above 70 years of age. The question on ideal weight was not included in the questionnaire given to those above 70. A subsample were invited to a second visit where measurements of, among other things, waist- and hip circumference were performed. Everyone in the the Tromsø municipality 55-74 years of age, as well as sample of 5-10% in the remaining age groups 25-54 and 75-84 were eligible for this second examination procedure. Excluding those that had relocated or died during the study period, response rate to the secondary examination was 78% (32).

Tromsø Survey 5 (T5) was conducted in 2001-2002. To this survey all participants from the second visit in T4 were invited, as well as all 30-, 40-, 45-, 60- and 75-year olds in the county of Tromsø. This latter group were invited as part of a nationwide survey by the Norwegian Institute of Public Health (FHI). In the former group response rate was very high, at 89%, but the second sample achieved a lower response rate at 57%. In all 8130 men and women participated in T5. Due to the invitation criteria there were a limited number of participants from the age groups 35-39 and 50-54, with the bulk of participants being in the age groups 55-79. The clinical examination included measurements of height, weight, waist- and hip circumference (33). At the clinical examination site participants were given a new,

more comprehensive questionnaire, which, amongst other things, asked what weight participants would be satisfied with. Unlike T4 this question was posed to all, irrespective of age.

Tromsø Survey 6 (T6) was conducted in 2007-2008. The 12984 participants where invited from 4 different groups; those that attended the secondary clinical examination in T4, a 10% random sample of the age group 30-39, everyone in the age group 40-42 and 60-87, and a 40% random sample of people aged 43-49 years. All in all the attendance rate was 65.7% (34). With the invitation came a 4-page questionnaire, which was handed in at the clinical examination. At the clinical examination measurements were taken of weight, height, waist- and hip circumference, as well as a few other variables. A comprehensive questionnaire was handed out, which included the question of ideal weight. In addition to this basic clinical examination, a subset of participants was invited to a more comprehensive examination.

2.3 Variables

The initial data set contained in total 61 variables from all three surveys presumed important to answer the hypothesis outlined in the introduction.

Gender

All analyses were conducted sex-specific.

Age

Age is given as age in years per 31.12.1994 in T4, per 31.12.2001 in T5 and per 31.12.2007 in T6. In the longitudinal analyses of BMI in T4, T5 and T6, the age of 69 in T4 was selected as cut off. This was because 10-year birth cohorts were used for presentation of these results, and subjects older than 70 consisted of relatively few people compared to those aged 65-69. Those aged 70 and above would have exerted undue influence on mean BMI, as this group

had a substantially lower BMI than those aged 65-69, and were therefore excluded from this particular analysis. For similar reasons people aged 75 or more were excluded from the longitudinal analyses of BMI in T4 and T6.

Height

Height was measured to the nearest 0.1 centimetres. Measurements were made in a standing position, without shoes. Steps were taken to exclude obvious measurement errors, for example when an 11-centimetre difference in height is observed between two surveys for a man aged 30 years at the time of the first survey.

Weight

In T4 weight was measured to the nearest 500 grams, while in T5 and T6 weight was measured to the nearest 100 grams. At all three surveys measurements were undertaken with minimal clothes.

Body Mass Index

The primary variable under analysis was body mass index, computed as body weight in kilograms divided by height in meters squared: $\frac{Weight\ in\ kilograms}{Height\ in\ meters^2}$.

Desired Body Mass Index

The question of "What weight would you be satisfied with (your "ideal" weight)?" was included for the first time in T4, and again in T5 and T6. In T4 the question was only asked to people between the ages of 25 and 69. Using this self-reported indication of ideal weight, as well as the standardized measured height, the variable "Desired BMI" was computed: $\frac{Desired\ weight\ in\ kilograms}{Height\ in\ meters^2}$. This variable could only be computed for those who had answered the question, and as such a number of participants were excluded from the analysis of this variable.

Waist circumference

Waist circumference was measured across the belly button to the nearest 0.1 cm by trained staff using a tape measure (35). This procedure is probably more difficult to standardize than measuring height and weight. Thus, in a separate set of analyses, a Z-score analysis was performed on WC in order to avoid the effect of possible systematic differences in how the measurements had been performed in the different surveys. Z-scores were computed for men and women separately for those with valid measurements of WC in both T4 and T6. The Z-score was computed separately for T4 and T6 as measured WC minus mean WC, divided by the standard deviation of WC ($\frac{WCT4-WC\ T4_{Mean}}{Standard\ deviation_{WC\ T4}}$). The Z-score variable then had a mean of 0 and a standard deviation of 1. The z-scores for T4 and T6 were then compared, enabling assessment of the changes in waist circumference in relative rather than absolute terms.

Waist-to-height-ratio (WHtR)

WHtR is computed as waist circumference divided by height. Eligible subjects therefore needed valid measurements of both these variables.

Pregnancy

Pregnant women were excluded from all analyses. In the surveys respondents had the options of answering "yes", "no" or "don't know" to the question "Are you pregnant at the moment?". Frequency counts of the pregnancy variables revealed a lot of missing responses to this question, presumably because a large number of the participating women were postmenopausal. Missing or "don't know" (only a few women answered that they did not know) was therefore assumed to indicate that the woman not was pregnant.

Smoking

Smoking is known to be an effect-modifier for BMI, and a separate analysis of the longitudinal changes in BMI was therefore conducted according to smoking status. Smoking

was coded as no (0) or yes (1) depending on the answer to the question on daily smoking habits of cigars, pipe or cigarettes. Since smoking was not the primary variable under investigation, no analyses were made on magnitude of smoking and it´s possible effect on BMI in the cross-sectional studies.

2.4 Statistical procedures.

All analyses were conducted using Statistical Package for the Social Sciences (SPSS) version 21. The tables and figures were produced in Microsoft Excel for Mac 2011, version 14.3.1. The tables contain means and standard deviations for each birth cohort in that particular survey. These values were obtained by selecting the relevant populations through the application of filters, and by splitting the output according to age groups or gender when necessary. Dichotomous variables were tested for significance either using a Chi Square test or, when adjusting for other variables, using logistic regression. Difference in BMI between two surveys was analysed using an independent sample t-test where mean difference was analysed between genders and age groups. When adjusting for age-, gender- and smoking effects on BMI, a general linear model was used. Age adjustment of mean BMI in the three surveys was done by direct method, with the population of T4 serving as reference population. In the longitudinal analyses linear regression was used to assess whether the difference between BMI (or WC and WHtR) in T4 and T6 followed a linear pattern with increasing age in 1994 (or birth cohort). P-values are reported in a summary before each table, with the level for significance set at $p < 0.05$. The primary variables of BMI, WC, WHtR and DBMI were all close to normally distributed.

In the cross-sectional analyses BMI is presented according to three customized categories, which were defined as underweight (BMI<20 kg/m^2), normal (BMI 20 – 29,99 kg/m^2) or obese (BMI ≥30 kg/m^2). The World Health Organization suggests using more specific categories (36), but in this specific dataset prevalence was very low in the WHO

category for underweight (BMI < 18.5 kg/m^2), and a higher cut-off point of BMI < 20 was therefore selected. Obesity is classified according to three groups by the WHO; obesity class 1 (BMI 30.00-34.99), obesity class 2 (BMI between 35.00-39.99) or obesity class 3 (BMI ≥ 40.00) (36). In the population under study in T4, prevalence was low in the obesity classes 2 and 3, and therefore a cut-off point of BMI ≥ 30 was selected for obesity. A more detailed distribution of BMI is nonetheless presented in Table 5. In the longitudinal analysis, the results are presented according to birth cohorts, while the results from the cross-sectional analyses are presented according to age groups in each survey.

Table 1 shows the percentage of participants from T4 that also took part in T6. Among men, 37.2% of those that participated in T4 were invited and took part in T6, while it was slightly higher for women at 39.2%. However, these percentages both reflect the proportion that was invited who attended and whether they were invited or not. They give an illustration of how many in each age group was followed up over this time period of 13 years. The 4746 men and 5421 women who were followed from T4 to T6 were compared to the rest of the cross-sectional cohort of T4, and in subjects who were followed to T6, no significant difference was found in BMI between the two cohorts at the time of T4 ($p = 0.5$ for men and women). When the cohorts were compared according to age group, a significant difference was found in BMI in T4 in the two male age groups of 45-49, with the complete longitudinal group having a BMI of 26.3 in T4 versus 26.0 among those that did not participate in T6. This difference in BMI, although statistically significant, was considered relatively marginal and these results indicate that the longitudinal cohort is representative of the cross sectional cohort of T4 at baseline.

Table 1: percentage of complete follow up according to age groups and gender in T4

	Men			Women		
Age groups	T4	T4 and T6	Percentage of T4	T4	T4 and T6	Percentage of T4
25-29	1506	495	32,9	1641	603	36,7
30-34	1540	345	22,4	1683	438	26,0
35-39	1643	440	26,8	1744	482	27,6
40-44	1674	470	28,1	1702	525	30,8
45-49	1596	868	54,4	1646	940	57,1
50-54	1296	890	68,7	1291	920	71,3
55-59	914	560	61,3	931	613	65,8
60-64	792	394	49,7	768	442	57,6
65-69	684	204	29,8	844	324	38,4
70-74	583	80	13,7	687	134	19,5
75-97	547	0	0	920	0	0
Total	12775	4746	37,2	13827	5421	39,2

2.5 Ethics

The Tromsø Study was approved by the Regional Committee for Research Ethics

Chapter 3. Results

3.1 Cross-sectional analyses of BMI

In T4 there were 12775 men and 13827 non-pregnant women with valid measurements of BMI (Appendix 1). Table 2 provides the mean BMI across genders in each age group with standard deviations (SD), as well as the prevalence (%) of underweight and obese individuals. The highest mean BMI among men was in the age groups 50-59 (26.3). Among the women the highest BMI was found in the age groups 70-79 (26,7). There was a higher total prevalence of both underweight (8.5 %) and obesity (11.6%) among women than men (2.7% and 9.6 % respectively), and the difference between genders were significant ($p < 0.001$). BMI was significantly different between genders, both with- and without adjustment for age ($p < 0.001$).

Table 2: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI ≥ 30) and underweight (BMI < 20) in T4 according to age groups and gender in T4.

	Men				Women			
Age groups	*n*	BMI (SD)	BMI<20	BMI ≥ 30	*n*	BMI (SD)	BMI<20	BMI ≥ 30
25-29	1506	24.8 (3.2)	4.0	6.2	1641	23.4 (3.7)	14.3	6.0
30-34	1540	25.0 (3.3)	2.9	7.7	1683	23.4 (3.7)	13.4	5.6
35-39	1643	25.3 (3.1)	1.9	7.5	1744	23.7 (3.7)	10.3	6.1
40-44	1674	25.5 (3.2)	2.3	8.7	1702	24.1 (3.7)	8.2	7.5
45-49	1596	26.2 (3.4)	1.9	12.4	1646	24.9 (4.0)	6.1	10.6
50-54	1296	26.3 (3.2)	1.9	12.8	1261	25.6 (4.4)	6.4	14.9
55-59	914	26.3 (3.2)	1.2	11.4	931	26.0 (4.4)	4.3	16.2
60-64	792	26.1 (3.5)	2.7	10.7	768	26.0 (4.4)	5.6	16.3
65-69	684	25.8 (3.4)	2.9	11.8	844	26.6 (4.8)	5.6	21.1
70-74	583	25.7 (3.7)	5.8	10.5	687	26.7 (4.6)	5.2	22.1
75-79	339	25.5 (3.4)	6.2	9.1	529	26.7 (4.9)	6.6	24.2
80-97	208	24.8 (3.3)	7.2	7.2	391	26.2 (4.5)	5.6	19.2
Total	12775	25.6 (3.3)	2.5	9.6	13827	24.8 (4.3)	8.0	11.6

In T5 there were 3453 men and 4501 non-pregnant women with valid measurements of BMI (Appendix 2). Table 3 provides the mean BMI in each age group with standard deviations (SD), as well as the prevalence of underweight and obese individuals. Prevalence of

underweight was higher in women than men in all age cohorts except the cohort of 80-89. In the five oldest age groups (60-89), the prevalence of obesity was higher among women than men, and with one exception the opposite was the case for the five youngest age groups. Total prevalence of obesity was 18.3 % for men and 20.8% for women, while prevalence of underweight was 1.7% for men and 4.8% for women. There was a significant difference in prevalence of both obesity and underweight between men and women, and the significance remained after adjustment for age ($p < 0.05$). In T5 the highest mean BMI among men was found in the age group 50-54 (28.2). Among women the highest mean BMI was found in the age group 75-79 (27.3).

Table 3: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI ≥ 30) and underweight (BMI < 20) in T5 according to age groups and gender.

	Men				Women			
Age groups	*n*	BMI (SD)	BMI < 20	BMI ≥ 30	*n*	BMI (SD)	BMI < 20	BMI ≥ 30
30-34	232	26.4 (4.0)	0.4	18.1	313	24.7 (4.3)	7.7	11.5
35-39	45	25.6 (3.1)	2.2	6.7	73	25.7 (4.6)	5.5	13.7
40-44	304	26.8 (3.7)	0.7	16.8	373	25.2 (4.5)	5.6	11.0
45-49	293	27.0 (3.7)	0.7	18.8	363	25.3 (3.9)	3.3	9.9
50-54	143	28.2 (3.9)	0.7	26.6	92	25.6 (3.8)	3.3	13.0
55-59	219	27.9 (3.6)	0.9	23.3	623	27.2 (4.9)	4.2	23.6
60-64	651	27.5 (3.4)	0.6	21.5	817	26.9 (4.8)	3.9	22.9
65-69	583	26.8 (3.4)	1.4	17.3	629	27.1 (4.6)	5.1	23.1
70-74	492	26.5 (3.5)	3.0	15.9	594	27.1 (4.8)	5.1	26.1
75-79	378	26.1 (4.1)	3.7	14.0	478	27.3 (4.6)	5.4	27.4
80-89	113	26.1 (4.1)	6.2	17.7	146	27.1 (4.1)	4.1	26.0
Total	3453	26.9 (3.6)	1.4	18.3	4501	26.6 (4.7)	4.6	20.8

T6 included 12984 men and women, of which 12961 had valid measurements of BMI (Appendix 3). Table 4 provides the mean BMI in each age group with standard deviations (SD), as well as the prevalence of underweight and obese individuals. The highest prevalence of obesity was found among men in the age group 35-39 (27.0%), with mean BMI in this age group also being the highest (27.9), irrespective of gender. For men all age groups from 30-69 had a mean BMI of more than 27. Among women, the highest prevalence of obesity was

found among those in the oldest age group (25.8 %). Prevalence of obesity was not significantly different between genders, while prevalence of underweight was. Mean BMI was significantly different between genders ($p < 0.001$), at 26.9 for men and 26.6 for women.

Table 4: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI ≥ 30) and underweight (BMI < 20) in T6 according to age groups and gender.

	Men				Women			
Age groups	*n*	BMI (SD)	BMI < 20	BMI ≥ 30	*n*	BMI (SD)	BMI < 20	BMI ≥ 30
30-34	90	27.2 (4.0)	1.1	18.9	121	25.0 (4,4)	7.4	14.0
35-39	122	27.9 (4.0)	0.0	27.0	164	25.9 (4,8)	6.1	18.9
40-44	1074	27.1 (3.9)	1.0	20.4	1279	25.9 (4,7)	5.2	17.0
45-49	588	27.2 (3.7)	0.3	18.0	618	26.3 (4,9)	4.0	19.9
50-54	534	27.4 (3.9)	0.7	20.2	665	25.9 (4,4)	3.8	13.7
55-59	613	27.6 (3.8)	0.8	21.4	620	26.3 (4,4)	3.2	18.2
60-64	1165	27.7 (3.7)	0.6	23.4	1277	27.3 (4,8)	2.8	23.2
65-69	829	27.4 (3.7)	1.4	22.1	825	27.0 (4,6)	2.9	22.2
70-74	516	26.9 (3.6)	1.2	18.4	548	27.3 (4,8)	3.8	24.1
75-79	323	26.5 (3.5)	1.5	15.8	435	26.8 (4,5)	5.3	23.9
80-87	194	26.1 (3.6)	3.6	11.9	333	27.2 (4,5)	4.2	25.8
Total	6048	27.3 (3.8)	1.0	20.5	6885	26.6 (4,7)	4.0	20.2

Table 5 provides the distribution of BMI in the study population according to the main categories suggested by the WHO (36). The mean BMI for each gender at each survey is also provided, and the age adjusted BMI for T5 and T6 is given with the age distribution of T4 serving as reference. Mean bodyweight at each survey is also presented. As is evident from the table, age-adjusted BMI was identical to actual BMI for men both in T5 and T6, but this was not the case for women. Age adjusted prevalence of obesity was lower than that observed for women in both T5 and T6 and men in T5, while it was somewhat lower than that observed for men in T6. Total prevalence of overweight and obesity increased from 54.5% in T4 to 71.6% in T6 for men, and from 40.8% in T4 to 58.5% in T6 for women. Mean weight was around 5 kilograms higher in T6 than T4 for both genders.

Table 5: Distribution of BMI (kg/m^2), mean weight as well as age-adjusted BMI and prevalence of obesity in the three cross sectional surveys.

	Men			Women		
BMI	T4	T5	T6	T4	T5	T6
< 18,50	0.6	0.4	0.3	2.1	1.5	1.0
18,50 - 19,99	1.9	1.0	0.7	5.8	3.1	3.0
20,00 - 22,99	17.9	10.9	9.6	30.1	17.4	19.4
23,00 - 24,99	25.0	18.9	17.8	21.2	19.2	18.1
25,00 - 29,99	44.9	50.5	51.1	29.1	38.0	38.3
30,00 - 32,49	6.4	11.4	11.8	6.0	9.6	9.9
32.50 - 34.99	2.0	4.1	5.5	3.1	6.1	5.0
≥ 35.00	1.2	2.8	3.2	2.4	5.3	5.4
≥ 25.00	54.5	68.8	71.6	40.8	58.9	58.5
≥ 30.00	9.6	18.3	20.5	11.6	20.8	20.2
Mean weight (sd)	80.3 (12.0)	82.5 (12.8)	85.4 (13.3)	66.2 (11.6)	69.5 (12.6)	70.9 (13.0)
Mean age (sd)	46.6 (14.5)	59.9 (14.1)	57.5 (12.3)	47.5 (15.5)	59.7 (13.9)	57.6 (12.9)
Crude BMI (sd)	25.7 (3.3)	26.9 (3.6)	27.3 (3.8)	25.0 (4.3)	26.6 (4.7)	26.6 (4.7)
$BMI_{adjusted}$*	25.7	26.9	27.3	25.0	25.9	26.2
$Obesity_{adjusted}$*#	10.1	17.7	20.8	12.3	16.0	18.7

*: Age adjustment based on those between age of 30 and 84 in the respective surveys, with the population of T4 serving as standard population.

#: Obesity is given as BMI ≥ 30.

Figures 1 and 2 present the mean BMI according to ten-year age groups from the three different surveys. These figures give a visual presentation of the cross-sectional distribution of BMI in the three surveys. Both T5 and T6 clearly have a higher mean BMI than T4 across all age groups, while the difference between T5 and T6 is less evident.

Figure 1: Time series displaying mean BMI (kg/m^2) among men in T4, T5 and T6 according to 10-year age groups.

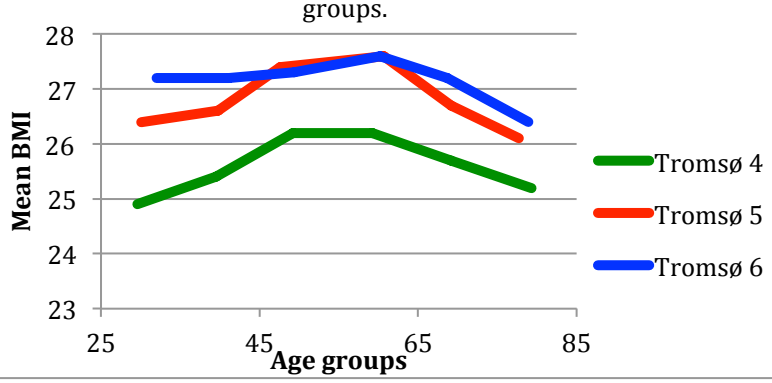
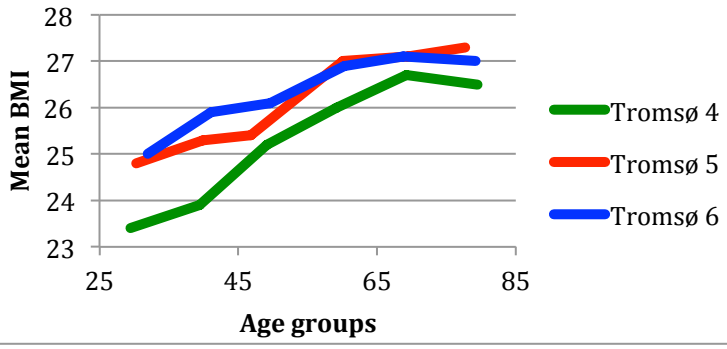


Figure 2: Time series displaying mean BMI (kg/m^2) among women in T4, T5 and T6 according to 10-year age groups



3.2.1 Longitudinal analyses of BMI: T4, T5 and T6.

There were a total of 1765 men and 2520 women under the age of 70 in 1994 that participated in all three surveys, had valid measurements of BMI in all of them and, regarding the women, were not pregnant in either of them (Appendix 4). Tables 6 and 7 present the prevalence of obesity and underweight among men and women respectively, that participated in T4, T5 and T6. The categories used for obesity and underweight are the same as previously. Mean BMI is presented with standard deviation for each age group at each survey. Figures 3 and 4 illustrate this longitudinal development. The lines represent 10-year birth cohorts, and each point on the line stems from the mean age in that particular birth cohort at each survey respectively.

Table 6: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI ≥ 30) and underweight (BMI < 20) in male participants of T4, T5 and T6, presented according to birth cohort.

		Tromsø 4			Tromsø 5			Tromsø 6		
Birth cohort	*n*	BMI (SD)	BMI < 20	BMI ≥ 30	BMI (SD)	BMI < 20	BMI ≥ 30	BMI (SD)	BMI < 20	BMI ≥ 30
1960-1969	119	24.6 (3.1)	0.8	5.0	26.2 (3.9)	2.5	13.4	26.9 (4.0)	0.0	19.3
1950-1959	139	25.8 (2.9)	0.7	10.8	27.2 (3.3)	0.0	16.5	27.7 (3.6)	0.0	18.7
1940-1949	449	26.8 (3.1)	0.9	13.1	28.0 (3.6)	0.0	26.1	28.0 (3.6)	0.9	25.8
1930-1939	861	26.2 (2.9)	0.5	10.2	27.1 (3.3)	0.5	18.8	27.0 (3.4)	0.8	17.9
1925-1929	197	25.7 (3.0)	1.0	10.7	26.5 (3.3)	1.0	14.2	26.5 (3.7)	1.5	15.7
Total	1765	26.1 (3.0)	0.7	10.7	27.2 (3.5)	0.5	19.6	27.2 (3.6)	0.8	19.8

Table 7: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI ≥ 30) and underweight (BMI < 20) in female participants of T4, T5 and T6, presented according to birth cohort.

		Tromsø 4			Tromsø 5			Tromsø 6		
Age in 1994	*n*	BMI (SD)	BMI < 20	BMI ≥ 30	BMI (SD)	BMI < 20	BMI ≥ 30	BMI (SD)	BMI < 20	BMI ≥ 30
1960-1969	168	23.4 (3.8)	11.3	4.2	24.9 (4.1)	6.5	10.7	25.6 (4.7)	6.0	16.7
1950-1959	206	24.1 (3.6)	6.8	7.8	25.7 (4.2)	3.4	12.1	26.1 (4.5)	2.9	15.5
1940-1949	871	25.2 (4.0)	4.9	11.9	26.9 (4.6)	3.3	21.4	27.1 (4.8)	3.1	21.7
1930-1939	977	25.8 (3.9)	3.3	14.2	27.1 (4.3)	3.3	23.4	27.0 (4.6)	3.8	22.7
1925-1929	298	26.4 (4.0)	4.0	18.8	27.6 (4.4)	3.4	28.5	27.1 (4.6)	5.0	26.5
Total	2520	25.4 (4.0)	4.8	12.8	26.8 (4.5)	3.5	21.5	26.8 (4.7)	3.8	21.8

Figure 3: Mean BMI (kg/m^2) at the time of T4, T5 and T6 among men participating in all three surveys, according to birth cohort.

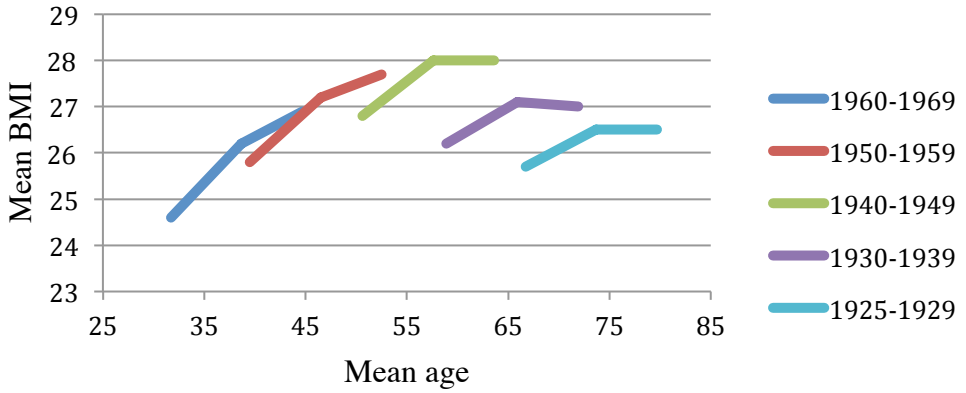
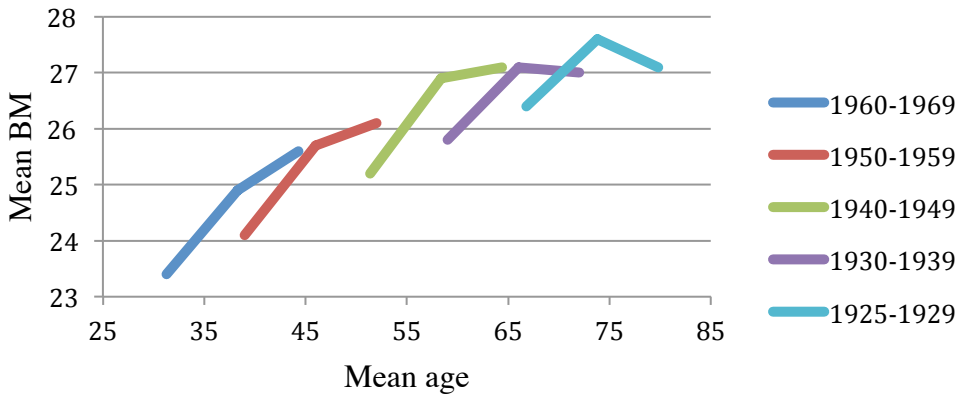


Figure 4:Mean BMI (kg/m^2) at the time of T4, T5 and T6 among women participating in all three surveys, according to birth cohort.



A pattern of BMI development is evident for both genders. For males, BMI increased with age in all birth cohorts from T4 to T5. At the time of T6, BMI had continued to increase for the two youngest birth cohorts, whereas it levelled out for the birth cohorts of 1940-1949 and 1925 - 1929. The birth cohort of 1930-1939 experienced a small decline in BMI from T5 to T6. Interestingly, all birth cohorts had a higher BMI than the birth cohort before it at the same mean age. Regarding the women, BMI increased between all three surveys for all birth

cohorts except the two oldest. Here BMI increased between T4 and T5, but declined from T5 to T6. The same pattern of higher BMI at the same mean age is apparent among the women too. The highest increase in mean BMI between two surveys occurred in the birth cohort of 1940-1949, where mean BMI increased by 1.7 between T4 and T5. Regarding obesity, prevalence in T6 was almost fourfold that of T4 among both men and women in the age group of 25-34. Total prevalence of obesity rose from T4 to T5 for both genders, but declined with 0.1 units from T5 to T6. Included in the Appendix (Appendix 5) are figures displaying the prevalence of obesity for men and women in the longitudinal cohorts from T4, T5 and T6. The pattern is largely the same as for the development in mean BMI.

3.2.2 Longitudinal analyses of BMI: T4 and T6.

As can be seen in the adjacent tables, the figures above are based on relatively small numbers. This is in large due to the invitation criteria for T5, and thus there were few men and women in the lower age groups (See Table 3). Another longitudinal analysis is therefore conducted based on the people participating in both T4 and T6, but not necessarily T5. This increases the number of people in each birth cohort, and enables the division of the population under analysis into narrower age groups.

There were a total of 10167 men and women between the age of 25 and 74 that participated in both T4 and T6, and had valid measurements of BMI at both surveys (Appendix 6). Table 8 and 9 provide the prevalence of obesity and underweight among the men and women respectively, that participated in both T4 and T6. The categories used for obesity and underweight are the same as previously. Mean BMI is presented with standard deviation for each 5-year age group at each survey.

Table 8: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI >= 30) and underweight (BMI < 20) among men participating in both T4 and T6 according to 5-year birth cohorts.

		Tromsø 4			Tromsø 6			BMI
Birth cohort	*n*	BMI	BMI < 20	BMI ≥ 30	BMI	BMI < 20	BMI ≥ 30	diff.
1965-1969	495	24.8 (3.3)	4.0	6.9	27.1 (3.9)	0.6	19.4	2.3
1960-1964	345	24.9 (3.2)	3.2	6.4	27.2 (3.7)	0.3	19.7	2.3
1955-1959	440	25.2 (2.9)	0.9	7.5	27.2 (3.6)	0.2	17.7	2.0
1950-1954	470	25.7 (3.1)	0.9	10.0	27.5 (3.1)	0.9	22.3	1.8
1945-1949	868	26.3 (3.3)	1.2	12.4	27.8 (3.8)	0.7	23.3	1.5
1940-1949	890	26.3 (3.1)	1.1	12.7	27.5 (3.8)	1.1	22.9	1.2
1935-1939	560	26.3 (3.0)	0.5	11.1	27.1 (3.5)	0.9	17.7	0.8
1930-1934	394	26.1 (2.9)	0.8	9.6	26.8 (3.5)	1.5	18.8	0.7
1925-1929	204	25.7 (3.0)	1.0	10.8	26.5 (3.7)	1.5	16.2	0.8
1920-1924	80	25.4 (3.1)	2.5	7.5	25.2 (3.5)	7.5	6.3	-0.2
Total	4746	25.8 (3.2)	1.5	10.2	27.3 (3.7)	0.9	20.3	1.8

BMI diff.: difference in BMI between the two surveys.

Table 9: Mean BMI (kg/m^2) and prevalence (%) of obesity (BMI 30) and underweight (BMI < 20) among women participating in both T4 and T6 according to 5-year birth cohorts.

		Tromsø 4			Tromsø 6			
Birth cohort	*n*	BMI (SD)	BMI < 20	BMI ≥ 30	BMI (SD)	BMI < 20	BMI ≥ 30	BMI diff.
1965-1969	603	23.3 (3.5)	12.8	5.6	25.9 (4.5)	5.3	17.2	2.6
1960-1964	438	23.4 (3.6)	12.3	5.5	25.7 (4.6)	5.7	16.2	2.2
1955-1959	482	23.8 (3.7)	8.5	5.8	26.0 (4.4)	2.7	16.2	2.2
1950-1954	525	24.3 (3.9)	7.8	8.4	26.3 (4.6)	4.2	17.9	2.0
1945-1949	940	25.0 (3.8)	4.7	10.6	26.9 (4.4)	3.2	21.3	1.9
1940-1949	920	25.5 (4.2)	5.2	13.8	27.3 (5.0)	2.9	23.0	1.8
1935-1939	613	25.8 (4.1)	3.6	14.8	27.0 (4.7)	3.9	23.7	1.2
1930-1934	442	25.9 (3.7)	2.9	13.1	26.9 (4.4)	4.3	22.4	1.0
1925-1929	324	26.4 (4.0)	3.7	19.1	27.1 (4.5)	4.9	26.5	0.7
1920-1924	134	27.1 (3.7)	0.0	19.4	26.6 (4.3)	4.5	18.7	0.5
Total	5421	24.9 (4.0)	6.5	11.0	26.6 (4.6)	3.9	20.5	1.7

BMI diff: difference in BMI between the two surveys.

Figures 5 and 6 provide the longitudinal development of mean BMI among men and women respectively. Each line illustrates the development of BMI between T4 and T6 in a 5-year birth cohort. Linear regression revealed that the difference in BMI between T6 and T4 is higher among younger age groups than older age groups. A five-year increase in age was associated with a 0.25 lower increase in BMI over the 13-year period. The difference was statistically significant with $p < 0.001$ for both men and women.

Figure 5: Mean BMI (kg/m^2) at the time of T4 and T6, among men participating in both T4 and T6 according to 5-year birth cohorts.

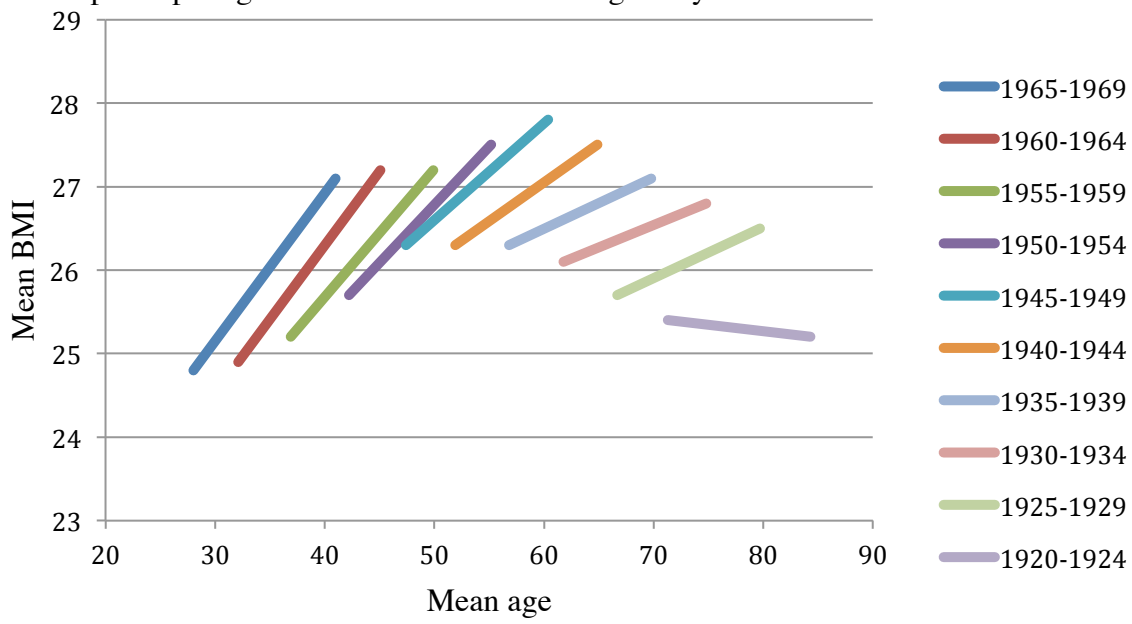
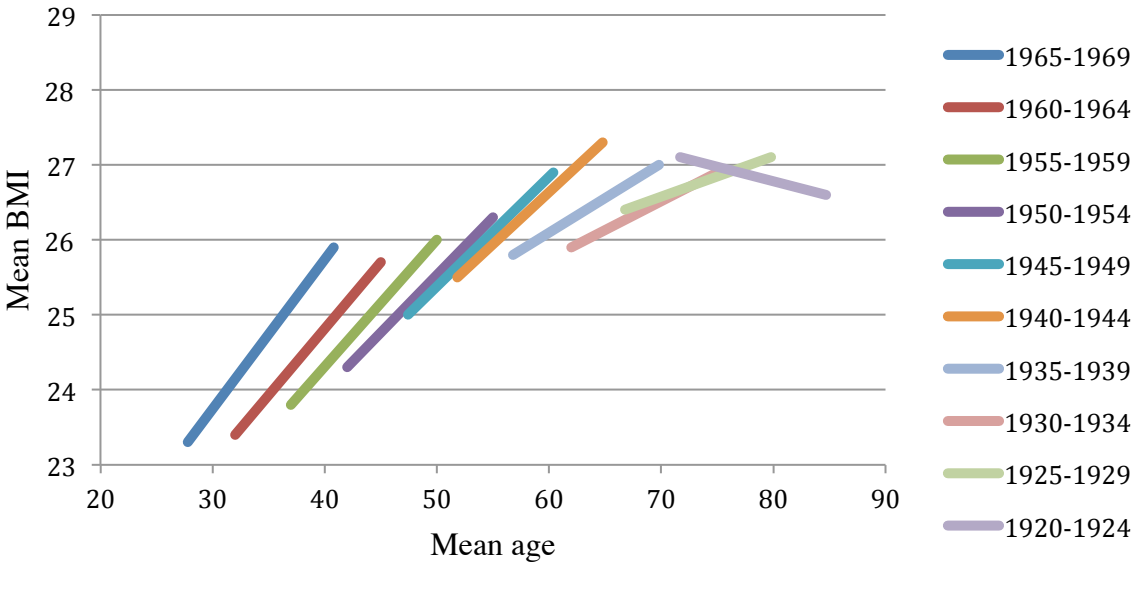


Figure 6: Mean BMI (kg/m^2) at the time of T4 and T6, among women participating in both T4 and T6 according to 5-year birth cohorts.



As is evident from both Table 8 and Figure 5, mean BMI among men increased in all birth cohorts but the last. The inversed U-shaped pattern from Figure 3 is evident also in Figure 5. This means that all birth cohorts experienced a higher BMI than the age group before it at the same mean age, and that the older birth cohorts never achieve as high BMI as the one

following it. The largest increase in mean BMI took place in the birth cohort of 1960-1964, i.e. the ones that were between the age of 30 and 34 in 1994 and between 43 and 47 in 2007. This group experienced a mean BMI increase of 2.4, equivalent to 7.5 kg for a man 1.77m tall.

For women the pattern is different. Table 9 and Figure 6 show that BMI increased in all birth cohorts except the last, where there was a decline in mean BMI from 27.1 to 26.6. At this particular point the mean age in this birth cohort was 84.7 years (data not shown). The major difference from the men is that all birth cohorts had a higher BMI in T4 than the birth cohort following it. In T6 however, three out of the four oldest birth cohorts had experienced a lower increase in BMI than the birth cohort of 1940-1944.

3.2.3 Longitudinal change in weight: T4 and T6.

Table 10 provides the mean weight in kilograms in T4, T6 and the difference between them according to gender and age group in 1994.

Table 10: Mean weight in kilograms in participants of both T4 and T6 and the difference in weight between surveys according to birth cohort and gender.

	Men				Women			
		Bodyweight				Bodyweight		
Birth cohort	*n*	T4	T6	Diff. (SD)	*n*	T4	T6	Diff. (SD)
1965-1969	495	79.9	87.5	7.6 (7.1)	603	63.6	71.2	7.6 (7.4)
1960-1964	345	79.7	87.2	7.4 (6.9)	438	63.9	70.3	6.4 (7.0)
1955-1959	440	81.1	87.1	5.9 (6.3)	482	65.1	71.1	6.0 (6.5)
1950-1954	470	81.9	87.1	5.2 (6.5)	525	65.8	70.8	5.1 (6.4)
1945-1949	868	82.6	86.4	3.8 (6.6)	940	67.5	71.9	4.5 (6.5)
1940-1944	890	82.3	85.1	2.8 (6.5)	920	68.0	71.9	3.9 (7.1)
1935-1939	560	81.4	82.8	1.4 (6.4)	613	68.0	70.0	2.0 (6.8)
1930-1934	394	80.4	81.0	0.6 (6.0)	442	67.5	68.5	1.0 (6.7)
1925-1929	204	78.5	78.9	0.4 (6.1)	324	68.4	68.2	- 0.2 (6.7)
1920-1924	80	77.3	74.8	- 2.5 (7.1)	134	69.0	65.6	- 3.4 (7.6)
Total	4746	81.2	85.1	3.8 (7.0)	5421	66.6	70.6	4.0 (7.3)

For men all age groups except the group of 70-74 experienced an increase in weight over this 13-year period. For women all groups except the 65-74 experienced an increase. Interestingly

both genders in the age group of 25-29 experienced the same increase, at 7.6 kilograms. This was also the age group with the highest weight gain in the period, and regarding the men the age group with the highest mean weight of all age groups at the time of T6.

3.2.4 Smoking effects on longitudinal change in BMI: T4 and T6.

Smokers are known to have a different development in BMI than non-smokers (17). Table 11 gives the mean BMI according to smoking status and gender in T4 and T6. There are 4 categories of smokers; those who did not smoke in either T4 or T6, those who smoked in both, those that stopped between T4 and T6 and those that started smoking between T4 and T6.

Table 11: Mean BMI (kg/m^2) in T4 and T6 and the difference in BMI between T4 and T6 according to smoking status and gender in participants of both surveys.

	Men				Women			
	n	BMI T4	BMI T6	Diff. BMI	n	BMI T4	BMI T6	Diff. BMI
Consistent smokers	3085	26.0 (3.1)	27.3 (3.6)	1.3	3494	25.3 (4.1)	26.8 (4.6)	1.5
Never-smokers	766	25.2 (3.3)	26.3 (3.8)	1.1	1031	24.0 (3.7)	25.6 (4.5)	1.6
Quit	808	25.6 (3.3)	28.1 (4.0)	2.5	821	24.1 (3.8)	27.1 (4.6)	3.0
Started	87	26.4 (3.5)	27.3 (3.7)	0.9	75	25.8 (4.3)	27.1 (5.2)	1.3
Total	4746	25.8 (3.2)	27.3 (3.7)	1.5	5421	24.9 (4.0)	26.6 (4.6)	1.7

Diff. BMI: BMI in T6 minus BMI in T4.

Statistical analyses with adjustment by age revealed that there was a statistically significant difference in the BMI difference between T6 and T4 between those that quit smoking and the three other categories of smoking ($p < 0.001$). Between non-smokers, start-smokers and consistent smokers there was no difference in BMI development between the two surveys. This was the case for both genders, meaning that cessation of smoking was associated with increased BMI. For men there was a significant interaction between age and smoking group ($p < 0.05$). This means that the effect of smoking status on BMI is dependent upon age; in older age groups the effect of smoking on change in BMI was less than among young age groups.

3.3 Waist circumference.

3.3.1 Cross-sectional analyses of waist circumference.

Tables 12 and 13 provide WC according to age groups and gender in T4, T5 and T6.

Among men in T4 the highest WC was 96.4 centimetres (cm), found in the age group 50-54, while total mean WC was 95.1cm. For women the highest value of WC, 92.0cm were found in the age group 75-84, with total mean WC at 85.1cm.

Table 12: cross-sectional analyses of waist circumference and prevalence of obesity (WC ≥ 102 cm) among men in T4, T5 and T6.

	T4			T5			T6		
Age groups	n	WC (SD)	Overweight[#]	n	WC (SD)	Overweight[#]	n	WC (SD)	Overweight[#]
25-29	56	89.7	25.2	x	x	x	x	x	x
30-34	48	86.3	24.1	232	90.4	26.4	86	95.9	27.3
35-39	75	88.9	24.9	44	87.8	25.5	115	98.5	27.9
40-44	61	93.7	26.5	304	92.1	26.8	1016	97.4	27.1
45-49	229	96.1	27.2	293	93.5	27.0	548	97.8	27.3
50-54	228	96.4	26.9	143	96.6	28.2	520	98.9	27.4
55-59	801	95.1	26.2	218	97.0	27.9	595	99.6	27.5
60-64	708	95.3	26.1	649	96.4	27.5	1138	100.8	27.7
65-69	614	95.5	25.9	582	95.8	26.8	809	101.0	27.4
70-74	507	95.9	25.8	489	96.1	26.5	504	100.3	26.9
75-79	29	96.1	25.4	377	95.8	26.1	303	100.9	26.5
80-89	5	89.6	21.5	110	97.1	26.1	185	100.3	26.1
Total	3361	95.1	26.1	3441	95.2	26.9	5819	99.5	27.3

x: Not applicable.

#: Prevalence of obese or overweight participants defined as WC ≥ 102 cm.

In T5 the highest WC among men was 97.1, found in the age group of 80-89. For the women, highest WC was found in the age group 80-89, at 88.2cm. Total mean WC for men were 95.2cm, 0.1cm higher than in T4. For women total WC was 84.3cm, 0.8cm less than in T4.

In T6, total mean WC was 99.5cm for men and 90.9cm for women. The highest WC among men was found in the age group 75-79 (100.9cm), and the highest WC among women found in the age group 60-64 (105.2cm).

Table 13: Cross-sectional analyses of waist circumference and prevalence of obesity (WC ≥ 88 cm) among women in T4, T5 and T6.

	T4			T5			T6		
Age groups	n	WC (SD)	Overweight[#]	n	WC (SD)	Overweight[#]	n	WC (SD)	Overweight[#]
25-29	50	74.2	22.2	x	x	x	x	x	x
30-34	66	79.5	24.1	312	77.5	24.8	119	85.7	25.0
35-39	91	78.4	23.7	73	80.5	25.7	158	88.7	25.9
40-44	84	79.4	24.4	371	80.1	25.3	1222	88.5	26.0
45-49	100	81.1	24.4	362	80.9	25.3	595	90.2	26.3
50-54	98	80.3	24.6	92	81.6	25.6	649	89.2	25.9
55-59	853	84.4	26.0	622	85.5	27.2	606	90.5	26.3
60-64	703	84.8	26.0	815	84.7	26.9	1248	93.0	27.3
65-69	765	87.2	26.6	628	85.7	27.1	806	92.0	27.0
70-74	587	88.0	26.8	591	86.5	27.2	530	92.4	27.2
75-79	31	95.2	28.7	472	88.0	27.3	419	92.4	26.8
80-89	15	85.5	24.7	144	88.2	27.1	316	93.6	27.2
Total	3443	85.1	26.0	4482	84.3	26.6	6668	90.9	26.6

x: Not applicable.

#: Prevalence of obese or overweight participants defined as WC ≥ 88 cm.

3.3.2 Longitudinal analyses of waist circumference

Tables 14 and 15 provide the longitudinal change in WC for those men and women respectively, that participated in both T4 and T6 and had valid measurements of WC in both. Ten-year age groups are used and the prevalence of overweight and obesity combined is also provided. The highest increase in WC between T4 and T6 took place among women in the age group 35-44. This group experienced a WC of 91.2cm in T6, up 12cm from T4. Among men the highest increase occurred in the youngest age group, at 9.8 cm difference between T4 and T6. Overall, women had a higher mean increase than men over this thirteen-year period. For both men and women the increase in WC between the surveys was significantly different between age groups ($p < 0.001$), with the increase in WC being lower with increasing age. The highest increase in abdominal obesity occurred in the female birth cohort of 1950-1959, where prevalence increased almost fourfold over this 13 year period. Appendix Table 1

(Appendix 7) provides the changes in Z-scores for each gender and each age group in the longitudinal cohort. These results confirm the pattern from table 14 and 15.

Table 14: Mean waist circumference and prevalence (%) of overweight and obese (WC ≥ 102 cm) in males participating in both T4 and T6.

		WC			WC ≥ 102 cm		
Birth cohort	n	T4	T6	Increase (SD)	T4	T6	Diff. (SD)
1960-1969	62	88.4	98.2	9.8 (7.3)	0.07	0.31	0.24 (0.43)
1950-1959	88	90.9	98.3	7.4 (7.3)	0.09	0.34	0.25 (0.51)
1940-1949	326	96.1	102.3	6.2 (7.2)	0.23	0.51	0.28 (0.48)
1930-1939	849	94.8	100.6	5.8 (7.0)	0.20	0.44	0.25 (0.48)
1920-1929	252	95.0	100.4	5.4 (7.3)	0.19	0.46	0.27 (0.48)
Total	1577	94.6	100.7	6.1 (7.2)	0.19	0.45	0.26 (0.48)

Diff.: difference in prevalence (%) of obesity (WC ≥ 102 cm) between T6 and T4.

Table 15: Mean waist circumference and prevalence (%) of overweight and obese (WC ≥ 88 cm) in females participating in both T4 and T6.

		WC			WC ≥ 88 cm		
Birth cohort	n	T4	T6	Increase (SD)	T4	T6	Diff (SD)
1960-1969	75	76.5	85.9	9.4 (8.9)	0.11	0.39	0.28 (0.53)
1950-1959	135	79.2	91.2	12.0 (8.7)	0.16	0.59	0.43 (0.50)
1940-1949	158	80.7	90.2	9.6 (7.8)	0.19	0.60	0.41 (0.52)
1930-1939	972	83.9	91.9	8.1 (8.7)	0.30	0.64	0.34 (0.52)
1920-1929	409	86.8	93.1	6.3 (8.7)	0.45	0.67	0.22 (0.51)
Total	1749	83.6	91.7	8.2 (8.7)	0.31	0.63	0.32 (0.52)

Diff.: difference in prevalence (%) of obesity (WC ≥ 88 cm) between T6 and T4.

3.4 Analyses of waist-to-height-ratio

Table 16 provides the cross sectional distribution of waist-to-height-ratio (WHtR) for the men and women that participated in T4, according to ten year age groups. Table 17 provides the cross sectional distribution of WHtR for T6. The tables also provide the percentage of participants with a WHtR higher or equal to 0.5, which is the suggested cut-off value used to assess overweight (26). Generally speaking, WHtR increased consistently with age for both genders in T4, and we found a significant increase with age group ($p < 0.001$) for both genders. The lowest prevalence of WHtR ≥ 0.5 is found among the youngest women (18.1%), while the highest prevalence of WHtR ≥ 0.5 is found in middle aged men (85.6%). The same pattern is found in T6, but here none of the age groups have a mean WHtR of less than 0.5.

Increase with age was significant in both genders ($p < 0.001$). The lowest prevalence of WHtR ≥ 0.5 is found in the female age group of 30-39, at 61%, while the highest is found in the male age group of 70-79, where prevalence of WHtR ≥ 0.5 is 91.7%.

Table 16: Cross-sectional distribution of mean waist-to-height-ratio (WHtR) and prevalence (%) of overweight and obesity (WHtR ≥ 0.5) in T4 according to birth cohort and gender.

	Men			Women		
Age groups	n	WHtR (SD)	% WHtR ≥ 0.5	n	WHtR (SD)	% WHtR ≥ 0.5
25-34	104	0.494	42.3	116	0.466	18.1
35-44	136	0.510	58.1	175	0.480	28.6
45-54	457	0.546	85.6	198	0.490	39.9
55-64	1509	0.543	82.0	1556	0.524	61.3
65-74	1121	0.551	83.6	1352	0.548	74.5
Total	3327	0.543	80.8	3397	0.527	62.1

Table 17: Cross-sectional distribution of mean waist-to-height-ratio (WHtR) and prevalence (%) of overweight and obesity (WHtR ≥ 0.5) in T6 according to birth cohort and gender.

	Men			Women		
Age groups	n	WHtR (SD)	% WHtR ≥ 0.5	n	WHtR (SD)	% WHtR ≥ 0.5
30-39	201	0.542	72.6	277	0.528	61.0
40-49	1564	0.549	77.7	1817	0.539	65.3
50-59	1115	0.560	84.5	1255	0.546	71.6
60-69	1948	0.574	89.8	2054	0.570	82.5
70-79	807	0.579	91.7	950	0.578	84.8
80-87	185	0.584	90.3	316	0.595	87.7
Total	5820	0.563	85.2	6669	0.557	75.4

Table 18 provides the longitudinal changes in WHtR among the men and women that participated in both surveys and had valid measurements of WC and body height. Among men the highest increase was experienced in the age group of 25-34, where a mean increase of 0.055 was found in WHtR between the two surveys. The difference was reduced with age, with a reduced increase of -0.064 per increase in 10-year birth cohort ($p = 0.12$). For women the highest increase occurred in the age group 35-44, where an increase in WHtR of 0.074 was experienced. The reduced difference with age was more significant and more profound among women than men, at a reduction in increase of -0.095 per increase in 10-year birth cohort ($p < 0.001$).

Table 18: Waist-to-height-ratio (WHtR) in T4 and T6, and the difference in WHtR between these surveys among the men and women that participated in both. Presented according to birth cohort.

Birth cohort	Men				Women			
	n	WHtR T4	WHtR T6	DIFF (SD)	n	WHtR T4	WHtR T6	DIFF (SD)
1960-1969	62	0.493	0.548	0.055	76	0.464	0.520	0.056
1950-1959	88	0.512	0.555	0.043	135	0.481	0.556	0.074
1940-1949	326	0.545	0.583	0.039	158	0.489	0.550	0.061
1930-1939	849	0.540	0.578	0.038	972	0.519	0.574	0.056
1920-1929	252	0.545	0.582	0.038	409	0.540	0.588	0.048
Total	1577	0.538	0.577	0.039	1750	0.516	0.571	0.056

3.5 Analyses of BMI and DBMI

Mean BMI in T4 was 25.1, while mean DBMI was 23.3. The difference between the two, 1.8 BMI units, amounts to 5,3 kg for a person at 1,71 cm of height (mean height in T4). In T5 mean BMI was 26.7, while mean DBMI was 24.4. The difference of 2.3 BMI units amounts to 6.5 kg for a person at 168.3 cm of height (mean height in T5). In T6 mean BMI was 27.1, with DBMI being 24.5. With mean height being 170 cm, the difference of 2.6 BMI units amounts to 7.5 kg.

3.5.1 Cross-sectional analyses of DBMI

DBMI was computed and analysed for T4, T5 and T6. Appendix Table 2 (Appendix 8) provides the cross-sectional distribution of DBMI for men and women in all three surveys. Table 19 provides the distribution of BMI and DBMI in T4 according to age group and BMI groups of either BMI < 25, BMI 25-30 or BMI > 30. The absolute difference between BMI and DBMI is also presented. Table 20 provides the same information for the women in T4. The reader is referred to Appendix 9 for the corresponding tables from T5 (Appendix Tables 3-4) and T6 (Appendix Tables 5-6), and the results from these surveys are summed up in the text below.

Table 19: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) and the difference between DBMI and BMI (kg/m^2) according to three categories of BMI among men in Tromsø 4.

	BMI < 25				BMI 25-25.99				Obese (BMI≥30)			
Age group	*n*	BMI	DBMI	Diff	*n*	BMI	DBMI	Diff.	*n*	BMI	DBMI	Diff.
25-29	670	22.7	22.9	-0.2	435	26.8	24.8	2.0	78	32.4	26.9	5.5
30-34	641	22.9	22.9	0.0	458	26.8	24.8	2.0	91	32.3	26.8	5.5
35-39	612	23.1	22.8	0.3	564	26.9	24.8	2.1	92	32.3	27.0	5.3
40-44	576	23.0	22.8	0.2	574	26.9	24.9	2.0	120	32.3	27.1	5.2
45-49	423	23.0	22.9	0.1	635	27.0	25.0	2.0	161	32.3	27.1	5.2
50-54	344	23.2	23.0	0.2	524	27.2	25.3	1.9	134	31.9	27.2	4.7
55-59	270	23.3	23.2	0.1	373	27.2	25.4	1.8	81	32.2	27.5	4.7
60-64	201	22.9	22.9	0.0	328	27.1	25.3	1.8	69	32.8	27.1	5.7
65-69	204	22.8	23.0	-0.2	244	27.0	25.3	1.7	59	32.0	26.8	5.2
Total	3941	23.0	22.9	0.1	4135	27.0	25.0	2.0	885	32.3	27.1	5.2

In T4, a total of 8961 men and 9995 women between the age of 25 and 69 had answered the question on ideal weight, and thus were included in the analysis. Total difference between DBMI and actual BMI was 0.1 for normal weight men, an indication of high weight satisfaction in this BMI group. Overweight men were less satisfied with their weight, with a difference of 2.0, while obese men had a difference of 5.2 BMI units between actual and desired BMI.

Table 20: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) and the difference between DBMI and BMI (kg/m^2) according to three categories of BMI among women in Tromsø 4.

	BMI < 25				BMI 25-25.99				Obese (BMI≥30)			
Age group	*n*	BMI	DBMI	Diff	*n*	BMI	DBMI	Diff.	*n*	BMI	DBMI	Diff.
25-29	1029	21.7	20.6	1.1	284	26.8	23.0	3.8	79	33.5	25.3	8.2
30-34	1056	21.8	20.7	1.1	302	26.9	23.1	3.8	76	33.3	25.6	7.7
35-39	1053	22.0	20.9	1.1	323	26.9	23.3	3.6	92	33.4	24.9	8.5
40-44	944	22.2	21.1	1.1	352	26.8	23.3	3.5	107	33.0	24.9	8.1
45-49	764	22.3	21.3	1.0	447	26.9	23.6	3.3	143	32.9	25.6	7.3
50-54	514	22.5	21.6	0.9	352	26.9	23.8	3.1	151	33.4	25.8	7.6
55-59	313	22.6	21.9	0.7	301	27.1	24,1	3.0	116	33.2	26.2	7.0
60-64	251	22.5	22.1	0.4	267	27.0	24.4	2.6	94	32.5	26.2	6.3
65-69	236	22.5	22.2	0.3	224	27.1	24.7	2.4	123	33.4	27.0	6.4
Total	6160	22.1	21.1	1.0	2852	26.9	23.7	3.2	983	33.2	25.8	7.4

For normal weight women the difference was 1.0. Among the overweight, women in the age groups 25-34 were the least satisfied with their weight, with a difference of 3.8 between

desired and actual BMI. Among the obese, the highest difference was found among the women in the age group 35-39, where participants ideally would like to have a BMI of 8.5 units less. This group actually reported a DBMI of 24.9, which would put them in the category ´normal weight´.

In T5 2940 men and 3750 women had answered the question on ideal weight, had valid measurements of height and BMI, and regarding the women, were not pregnant (Appendix Tables 3-4). Normal weight men had high weight satisfaction, with the difference only being -0.1 BMI units. Overweight men had a difference of 1.8 units, and a mean DBMI of 25.4. Regarding normal weight women the difference was 0.7, while it was 2.8 for overweight. Among the obese difference between desired and actual BMI was 6.6.

In T6 there were 5012 men and 5538 women with a reported ideal weight and valid BMI. Appendix Tables 5 and 6 provide the mean BMI and mean DBMI according to the before-mentioned BMI categories for each gender respectively. Normal weight men reported a total mean difference of 0, while DBMI for overweight men was 25.4, same as in T5, with a difference of 2.0 BMI units. Obese men had a difference of 5.2. Normal weight women were not entirely satisfied with their weight, with a difference of 0.8. Here too, older age groups reported a desired to gain some or loose quite little weight, while younger age groups reported a desire to loose some weight. The overweight group had a difference of 2.9 BMI units between desired and actual BMI, while the obese had a difference of 7.0.

3.5.2 Longitudinal changes in desired BMI

Table 21 displays the mean BMI and mean DBMI among men according to ten-year age groups in T4 and T6, while table 22 provides the same information for the women. As is evident both BMI and number of participants differ from Tables 8 and 9, which is because all those participating in T4 and T6 did not answer the question of desired weight.

All birth cohorts in both genders have an increased BMI in T6 compared to T4, and all have increased their desired BMI from T4 to T6. The difference between BMI and DBMI is higher in T6 than T4 for both genders in all age groups, except for the female age group of 65-69, which demonstrate a difference of 2.2 in T6 compared to 2.4 in T4. The greatest difference between DBMI in T4 and BMI in T6 is found the female age cohort of 25-34, where there is a difference of 4.7. Its interesting to note that the male age cohort of 25-34 would be satisfied with a BMI of 25.1 in 2007, which is in fact the same BMI as the cohort was dissatisfied with in 1994. This is an exception, as all the other age cohorts of both genders would like to have a lower BMI in 2007 than their actual BMI was in 1994. The change in difference between BMI and DBMI was significantly associated with age for both men and women, in that the change in difference was reduced with age ($p < 0.001$).

Table 21: Mean BMI (kg/m^2), DBMI (desired BMI) and the discrepancy between them, for T4 and T6 among men that participated in both surveys. The change in discrepancy between surveys is provided, and the results are presented according to 10-year birth cohorts.

Birth cohort	n	BMI T4	DBMI T4	Diff.	BMI T6	DBMI T6	Diff.	Diff. change
1960-1969	590	25.1	23.8	1.3	27.4	25.1	2.3	1.0
1950-1959	623	25.7	24.2	1.5	27.6	25.3	2.3	0.8
1940-1949	1232	26.6	24.8	1.8	27.9	25.6	2.3	0.5
1930-1939	647	26.3	24.8	1.5	27.2	25.4	1.8	0.3
1925-1929	122	26.0	24.5	1.5	26.8	25.0	1.8	0.3
Total	3214	26.0	24.5	1.5	27.6	25.4	2.2	0.7

Diff. change: Diff. in T6 minus diff. in T4.

Table 22: Mean BMI (kg/m^2), DBMI (desired BMI) and the discrepancy between them, for T4 and T6 among women that participated in both surveys. The change in discrepancy between surveys is provided, and the results are presented according to 10-year birth cohorts.

Birth cohort	n	BMI T4	DBMI T4	Diff.	BMI T6	DBMI T6	Diff.	Diff. change
1960-1969	796	23.5	21.4	2.1	26.1	23.1	3.0	0.9
1950-1959	733	24.2	21.9	2.3	26.5	23.5	3.0	0.7
1940-1949	1306	25.4	22.8	2.6	27.4	24.3	3.1	0.5
1930-1939	679	25.9	23.5	2.4	27.2	24.7	2.5	0.1
1925-1929	176	26.3	23.9	2.4	27.0	24.8	2.2	-0.2
Total	3690	24.9	22.5	2.4	26.9	23.9	2.9	0.5

Diff. change: Diff. in T6 minus diff. in T4.

Chapter 4. Discussion

4.1 Cross-sectional- and longitudinal analyses of BMI.

The main findings in this thesis are that BMI has increased across all age groups in both genders in the population under study, suggesting a continuation of the development in BMI in the Tromsø Study described in previous studies (15, 37). As is evident from figures 1 - 2 and tables 2 - 4, the T5 and T6 cohort experienced a higher BMI than T4 for all age groups and both genders. The difference between T5 and T6 is less profound. The results from the cross-sectional results indicate that among men, BMI peaks at around 60 years of age before declining. The pattern is consistent in all three surveys analysed. This pattern of flattening and decline observed among men is disproved in both of the longitudinal analyses, where BMI is found to increase substantially between T4 and T5 for all age groups, and while it continued to increase until T6 for the three youngest age groups it remained stable for the two oldest. The second analyses, which included T4 and T6 only, show that BMI increased in all age groups but the oldest.

Among women the cross-sectional results show that BMI continues to increase more or less throughout life, with only a slight decline in the very highest age groups. The longitudinal analyses largely confirm this, showing that BMI increased in all but the oldest age group among those that participated in T4 and T6. Among those women that participated in all three surveys, results indicate that a decline in BMI takes place late in life.

This slight decline or levelling off in BMI is not synonymous with a favourable change in body composition, since BMI is not an anthropometric measure without faults. In this particular dataset average height for women in the longitudinal cohort aged 65 or more in 1994, fell from 160.6cm at T4 to 158.2 cm at T6 (data not shown). However, in the same period mean weight decreased from 68.6 kg to 67.4 kg. If BMI in T6 were calculated based on height in T4, not T6, this particular group would have a mean BMI of 26.1, rather than the

calculated 26.9. Because of this it would perhaps be more fitting to consider other anthropometric measurements to assess the degree of obesity in this particular group (38-40). As mentioned, BMI for this group was 26.9 in T6, compared to 26.7 at the time of T4. During the same period, waist circumference increased from 86.8 to 93.1. These two variables would therefore appear to contradict each other, as one indicates a favourable development whereas the other indicates a negative development. This is an indication of how BMI is insufficient as a measure of obesity among some groups of elderly, and in fact elevated BMI is not necessarily associated with morbidity and mortality in the elderly (41). Arguably WHtR, like BMI, suffers from the influence of height reduction. The female age group discussed above had an increase in WHtR of 0.0479 between T4 and T6. However, because the formula for WHtR is WC divided by height, and with an observed decrease in height and increase in WC, these two variables both pull in the direction of an increase in WHtR. WHtR might therefore be more useful to assess overweight and obesity in younger age groups when used in longitudinal research. It should be noted that BMI, WC and WHtR all described this particular age group as overweight according to the cut off values commonly used. In a longitudinal perspective though, BMI declines from T4 to T6, while WHtR and WC both demonstrate an increase. For the younger age groups of both genders, longitudinal analyses show a consistent increase in BMI, WC and WHtR.

The differing results from the longitudinal- and cross-sectional analyses appear to be influenced by a cohort effect, in which the age distribution in the population under study affects the results due to the traits of the different age groups. Table 5 shows that after age adjustment, mean BMI increased from T4 to T5 and to T6, but that the increase was largest from T4 to T5. This is in accordance with the figures data presented in table 2-4 and figures 1 and 2. The longitudinal results demonstrate that the older age groups, which would appear to

experience a decline in BMI in the cross sectional analyses of T4, in fact continue to gain weight.

The complete longitudinal cohort indicates that the biggest increase in weight occurred between T4 and T5 for both men and women, and that weight in the older age groups only increased slightly between T5 and T6. This is similar to the results found by Midthjell et. al. (5) in a comparable population, where both prevalence of obesity and weight increased more between HUNT 1 and HUNT 2 than between HUNT 2 and HUNT 3. This article too reported a greater increase between surveys among younger age groups.

4.2 Desired Body Mass Index

Desired BMI was included in this thesis to assess how normal weight, overweight and obese people differ on weight satisfaction, and to investigate how peoples weight satisfaction change over time.

The cross-sectional analysis of DBMI demonstrates that the level of weight dissatisfaction is different between normal weight, overweight and obese, and that normal weight women are less satisfied with their bodily composition than normal weight men. Previous studies have confirmed differences in weight satisfaction between genders and between classes of BMI (42, 43). Interestingly, the mean desired BMI among overweight women in all age groups in T4 was less than 25, indicating a desire to not just loose some weight, but to loose enough weight as to be classified as being of normal weight. This was the case too in T5 and T6, with the exception of women aged 70 or more. This is of particular interest since DBMI has been computed based on the question of desired weight, not desired BMI, meaning that desired weight seems to be dependent on the height of the individual.

In the longitudinal analyses, all age cohorts of both genders reported a desired BMI in T6 lower then their actual BMI in T4. This might be an indication of upholding ambitions with regards to body weight. There was one exception to this pattern, namely the male age

cohort of 25-34. This cohort reported a desired BMI of 25.1 in T6, identical to their measured BMI in T4, which they at the time were dissatisfied with.

BMI increased more during the study period than DBMI, and might in some respects indicate that people uphold their ambitions, so to speak. If DBMI had increased just as much as actual BMI, then this would simply indicate that everyone would wish to weigh a little less, regardless of their actual weight. When DBMI increased relatively less than BMI, this indicates that people do not change what weight they would be satisfied with as much as they actually change in weight. The results are similar to that of Maynard et.al., although they applied a different design (44).

The results from this section of the thesis illustrate what is perhaps generally assumed, namely that overweight and obese people are less satisfied with their weight than normal weight people. Furthermore, the longitudinal results indicate that people do not necessarily grow accustomed to an increase in bodyweight. One might hypothesize that, although obesity is "contagious" (10), a general increase in weight is not followed by a subjective acceptance or satisfaction with this increase. This is up to future research to investigate.

4.3 Strengths and limitations

On a general note, the Tromsø Study enjoys a relatively high response rate, and the Study has high credibility in its source population after being performed regularly in the last 30 years.

4.3.1 Measures of body composition

This thesis has sought to describe the bodily composition in the population that participated in T4, T5 or T6, or the changes in bodily composition among those that participated in all or two of the surveys. The primary variable sought to describe this was Body Mass Index, which in the selected population was measured using standardized procedures. Previous studies have indicated that self-reported weight is likely to be underestimated, while self-reported height is

likely to be overestimated (45). Therefore the data available on these two measurements in this thesis is likely to represent the actual weight and height of the survey cohorts, and a correct BMI would have been computed as a result of this. That being said, BMI is to some extent flawed as a measure of body composition among elderly. With age follows a change in body composition, where the percentage of fat increases relative to that of lean mass. Particularly women often loose height with age, which too would have an effect on BMI if the same weight were maintained (40). Since the proportion of lean mass is likely to decline, maintenance of weight would imply an increase of fat mass (15).

To avoid the dependency on this one variable, BMI, other variables were included to assess the changes in body composition over the study period. The variables included were waist circumference and waist-to-height-ratio. Waist circumference was preferred over hip circumference, simply because this is a more commonly used measure of overweight and obesity. The inclusion of these variables to describe changes in bodily composition is a strength of the thesis.

WC is prone to measurement error, and to avoid the effect of systematic differences in how the circumference might have been measured at the surveys, a z-score was computed. When comparing the longitudinal results from the WC and $WC_{z\text{-}score}$ analyses, no difference was found in the pattern of increase or decrease over the study period. This further strengthening the results of the waist circumference analyses.

A sub-analysis was carried out on BMI development according to smoking status. The results confirm the existing knowledge that those who cease to smoke are likely to gain more weight than those that uphold smoking, never smoke or start to smoke (27). A possible source of bias regarding smoking is the possibility of smokers not being honest about their smoking habits. An individual failing to report his/hers smoking habit in T4, would appear to have started smoking during the study period if honest about his/her smoking habit in T6.

4.3.2 Sample size

The cohorts in the cross-sectional analyses all included a large number of people, the exception being two age groups in T5, 35-39 and 50-54, where the number of participants was somewhat low. This had implications for the longitudinal analyses of T4, T5 and T6, where 5-year age groups were combined to achieve larger numbers. Because of this there is less room for robust conclusions regarding the longitudinal development in BMI in some of the age groups. The two longitudinal analyses differ somewhat in their results, and the prime focus of the thesis was laid on the T4-T6 section, since the inclusion criteria in T5 could have had undue influence on the age distribution in the population available for analyses. However, as described in chapter 2, BMI in the complete longitudinal cohort did not differ from the cross-sectional cohort at baseline, which would indicate internal validity and that the results from the complete longitudinal analyses are indeed representative of its underlying population.

4.3.3 Age distribution and selective attrition

In the longitudinal analyses of T4, T5 and T6, participants born before 1925 were excluded. This was because they constituted a small proportion of the birth cohort of 1920-1929, and mean age in this age group was 68.1 even when they were included. These participants differed quite substantially from the 1925-29 group with respect to BMI, and gave a false impression of decline in BMI between T5 and T6. It is likely that this excluded group represents selective attrition, since a substantial number of people at this age in 1994 would have died or suffered illness between surveys. In other words would only the most healthy of those born before 1925 survive until- or be able to attend T6.

Selective attrition is itself an issue regarding the entire longitudinal analysis, and a possible source of bias. The Tromsø Surveys are conducted as a series of cross-sectional studies. In order to investigate BMI increase for a person between two surveys, that person would first of all have to survive the study period, and second he/she would have to show up

for both the first and second survey. It is likely that the ones who die during the study period differ from those that survived, and as such any increase in BMI up to the point they died is not known and not analysed. Analysis of BMI among the elderly is therefore prone to survival bias (46). To assess the degree of survival bias in this thesis, the population of T4 *and* T6 can be compared to T4 with regards to BMI. One might also compare the two populations with regards to socioeconomic status, morbidity, physical activity or nutritional habits, but this is beyond the scope and limits of this particular thesis.

A previous study on selection bias and non-response among participants in Tromsø Survey 2 found that non-respondents differed little from respondents, with the exception of young, unmarried men, which were less likely to respond (47). This study though, investigated differences in characteristics between those that answered a second questionnaire and those that did not, after attending a health screening. In another study undertaken on non-respondents in a large health survey, researchers found that non-respondents generally had higher mortality and were of lower socioeconomic status than respondents (48). In this thesis respondents could not be compared to non-respondents, since the collection of such data would be incomprehensible. The longitudinal cohorts however, could – and was, compared to the population of T4, and it was found that this cohort differed in age distribution but not on the primary variable under analyses, namely BMI.

4.3.4 Desired weight and DBMI

When desired weight is analysed the unit of measurement is commonly kilograms or lbs., as these are the units people report and measure their actual bodyweight in. In this thesis desired BMI was computed and chosen rather than desired weight. This was to assess how obese- or overweight people differed from normal weight individuals in their assessment of ideal weight, and which BMI category the different groups ideally would belong to. Furthermore DBMI, like BMI, enables the researcher to make relative comparisons rather than absolute. A

strength of this method of analysis was the possibility to assess desired weight according to BMI weight categories. A limitation is that people think of neither bodyweight nor desired bodyweight in relation to the concept of BMI, and as such the results would represent theoretical classifications. After all, participants were not asked "would your rather be classified as normal weight, overweight or obese?". Despite this I would not consider the issue a greater flaw than those associated with the concept of BMI in the first place, as BMI too is a theoretical concept.

4.4 Comment

The data on BMI from the three Tromsø Surveys analysed in this thesis has to some extent been analysed and published previously, but not in a longitudinal perspective. Accordingly, the cross sectional results presented here fits well with the previously published results from the same source of data. The data from Tromsø 4 was analysed and published by Jacobsen et. al. in 2001(15), but was included in this thesis to serve as baseline for the subsequent two surveys. The population under analysis from T4 in Jacobsens article differs slightly from the T4 population in this thesis, the reason being that T4 data has been updated as a part of establishing of the entire Tromsø Study database. The cross sectional data on BMI from some selected age groups in T5 was included in a paper by Meyer et. al. in 2005 (49), while some cross-sectional data concerning BMI and WC in T6 was published by Eggen et.al in 2013 (35).

This thesis confirms the BMI pattern observed by Jacobsen, but extends it. It is still the youngest age groups that demonstrate the largest increase. The results from the repeated cross sectional surveys indicate that the largest weight gain takes place between T4 and T5. The inclusion of WC and WHtR to describe the changes in bodily composition in this particular population is new, and so are the analyses of DBMI. The discrepancy between actual BMI and DBMI among the obese and overweight is clear evidence to confirm what

might already be assumed, namely the fact that people with excess body weight are indeed dissatisfied with their weight. The fact that the discrepancy between BMI and DBMI was higher in T6 than T4, suggests that people do not entirely grow accustomed to their increased body weight, and that ambitions with regards to ideal weight to some extent are upheld.

The implications of continuing increase in prevalence of obesity and overweight could be severe. With a continuing increase in prevalence of overweight and obesity, an increase in incidence of diabetes, stroke, and CHD is likely. The different measures used to describe obesity and overweight in this thesis differ somewhat in their ability to predict different diseases. It has been argued that WC is a better predictor of obesity related health risks than BMI (50, 51), and that both BMI and WC are suited predictors of osteoarthritis (52). In turn, WHtR has been suggested as an even better screening tool than both BMI and WC of cardiometabolic risk factors (25), and a better predictor of CVD among children than BMI (53). One might therefore suggest that the measure of bodily composition chosen in any research should depend on the outcome analysed, as well as the population of interest.

Chapter 5. Conclusion

In conclusion I have found that BMI increased in all birth cohorts except the oldest in the population that participated in both T4 and T6. This coincides with an increase in waist circumference and waist-to-hip-ratio across all age groups and both genders, and close to a doubling of obesity prevalence in both genders. Rather worryingly, increase in BMI was highest in the youngest age group of both genders, and relatively higher among women than men. Comparison of BMI according to categories of smoking shows that those who ceased to smoke during the study period had a larger increase in BMI than others. DBMI increased in all birth cohorts and both genders, but the increase was smaller than actual increase in BMI. Difference between BMI and DBMI was higher in T6 than T4 in the longitudinal analyses, indicating that with increase in weight follows an increase in weight dissatisfaction.

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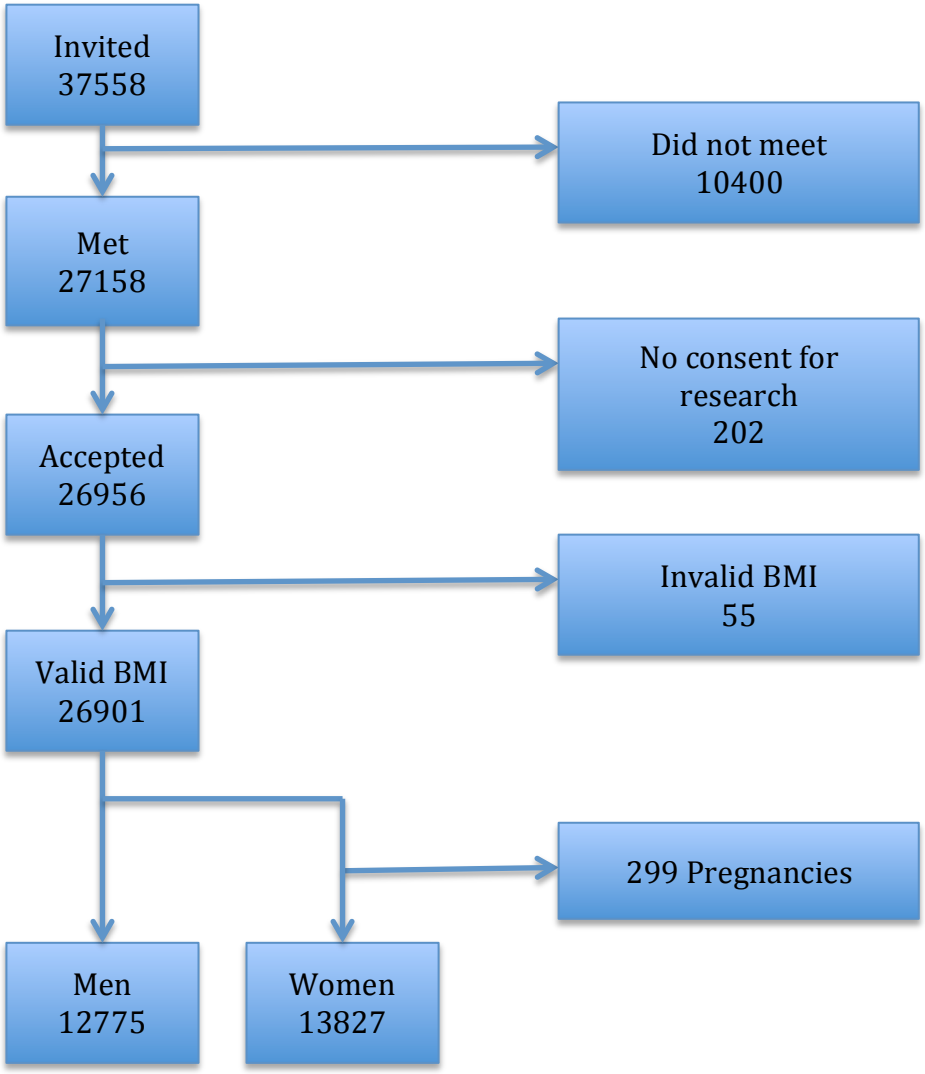
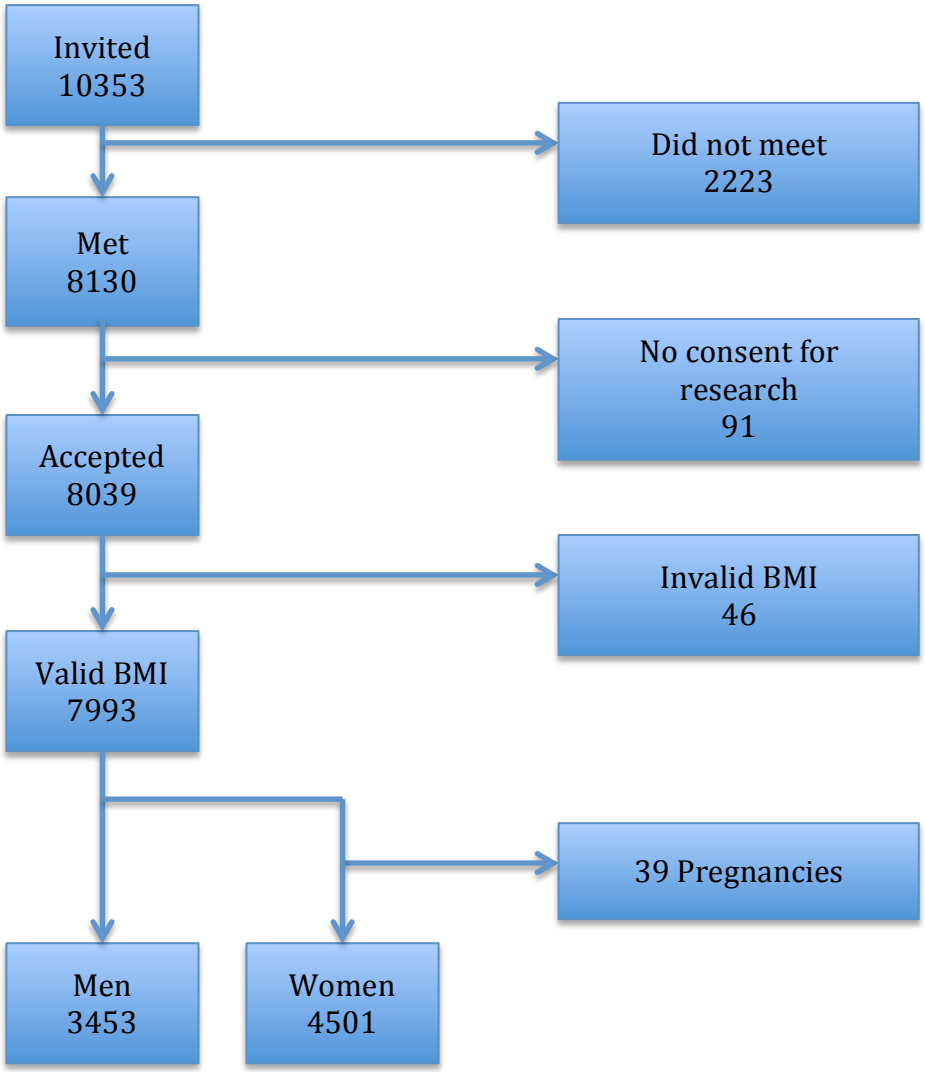
Appendix.

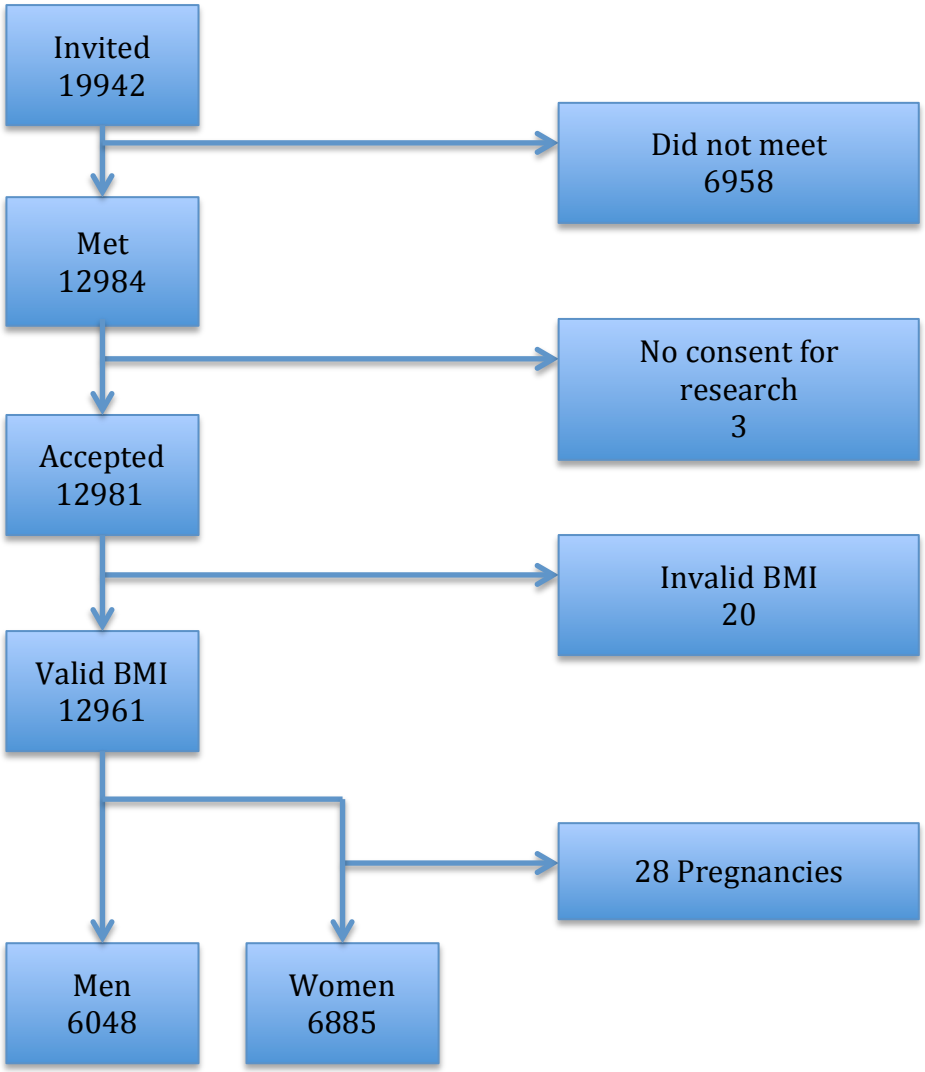
Appendix 1: Flowchart T4



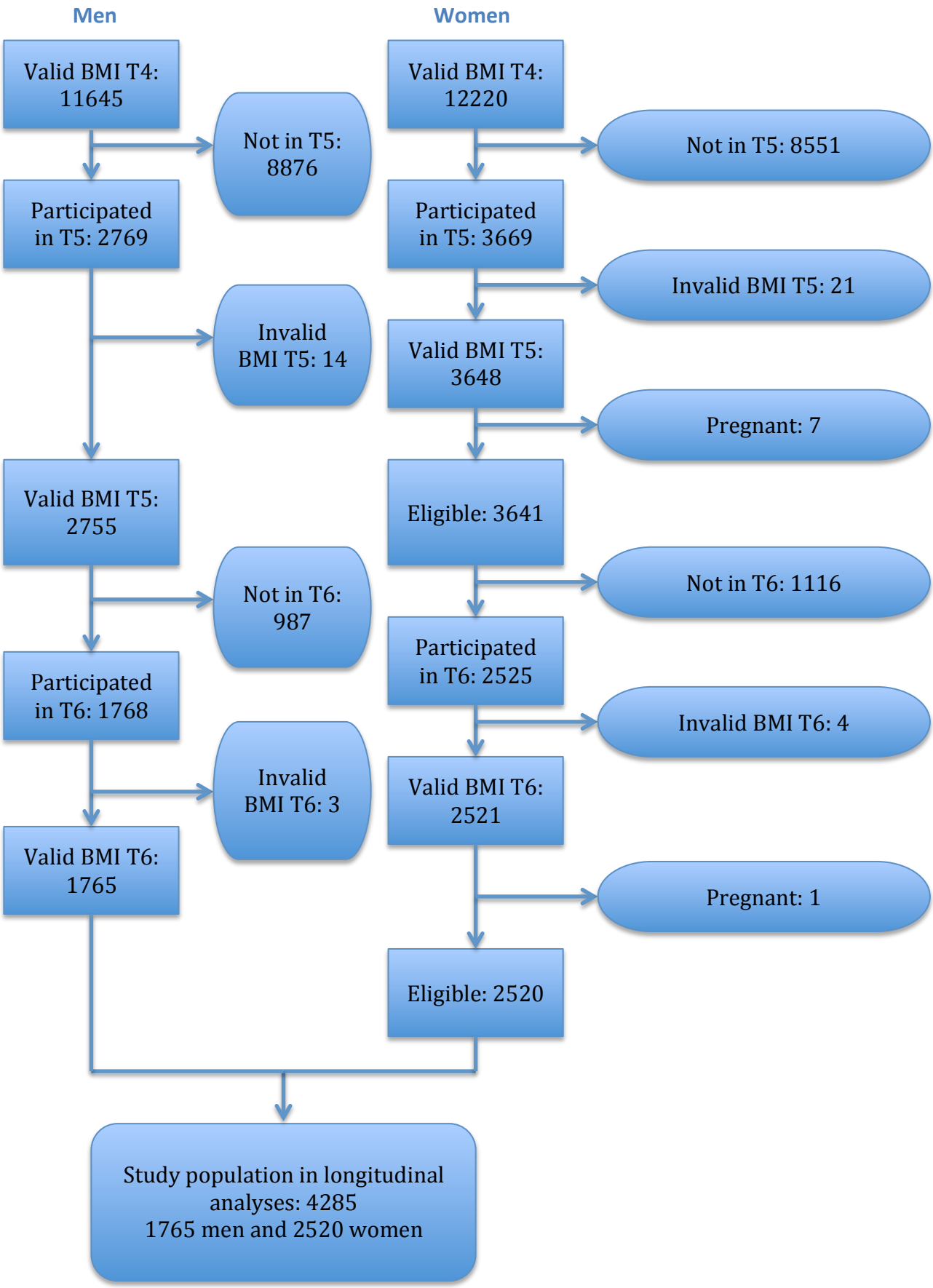
Appendix 2: Flowchart T5



Appendix 3: Flowchart T6

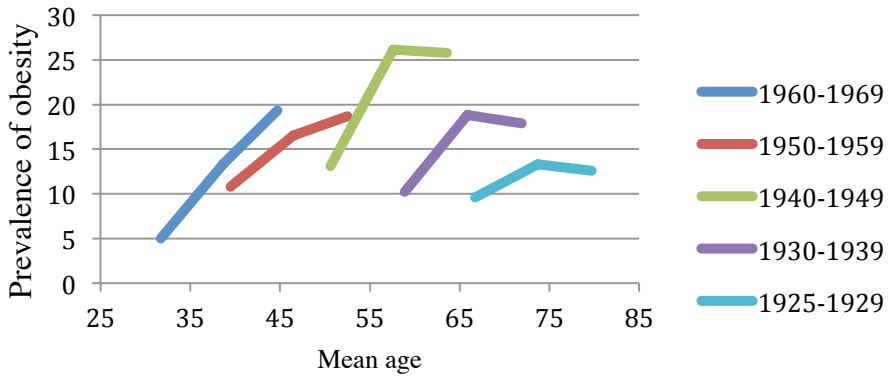


Appendix 4: Flow chart longitudinal analysis, T4, T5 and T6.

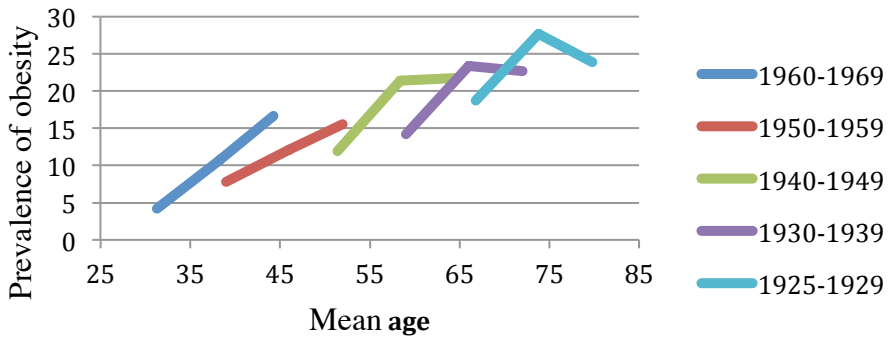


Appendix 5. Longitudinal prevalence of obesity.

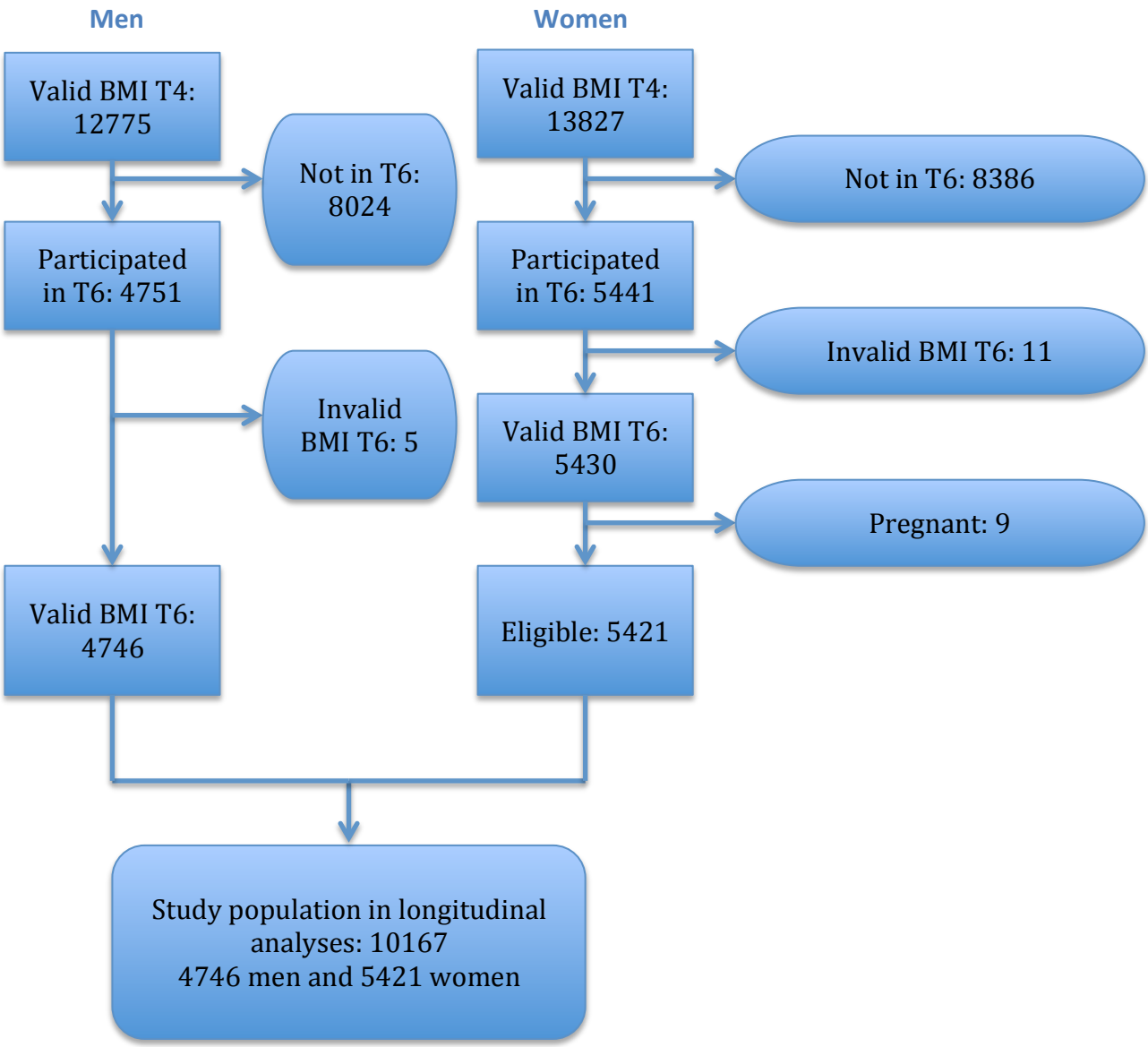
Appendix Figure 1: prevalence (%) of obesity (BMI ≥ 30) among male participants in all surveys T4, T5 and T6 according to 10-year birth cohorts.



Appendix Figure 2: prevalence of obesity (BMI ≥ 30) among female participants in all surveys T4, T5 and T6 according to 10-year birth cohorts.



Appendix 6: Flow chart longitudinal analysis T4 and T6.



Appendix 7: Longitudinal z-scores for waist circumference.

Appendix Table 1: longitudinal analysis of z-scores for waist circumference, with z-scores at surveys T4 and T6 as well as the difference between them, presented according to gender and 10-year birth cohort.

	Men				Women			
Birth cohort	n	Z-score T4	Z-score T6	Diff	n	Z-score T4	Z-score T6	Diff
1960-1969	62	-0.7439	-0.2455	0.4984	76	-0.6757	-0.4701	0.2055
1950-1959	89	-0.4501	-0.2464	0.2038	135	-0.4474	-0.0464	0.4010
1940-1949	326	0.1719	0.1560	-0.0160	158	-0.2924	-0.1287	0.1636
1930-1939	850	0.0201	-0.0078	-0.0280	973	0.0271	0.0156	-0.0115
1920-1929	253	0.0514	-0.0278	-0.0792	409	0.3218	0.1165	-0.2053
Total	1580	0.0	0.0	0.0	1751	0.0	0.0	0.0

Appendix 8. Mean DBMI according to age groups and gender in all three surveys.

Appendix Table 2: Desired BMI (desired weight in kilograms/m^2) in all three cross-sectional surveys, presented according to 5-year age groups and gender.

	T4				T5				T6			
	Men		Women		Men		Women		Men		Women	
Age group	n	DBMI (SD)	n	DBMI (SD)	n	DBMI (SD)	n	DBMI (SD)	n	DBMI (SD)	n	DBMI (SD)
25-29	1183	23.9 (1.8)	1392	21.4 (2.0)	x	x	x	x	x	x	x	x
30-34	1190	23.9 (1.9)	1434	21.5 (1.9)	176	25.0 (2.1)	272	22.3 (2.2)	77	25.0 (2.4)	104	22.8 (2.4)
35-39	1268	24.0 (1.9)	1468	21.7 (1.8)	37	24.2 (1.9)	67	22.7 (2.6)	104	25.3 (2.2)	140	23.0 (2.4)
40-44	1270	24.2 (1.9)	1403	22.0 (1.8)	248	24.7 (1.9)	309	22.5 (2.2)	915	25.1 (2.2)	1113	23.1 (2.4)
45-49	1219	24.6 (2.0)	1354	22.5 (2.0)	240	24.8 (2.0)	299	22.7 (2.1)	499	25.1 (2.0)	522	23.4 (2.4)
50-54	1002	24.8 (2.0)	1017	23.0 (2.1)	126	25.6 (2.0)	88	22.9 (2.3)	447	25.3 (2.0)	554	23.3 (2.3)
55-59	724	24.8 (1.8)	730	23.5 (2.1)	201	25.8 (2.1)	559	23.8 (2.3)	505	25.4 (2.6)	517	23.6 (2.3)
60-64	598	24.7 (1.9)	612	23.7 (2.0)	575	25.4 (2.0)	703	23.9 (2.3)	985	25.5 (2.1)	1044	24.2 (2.4)
65-69	507	24.5 (1.9)	583	25.4 (3.1)	500	25.2 (2.0)	542	24.3 (2.3)	693	25.5 (2.1)	625	24.5 (3.2)
70-74	7	25.4 (2.1)	9	25.4 (3.1)	441	25.0 (2.1)	473	24.7 (2.6)	411	25.4 (2.0)	408	24.7 (2.6)
75-79	3	25.1 (1.7)	x	x	303	25.0 (2.3)	346	25.2 (2.8)	245	24.9 (2.1)	309	24.7 (2.7)
80-89	x	x	x	x	93	25.2 (2.3)	92	25.5 (2.8)	131	25.3 (2.1)	202	25.3 (3.0)
Total	8971	24.3 (1.9)	10002	22.3 (2.2)	2940	25.1 (2.1)	3750	23.8 (2.6)	5012	25.3 (2.2)	5538	23.8 (2.6)

Appendix 9. Desired BMI according to BMI categories in T5 and T6.

Appendix Table 3: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) according to three categories of BMI (kg/m^2) among men in Tromsø 5.

	BMI < 25				BMI 25-25.99				BMI≥30			
Age group	*n*	BMI	Ideal BMI	Diff	n	BMI	Ideal BMI	Diff.	*n*	BMI	Ideal BMI	Diff.
30-34	75	23.2	23.5	-0.3	68	27.0	25.2	1.8	33	32.4	27.9	4.5
35-39	12	22.4	22.4	0.0	22	27.0	24.8	2.2	3	31.9	27.4	4.5
40-44	85	23.3	23.1	0.2	125	27.0	25.0	2.0	38	33.2	27.5	5.7
45-49	74	23.3	22.8	0.5	128	27.1	25.0	2.1	38	33.1	27.5	5.6
50-54	27	23.5	23.5	0.0	67	27.6	25.5	2.1	32	33.2	27.8	5.4
55-59	36	23.7	23.4	0.3	116	27.5	25.6	1.9	49	32.6	28.0	4.6
60-64	136	23.4	23.3	0.1	313	27.4	25.5	1.9	126	32.3	27.5	4.8
65-69	154	23.2	23.3	-0.1	263	27.1	25.5	1.6	83	32.3	27.9	4.4
70-74	146	22.7	23.1	-0.4	228	27.1	25.5	1.6	67	32.0	27.5	4.5
75-79	123	22.8	23.2	-0.4	137	27.2	25.7	1.5	43	31.8	27.7	4.1
80+	35	22.2	23.2	-1.0	42	27.5	26.0	1.5	16	32.1	27.5	4.6
Total	903	23.1	23.2	-0.1	1509	27.2	25.4	1.8	528	32.4	27.7	4.7

Appendix Table 4: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) according to three categories of BMI (kg/m^2) among women in Tromsø 5.

	BMI < 25				BMI 25-25.99				BMI≥30			
Age group	*n*	BMI	Ideal BMI	Diff	n	BMI	Ideal BMI	Diff.	*n*	BMI	Ideal BMI	Diff.
30-34	169	22.2	21.2	1.0	71	26.8	23.3	3.5	32	33.9	25.9	8.0
35-39	39	22.9	21.4	1.5	20	26.7	23.4	3.3	8	34.8	27.7	7.1
40-44	174	22.4	21.3	1.1	99	26.9	23.5	3.4	36	34.3	26.2	8.1
45-49	157	22.5	21.4	1.1	112	27.1	23.9	3.2	30	33.4	25.9	7.5
50-54	47	22.9	21.6	1.3	30	27.0	23.4	3.6	11	33.3	26.8	6.5
55-59	197	22.7	21.8	0.9	228	27.4	24.1	3.3	134	33.8	26.1	7.7
60-64	276	22.7	22.0	0.7	272	27.2	24.4	2.8	155	33.6	26.4	7.2
65-69	188	22.5	22.2	0.3	237	27.4	24.7	2.7	117	33.2	26.8	6.4
70-74	173	22.4	22.3	0.1	182	27.3	25.0	2.3	118	33.4	27.7	5.7
75-79	112	22.3	22.5	-0.2	143	27.4	25.5	1.9	91	33.1	28.1	5.0
80+	24	22.4	22.8	-0.4	41	27.2	25.5	1.7	27	32.0	28.1	3.9
Total	1556	22.5	21.8	0.7	1435	27.2	24.4	2.8	759	33.5	26.9	6.6

Appendix Table 5: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) according to three categories of BMI (kg/m^2) among men in Tromsø 6.

	BMI < 25				BMI 25-29.99				BMI≥30			
Age group	*n*	BMI	Ideal BMI	Diff	n	BMI	Ideal BMI	Diff.	*n*	BMI	Ideal BMI	Diff.
30-34	27	23.3	23.1	0.2	35	27.9	25.0	2.9	15	33.5	28.5	5.0
35-39	23	23.3	23.0	0.3	53	27.3	25.2	2.1	28	32.9	27.6	5.3
40-44	275	23.1	23.1	0.0	440	27.3	25.2	2.1	200	32.9	27.5	5.4
45-49	125	23.3	23.0	0.3	282	27.4	25.3	2.1	92	33.1	27.6	5.5
50-54	114	23.3	23.2	0.1	234	27.3	25.3	2.0	99	33.2	27.5	5.7
55-59	116	23.3	23.0	0.3	273	27.4	25.4	2.0	116	33.0	28.0	5.0
60-64	218	23.3	23.1	0.2	518	27.5	25.5	2.0	249	32.7	27.5	5.2
65-69	163	23.1	23.2	-0.1	367	27.4	25.6	1.8	163	32.6	27.6	5.0
70-74	114	23.0	23.4	-0.4	214	27.3	25.6	1.7	83	32.4	27.6	4.8
75-79	90	23.0	23.2	-0.2	118	27.2	25.4	1.8	37	32.5	27.4	5.1
80+	46	23.1	23.6	-0.5	68	27.6	25.8	1.8	17	32.6	28.1	4.5
Total	1311	23.2	23.2	0.0	2602	27.4	25.4	2.0	1099	32.8	27.6	5.2

Appendix Table 6: Cross-sectional analysis of DBMI (desired bodyweight in kg/m^2) according to three categories of BMI (kg/m^2) among women in Tromsø 6.

	BMI < 25				BMI 25-25.99				BMI≥30			
Age group	*n*	BMI	Ideal BMI	Diff	n	BMI	Ideal BMI	Diff.	*n*	BMI	Ideal BMI	Diff.
30-34	59	22.3	21.3	1.0	29	27.2	23.8	3.4	16	33.0	26.5	6.5
35-39	66	22.4	21.2	1.2	47	27.1	24.0	3,1	27	33.5	25.5	8.0
40-44	514	22.3	21.3	1.0	397	27.1	23.8	3.3	202	34.1	26.4	7.7
45-49	223	22.6	21.5	1.1	185	27.1	23.9	3.2	114	34.1	26.4	7.7
50-54	243	22.6	21.6	1.0	229	27.1	24.1	3.0	82	33.8	26.4	7.4
55-59	223	22.8	21.8	1.0	195	27.2	24.2	3.0	99	33.3	26.3	7.0
60-64	325	22.7	22.0	0.7	468	27.3	24.4	2.9	251	34.0	26.8	7.2
65-69	217	22.6	22.4	0.2	262	27.5	24.8	2.7	146	33.7	27.0	6.7
70-74	135	22.5	22.3	0.2	172	27.6	25.0	2.6	101	33.6	27.4	6.2
75-79	101	21.9	22.0	-0.1	127	27.5	25.3	2.2	81	32.7	27.2	5.5
80+	67	22.0	22.6	-0.6	83	27.4	25.6	1.8	52	32.9	28.2	4.7
Total	2173	22.5	21.7	0.8	2194	27.3	24.4	2.9	1171	33.7	26.7	7.0