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Effect of Weight Loss in Adults on Estimation of Risk Due to Adiposity in a Cohort Study

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Abstract

The effect of overweight and obesity on the risk of fatal disease tends to attenuate with age. To evaluate whether this effect is partly attributable to disease-related weight loss, we examined the prebaseline history of weight loss and diseases associated with weight loss among adults enrolled in a cohort study. We conducted an analysis of 7,855 adult cohort members of the Adventist Health Study (AHS) I who had provided anthropometric data on surveys at baseline and 17 years prior to baseline. Among adults in the recommended range of BMI (19–25 kg/m²) at baseline we found that: (i) the prevalence of prebaseline weight loss of 5 kg/m² from an overweight or obese state was 20.4% and increased with age (12.6% for <65 years; 27.7% for 65–84 years; 36.7% for >85 years) and (ii) prebaseline weight loss of 5 kg/m² from an overweight or obese state was associated with diabetes (odds ratio (OR) = 2.91 95% confidence interval (CI) = (2.16, 3.93)), coronary heart disease (OR = 1.84 95% CI = (1.42, 2.40)), and high blood pressure (OR = 1.51 95% CI = (1.26, 1.82)). During 12 years of follow-up, we found evidence that hazard ratios for adiposity can be confounded by disease-related weight loss. Our findings raise the possibility that prebaseline weight loss can confound the estimation of risk due to adiposity at baseline in a cohort study.

INTRODUCTION

The current US recommendations for body weight identify “healthy weight” as a BMI in the range of 19–25 kg/m² (1). These recommendations are based in part on the findings from prospective studies in which those adults who are overweight (>25–30 kg/m²) or obese (>30 kg/m²) tend to have a higher risk of morbidity and mortality relative to those adults in the range of about 19–25 kg/m².

One controversy about the increased risk observed among adults whose BMI exceeds the recommended range (relative to those in the recommended range) is that in older adults the risk appears to attenuate, sometimes to the point of being protective (2–4). A number of non-causal explanations for this attenuation have been proposed. One very plausible explanation is that when computing risk for overweight or obesity relative to adults of BMI 25 kg/m², a proportion of those 25 kg/m² will be lean due to disease-related weight loss – an effect that will attenuate risk for overweight and obesity (5,6). Moreover, if the prevalence of disease-related weight loss among those subjects increases among the lean elderly, then this effect may be contributing to the apparent attenuation in risk due to higher body mass at older age.

Stevens *et al.* (6), using data from the Atherosclerosis Risk in Communities Study (aged 45–64 years), reported that those who were either ill at baseline or died during early follow-up were more likely to have lost weight to the point that they converted from an obese classification ($>30 \text{ kg/m}^2$) to nonobese ($\leq 30 \text{ kg/m}^2$). Further studies are needed to determine whether this effect is more prominent in older adults.

The aim of the present study was to examine whether the attenuation in risk for overweight ($>25\text{--}30 \text{ kg/m}^2$) or obesity ($>30 \text{ kg/m}^2$) that tends to occur in studies of elderly adults, may be at least partly attributable to confounding by prebaseline weight loss (all weight loss, weight loss from obesity-related disease). We specifically sought to answer the following four questions:

1. Among adults at baseline in a cohort study, does the prevalence of prebaseline weight loss in the overweight or obese increase with age?
2. Among adults at baseline in a cohort study, what specific diseases were associated with prebaseline weight loss in the overweight or obese?
3. Among adults at baseline in a cohort study, what is the effect of excluding prebaseline weight loss of 5 kg/m^2 in the overweight or obese (from $>25 \text{ kg/m}^2$ prebaseline to $19\text{--}25 \text{ kg/m}^2$ at baseline) from a survival analysis that relates baseline BMI to mortality?
4. Among adults at baseline in a cohort study, what is the effect of excluding all adults with prebaseline weight loss of 5 kg/m^2 or more from a survival analysis that relates baseline BMI to mortality?

To address these questions, we used the data from 7,855 adult cohort members of the Adventist Health Study (AHS) (7) for whom anthropometric data were available at baseline and at 17 years before baseline (8,9).

METHODS AND PROCEDURES

Parent cohort

A population of California Seventh-day Adventists was identified by a census taken from households listed on the church membership rosters in 1958 ($n = 57,707$, aged 25 years or older) and in 1974 ($n = 59,081$, aged 25 years or older). The details of each census have been previously described (7,8,10,11). The population identified in the 1958 census was used to enroll subjects into the Adventist Mortality Study (AMS) in 1960 in which 27,530 non-Hispanic white adults completed the American Cancer Society Questionnaire and underwent 26 years of mortality surveillance (1960–1985) (7,8). The population identified in the 1974 census was used to enroll subjects to the AHS in 1976 in which 34,198 non-Hispanic white adults completed a lifestyle questionnaire and underwent 12 years of mortality surveillance (1976–1988) (12).

Final sample

In this study, we used the records from 8,401 AHS cohort members (enrolled in 1976) who had also been enrolled in the AMS cohort 17 years prior. Of these subjects, 7,855 had provided complete reports of height and weight in 1976 during the AHS and in 1960 during the AMS (8,9).

These 7,855 adults of the AHS cohort became the sample for the present study in which each subject provided anthropometric data at baseline (1976) and at 17 years before baseline (1960). The subjects in the sample underwent 12 years of mortality surveillance (1976–1988) by the AHS.

Questionnaires administered at baseline and 17 years before baseline

During baseline data collection in 1976, subjects completed the AHS lifestyle questionnaire that has been previously described (7,13). The questionnaire included items on demographics, dietary intake, anthropometric data, physical activity level, and medication use. In 1960, the sample of AHS cohort members we studied ($n = 7,855$) had also completed (as part of AMS enrollment) a lifestyle questionnaire designed by the that consisted of similar items (10,11,14,15).

For the analysis, height in inches (without shoes), and weight in pounds (in indoor clothing) were obtained from both questionnaires. The validity of the self-reported anthropometric data was tested in a random sample of 118 AHS cohort members (16) in which the correlation between body weights given on the questionnaire administered in 1976 and body weight measured by a dietitian up to one year after questionnaire return was 0.94 for women and 0.96 for men. The correlation between body height given on the questionnaire and body height measured by a dietitian up to one year after questionnaire return was 0.94 for women and 0.96 for men.

For the analysis of baseline data, dietary intake was assessed by a 55-item semi-quantitative food frequency questionnaire that has been described in detail in previous reports (12). In a validity sub-study among 147 cohort members (12,16), the correlation between total meat intake determined from this questionnaire and the corresponding measures from five 24-h recalls was 0.83. A previously described physical activity index was calculated from the response to nine items on vigorous leisure-time or occupational activities. Survey measures of vigorous activity are positively correlated with maximal treadmill time among non-Hispanic white Adventists (17). Additionally, the physical activity index we used is a significant predictor of coronary events (18) in the cohort. Other variables used in the analysis include disease history, alcohol use, education, marital status and, among women, use of hormone replacement therapy.

Statistical analysis

In the sample of AHS cohort members we used their 1976 baseline questionnaire data to compute baseline BMI, and then we used the anthropometric data from their 1960 AMS questionnaire to compute the prevalence of previous overweight ($>25\text{--}30\text{ kg/m}^2$) and previous obesity ($>30\text{ kg/m}^2$). Special emphasis was given to (i) studying the history of overweight/obesity among those 4,201 adults who were in the recommended range ($19\text{--}25\text{ kg/m}^2$) of BMI at baseline, and (ii) studying the history of obesity among 2,510 adults who were overweight ($>25\text{--}30\text{ kg/m}^2$) at baseline.

To determine whether weight loss was associated with disease among adults who were currently in the recommended range of BMI, we conducted a logistic regression analysis with disease status (coronary heart disease, cancer, stroke, high blood pressure, diabetes, asthma) in 1976 as the outcome variable and previous history of overweight or obesity as the independent variables. This analysis was also done to relate weight loss to disease among adults who were overweight at baseline, but had a history of obesity 17 years before baseline.

To test the effect of previous history of overweight and/or obesity on the risk due to overweight and/or obesity, we conducted a survival analysis with all-cause mortality (1976–1988) as the outcome variable. Hazard ratios for overweight and/or obesity were computed relative to the recommended range ($19\text{--}25\text{ kg/m}^2$) from proportional hazard regression with time on study (in months) as the time variable. All models included a continuous variable for age at baseline (1976), and in larger models additional covariates were tested. The model assumption was evaluated by adding product terms for BMI quintile $\times$ time on study and by

examining age-adjusted (by direct standardization) log-log plots of the product limit estimator of the survival function for BMI categories. We also evaluated possible dependency on follow-up time by dividing the 12-year follow-up period into two smaller study periods (years 1–6, 7–12) of approximately equal person-years and determining the BMI-mortality relation for each study period.

RESULTS

In Table 1, we examined the weight history and baseline characteristics of adult cohort members by category of baseline BMI. As previously reported in other analyses (8,9,13), the baseline characteristics of this cohort indicate a low prevalence of cigarette smoking, alcohol use, and animal product consumption. The results on prebaseline weight history and baseline disease in Table 1 are discussed below.

Prevalence of a history of overweight or obesity (17 years prior to baseline)

In Table 1, we found that the prevalence of a history of overweight or obesity ($>25 \text{ kg/m}^2$) 17 years prior to baseline was 10.6% among the underweight ($<19 \text{ kg/m}^2$ at baseline) and 20.4% among adults in the recommended range ($19\text{--}25 \text{ kg/m}^2$ at baseline). Among cohort members who were overweight at baseline, 8.3% had been obese 17 years before baseline.

Thus the findings indicate that 10–20% of the “low baseline BMI” subjects typically used as a “referent category” ($<19 \text{ kg/m}^2$, $19\text{--}25 \text{ kg/m}^2$) when calculating the risk of obesity were once overweight or obese themselves. This trend raises the possibility that some of this weight loss occurring before baseline was due to obesity-related disease. In this context, we note that among cohort members who were underweight at baseline there was a greater prevalence of coronary heart disease, cancer, and stroke.

Relation between history of overweight or obesity (17 years prior to baseline) and age at baseline

We further stratified the analysis of weight history by age at baseline. In Table 2, we found that in those adults who were underweight at baseline, the prevalence of a prebaseline weight loss from an overweight or obese state substantially increased with age to the point that it tripled for the oldest old (21% for >85 years) relative to the younger adults (6% for <65 years). For those adults who were in the recommended range at baseline (Table 2), a similar trend with age occurred where the prevalence of prebaseline weight loss from an overweight or obese state was about threefold higher in the oldest old (37.0% for >85 years) relative to the younger adults (12.6% for <65 years). Also, among those adults who were overweight at baseline (Table 3) the prevalence prebaseline weight loss from a BMI $>30 \text{ kg/m}^2$ was threefold higher for the oldest old relative to the younger adults.

Thus, the findings indicate that in the oldest old, 20–37% of the “low baseline BMI” subjects typically used as a “referent category” ($<19 \text{ kg/m}^2$, $19\text{--}25 \text{ kg/m}^2$) when calculating the risk of obesity or overweight were once overweight or obese themselves. Again, the possibility that weight loss from obesity-related disease is adding an increasing number of lean elderly with co-morbidities to analyses of baseline BMI and mortality needs further examination in the data.

Relation between history of weight loss ($\geq 25 \text{ kg/m}^2$ to lower BMI, $\geq 30 \text{ kg/m}^2$ to lower BMI) and disease at baseline

In Table 4, we conducted a multivariable logistic regression analyses (adjusted for age, sex, ever-smoking) to determine which diseases were associated with weight loss from $>25 \text{ kg/m}^2$ at 17 years before baseline to $19\text{--}25 \text{ kg/m}^2$ at baseline (loss of 5 kg/m^2 by difference in

category medians). We found that adults who lost weight from $>25 \text{ kg/m}^2$ to $19\text{--}25 \text{ kg/m}^2$, were more likely to have been diagnosed with diabetes (odds ratio (OR) = 2.91 95% confidence interval (CI) (2.16, 3.93)), coronary heart disease (OR = 1.84 95% CI (1.42, 2.40)), high blood pressure (OR = 1.51 95% CI (1.26, 1.82)), or asthma (OR = 1.32 95% CI (0.94, 1.87)). In Table 4, we also found that those who lost weight from $>30 \text{ kg/m}^2$ to $19\text{--}25 \text{ kg/m}^2$ were about two times (OR = 1.97 95% CI (0.88, 4.38)) more likely to have been diagnosed with cancer. When considering whether the weight loss (from overweight/obesity) in the adults in the recommended range in Table 4 is due to disease pathology it is also noteworthy that the prevalence of disease in this group tended to increase from age <65 years (coronary heart disease, 6.1%; cancer, 3.9%; stroke, 0%; high blood pressure, 23.1%; diabetes, 8.5%; asthma, 7.6%) to age >65 years (coronary heart disease, 18.9%; cancer, 10.5%; stroke, 6.8%; high blood pressure, 36.6%; diabetes, 14%) for all outcomes but asthma.

We also conducted multivariable analyses (adjusted for age, sex, ever-smoking; not shown in the tables) to determine which diseases were associated with an even larger weight loss from $>25 \text{ kg/m}^2$ at 17 years before baseline to $<19 \text{ kg/m}^2$ at baseline (a loss of 9 kg/m^2 by difference in category medians). Weight loss at this level was associated with greater odds of stroke (OR = 11.55 95% CI (3.06, 43.66)), high blood pressure (OR = 5.20 95% CI (2.42, 11.20)), diabetes (OR = 4.41 95% CI (1.45, 13.47)), and coronary heart disease (OR = 1.86 95% CI (0.78, 4.42)).

We also considered in multivariable analyses (adjusted for age, sex, ever-smoking; not shown in tables) which diseases were associated with loss of weight from obesity ($>30 \text{ kg/m}^2$) at 17 years before baseline to overweight at baseline ($>25\text{--}30 \text{ kg/m}^2$) and found that this type of weight loss was associated with diabetes (OR = 2.60 95% CI (1.70, 3.97)), high blood pressure (OR = 2.07 95% CI (1.51, 2.83)), and stroke (OR = 1.96 95% CI (0.97, 3.96)).

Excluding subjects with prebaseline weight loss from a survival analysis of baseline BMI and mortality

We conducted a survival analysis that related baseline BMI to 12-year risk of mortality among AHS I Cohort members (Table 5). To examine confounding by obesity-related disease, we present in Table 5 an analysis that excludes those adults in of BMI $19\text{--}25 \text{ kg/m}^2$ at baseline who had experienced a prebaseline weight loss of 5 kg/m^2 from an overweight or obese ($>25 \text{ kg/m}^2$) state at 17 years before baseline. To examine confounding by weight loss in all subjects we also present analysis in Table 5 that excludes all subjects with prebaseline weight loss of 5 kg/m^2 or more during the 17 years before baseline.

Among all men and women in Table 5, the age-adjusted findings indicate significant 57–58% increases in risk for obesity relative to $19\text{--}25 \text{ kg/m}^2$; no association was found with overweight in these models. Exclusion of adults who experienced prebaseline weight loss from an obese or overweight state ($>25 \text{ kg/m}^2$ prebaseline to $19\text{--}25 \text{ kg/m}^2$) strengthened the findings for obesity to significant 70–80% increases in risk (relative to $19\text{--}25 \text{ kg/m}^2$) and also revealed a significant 27% increase in risk for overweight (relative to $19\text{--}25 \text{ kg/m}^2$). In age-stratified analyses, this effect was more evident in the elderly (≥ 65 years) than the nonelderly (<65 years). Exclusion of adults indicating any prebaseline weight loss of 5 kg/m^2 or more also strengthened the risk estimates for baseline overweight and obesity, but not to the same extent as the exclusion weight loss following a history of excess adiposity. Multivariable adjustment for other variables (smoking, alcohol, vegetarian status, physical activity) did not alter these results.

To determine the effect aging on these results, we ran models with interaction terms for Categories of BMI (<19 , $19\text{--}25$, $>25\text{--}30$, $>30\text{ kg/m}^2$) $\times$ Age (<65 years, ≥ 65 years). The log likelihood ratio test for these terms indicated a significance for the interaction among women ($P < 0.001$), but not men ($P = 0.70$). We have previously reported such effects indicating a direct relation between BMI and Mortality among men (no interaction with age), and an increased risk for lean women that emerges during menopause (interaction with age among lean women (8,13)). Overall, any evidence of interaction with age does not negate the findings that both overweight and obesity become strong risk factors even among older (age ≥ 65 years) men and women after accounting for weight loss.

DISCUSSION

Our study considered whether prebaseline weight loss is an important confounder of the relation between adiposity and the risk of death in a prospective cohort study. Our key finding is that when we excluded from the survival analysis those adults who experienced prebaseline weight loss from an overweight or obese state ($>25\text{ kg/m}^2$) to $19\text{--}25\text{ kg/m}^2$ at baseline, a significant and stronger risk for both overweight and obesity (relative to $19\text{--}25\text{ kg/m}^2$) became evident for all adults, and was most prominent among older adults (≥ 65 years). We found that the weight loss from $>25\text{ kg/m}^2$ prior to baseline to lower BMI at baseline that confounded the BMI-Mortality relation had the following characteristics: (i) It was associated with higher risk of coronary heart disease, stroke, diabetes, cancer, and asthma (Table 4) (ii) It increased in prevalence (about threefold) among the oldest subjects (Tables 2 and 3).

We note that the technique of excluding “weight loss” from all BMI categories (Table 5) did not identify a strong confounding pathway. This may be due to factors that include but are not limited to the following: (i) our inability to discriminate between intentional and unintentional weight loss, (ii) unintentional weight loss among the overweight and obese represents a different pathology to unintentional weight loss among adults at a BMI of $19\text{--}25$ or <19 , and (iii) weight loss is representing an intermediate in the pathway from obesity to death. Multiple measures of lifestyle variables (diet, physical activity, adiposity) that include reasons for changes (intentional, unintentional(i.e., disease-related)) are needed to further explain the findings.

Confounding due to weight Loss in studies of healthy weight

Taken together, our findings indicate that the use of a single BMI measure to identify a healthy “referent” group (i.e., BMI of $19\text{--}25$) can produce risk estimates for adiposity that are confounded by prebaseline weight loss due to obesity-related disease. When interpreting the magnitude of this confounding, it is important to note that we studied a healthy population with a low prevalence of smoking, alcohol use, and animal products. It may be reasonable to conclude that the prevalence of weight loss due to obesity-related disease may be even greater in the general population. It follows that the magnitude of the confounding due to this weight loss may also be higher. Several prospective studies have shown that exclusion of subjects with weight loss or indicators of weight loss before baseline tends to reveal a higher risk in heavier adults (5,9,19–21). The overall conclusion that weight loss is a confounder has been questioned (22), and needs further study.

Pathophysiology of weight loss among obese and overweight adults

In this study, we found that diabetes, coronary heart disease, stroke, high blood pressure, asthma, or cancer were associated with a weight from $>25\text{ kg/m}^2$ to a lower BMI during a 17 year interval. Is it biologically plausible to assume these associations with weight loss are at least partly attributable to obesity-related disease?

When considering the association between diabetes and weight loss, it is important to note that insulin resistance, a condition that can both precede and manifest in the diabetic state, has been associated with weight loss in a number of studies (23–26). Weight loss in diabetics has been attributed to pathophysiologic mechanisms such as the catabolic effect of hyperinsulinemia (27) or elevated levels of pro-inflammatory cytokines (28,29) that occur in insulin-resistant individuals. The effect of hyperinsulinemia on cytokines activity has been shown to be particularly evident in the elderly where the prevalence of hyperinsulinemia is higher due to an increased prevalence of visceral adiposity in the elderly (30,31). Also, Looker *et al.* (32) have documented a tendency towards weight loss after the diagnosis of diabetes among individuals who were not on medications (sulfonylureas, insulin preparations) that have a weight stabilizing effect (32). Overall, weight loss (likely involuntary) has been shown to be an independent risk factor for mortality among diabetics (23).

Weight variability and adiposity in coronary heart disease patients have been the controversial area due to the reports of higher BMI in these patients being associated with better outcomes—a trend labeled the “the obesity paradox (33)”. Of relevance to our analysis is that a number of studies have attributed the “obesity paradox” to confounding by in which low BMI and involuntary weight loss in coronary heart disease patients are due to higher rates of chronic lung disease, excessive alcohol intake, poor cardiorespiratory fitness, and other comorbidities in them (33,34). The argument for the paradox being confounding is further supported by the considerable data to indicate clear benefits of intentional weight loss in these patients (33,35).

For stroke, Jönsson *et al.* have noted that there is paucity of data on prevalence and indicators (36) of weight loss in stroke survivors. In their study of stroke patients from the Lund Stroke Register, they found that weight loss of >3 kg was associated with a greater severity of disease, eating difficulties, low prealbumin values, and impaired glucose metabolism (36).

In asthma and chronic obstructive pulmonary disease (37), disease-related weight loss, particularly of fat-free mass, is well documented in, and is attributed to pathophysiologic mechanisms such as: (i) oxidative stress in the systemic circulation (37), (ii) bone loss due to long term steroid therapy or physical inactivity (38,39). Similarly, disease-related weight loss in cancer patients is also a well documented effect due to the effects of cachexia such as anorexia due to obstruction of the bowels in *gastrointestinal* cancers (40), hypermetabolism, Elevated Resting Energy Expenditure (41) or substantial loss of adipose tissue and lean body mass observed in cancer cachexia (42) and the acute phase protein response in cancer patients has been related to accelerated weight loss (43).

Lastly, we note that some of the associations between disease states and prebaseline weight loss may be due to a treatment effect where weight loss has been prescribed to overweight/obese individuals with diagnosed disease. Weight loss is commonly part of the therapeutic regimens for diabetes, hypertension, and perhaps coronary heart disease. This may explain some of the correlation between these disease states and previous overweight and obesity depicted in Table 3.

Limitations

Limitations to our analysis of this cohort should be noted. The variation in the hazard ratios in Table 5 (by age) may be attributable to factors other than simply disease-related weight loss. Measurement error in self-reported weight and height is noteworthy, particularly if the error is itself associated with adiposity or age (44). Also, when attempting to extrapolate the hazard ratios from the AHS follow-up (1976–1988) to more recently enrolled cohorts, the possibility of a cohort effect should be considered. When considering our analysis of

diseases associated with weight loss, we note that data were not available for some of the pertinent diseases (i.e., chronic obstructive pulmonary disease). Lastly, it is important to note that this analysis does not represent a comprehensive analysis of the BMI-Mortality relation in this cohort. It is a study in confounding due to disease-related weight loss.

Overall, in this study, we have found evidence in prospective data for a pathway whereby overweight or obese individuals develop obesity-related diseases (i.e., vascular disease, respiratory disease, cancer), lose weight due to the disease, and are classified as being in the “healthy range” of body weights ($< 25 \text{ kg/m}^2$) when enrolled in a cohort study. We found evidence that such confounding is particularly evident in the elderly and, when not controlled, can attenuate the risk ratios for both overweight and obesity in a survival analysis. The findings raise the possibility that prospective studies that use only a single measure of adiposity at baseline can underestimate the hazard of obesity/overweight, particularly in the elderly.

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Table 1

Weight history (17 years before baseline) and selected baseline characteristics of 7,855 cohort members of the Adventist health study I are given by category of baseline BMI

	Underweight (<19 kg/m²) at baseline ($n = 394$)	Recommended range ($19-25$ kg/m²) at baseline ($n = 4,201$)	Overweight (>25 to 30 kg/m²) at baseline ($n = 2,510$)	Obese (>30 kg/m²) at baseline ($n = 750$)
Weight history				
Overweight 17 years before baseline	8.6%	19.3%	61.9%	46.0%
Obese 17 years before baseline	2.0%	1.1%	8.3%	46.1%
Smoking				
Past	10.2%	14.5%	18.7%	17.9%
Current	0.8%	0.7%	0.7%	1.0%
Alcohol use	2.6%	4.0%	5.4%	4.9%
Nonvegetarian (weekly meat intake)	24.9%	32.5%	47.7%	54.9%
Education >12 years	22.4%	25.3%	24.5%	20.1%
Vigorous physical activity	59.2%	64.9%	62.7%	52.0%
Physician visit within last 2 years	12.7%	13%	13%	8.8%
Disease history				
Coronary heart disease	13.8%	7.6%	8.2%	8.6%
Cancer	13.7%	8.5%	7.2%	7.8%
Stroke	4.2%	2.6%	2.3%	3.4%
High blood pressure	23.7%	23.0%	34.4%	53.0%
Diabetes	6.2%	5.6%	7.2%	12.7%
Asthma	7.4%	5.6%	6.9%	10.8%

Table 2

Prevalence of history of overweight/obesity ($>25 \text{ kg/m}^2$ at 17 years before baseline) among adult cohort members who were underweight ($<19 \text{ kg/m}^2$) or in the recommended range of BMI ($19\text{--}25 \text{ kg/m}^2$) at baseline

	Total	Women	Men
Underweight at baseline			
<65 years	6.0% ($n=100$)	2.7% ($n=75$)	16% ($n=25$)
65–<85 years	8.9% ($n=164$)	6.1% ($n=49$)	18.4% ($n=213$)
85 years	21.0% ($n=81$)	22.4% ($n=67$)	14.3% ($n=14$)
Recommended range at baseline			
<65 years	12.6% ($n=2,185$)	7.7% ($n=1,392$)	21.2% ($n=793$)
65–<85 years	27.7% ($n=1,786$)	24.7% ($n=1,164$)	33.4% ($n=622$)
85 years	37.0% ($n=230$)	37.1% ($n=132$)	36.7% ($n=98$)

Table 3

Prevalence of history of obesity ($>30 \text{ kg/m}^2$) among 2,510 adult cohort members who were overweight ($>25\text{--}30 \text{ kg/m}^2$) at baseline

	Total	Women	Men
<65 years	4.8% ($n = 1,429$)	5.0% ($n = 705$)	4.6% ($n = 724$)
65 to <85 years	12.8% ($n = 1,011$)	15.4% ($n = 585$)	9.2% ($n = 426$)
85 years	15.7% ($n = 70$)	18.4% ($n = 49$)	9.5% ($n = 21$)

Table 4

Prevalence and odds ratio of disease associated with weight loss from a BMI of >25 kg/m² measured 17 years before baseline to a BMI of 19–25 kg/m² measured at baseline (loss of 5 kg/m² by difference in category medians)

	<i>n</i>	Disease prevalence	Disease OR ^a	95% CI
Coronary heart disease				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	750	14.0%	1.75	(1.34, 2.30)
Obesity (>30 kg/m ²) at 17 years before baseline	40	25.0%	4.00	(1.81, 8.82)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	790	14.7%	1.84	(1.42, 2.40)
Cancer				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	738	7.6%	0.74	(0.54, 1.02)
Obesity (>30 kg/m ²) at 17 years before baseline	42	21.4%	1.97	(0.88, 4.38)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	780	8.3%	0.81	(0.60, 1.09)
Stroke				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	732	4.5%	1.32	(0.84, 2.07)
Obesity (>30 kg/m ²) at 17 years before baseline	39	5.1%	1.49	(0.34, 6.57)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	771	4.5%	1.33	(0.85, 2.07)
High blood pressure				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	769	31.5%	1.47	(1.22, 1.78)
Obesity (>30 kg/m ²) at 17 years before baseline	42	45.2%	2.24	(1.16, 4.31)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	811	32.2%	1.51	(1.26, 1.82)
Diabetes				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	744	11.2%	2.60	(1.90, 3.55)
Obesity (>30 kg/m ²) at 17 years before baseline	41	31.7%	10.10	(4.96, 20.53)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	785	12.2%	2.91	(2.16, 3.93)
Asthma				
Overweight (>25 – 30 kg/m ²) at 17 years before baseline	759	6.2%	1.30	(0.92, 1.86)
Obesity (>30 kg/m ²) at 17 years before baseline	40	7.5%	1.66	(0.50, 5.50)
Overweight or obesity (>25 kg/m ²) at 17 years before baseline	799	6.3%	1.32	(0.94, 1.87)

CI, confidence interval; OR, odds ratio.

^aLogistic regression model with disease as the outcome variable, previous overweight or obesity as the exposure variable, and covariates for age, gender, and ever-smoker. Referent category in adults is the recommended range of BMI with no previous of overweight or obesity (i.e., 17 years prior to baseline).

Table 5

Age-adjusted hazard ratios (hr) relating overweight ($>25-30$ kg/m²) and obesity (>30 kg/m²) to all-cause mortality are computed relative to the recommended range of weight ($19-25$ kg/m²) in analyses of 7,855 ahs cohort members that also consider biases due to weight loss in adults in the recommended range and weight loss among all adults

	All			Excluding those adults in the recommended range at baseline who had been overweight or obese 17 years before baseline ^a			Excluding all adults who lost 5 kg/m ² or more during the 17 years prior to baseline		
	HR (95% CI)	n	Deaths	HR (95% CI)	n	Deaths	HR (95% CI)	n	Deaths
All women									
>25-30 kg/m ²	1.12 (0.98, 1.27)	1,339	322	1.21 (1.05, 1.39)	1,339	322	1.15 (1.00, 1.33)	1,301	302
>30 kg/m ²	1.57 (1.30, 1.89)	530	138	1.70 (1.40, 2.06)	530	138	1.62 (1.34, 1.96)	520	133
Women <65 years									
>25-30 kg/m ²	0.90 (0.63, 1.28)	705	45	0.94 (0.65, 1.36)	705	45	0.91 (0.62, 1.32)	670	41
>30 kg/m ²	2.19 (1.53, 3.14)	320	44	2.32 (1.61, 3.35)	320	44	2.32 (1.60, 3.35)	320	44
Women >65 years									
>25-30 kg/m ²	1.17 (1.02, 1.35)	634	277	1.27 (1.09, 1.49)	634	277	1.21 (1.04, 1.41)	603	257
>30 kg/m ²	1.40 (1.13, 1.75)	210	94	1.53 (1.22, 1.92)	210	94	1.46 (1.17, 1.83)	205	91
All men									
>25-30 kg/m ²	1.11 (0.95, 1.29)	1,171	266	1.27 (1.06, 1.50)	1,171	266	1.14 (0.97, 1.33)	1,130	255
>30 kg/m ²	1.58 (1.17, 2.12)	220	50	1.80 (1.32, 2.45)	220	50	1.62 (1.20, 2.19)	219	49
Men <65 years									
>25-30 kg/m ²	1.20 (0.84, 1.71)	724	62	1.27 (0.86, 1.87)	724	62	1.23 (0.83, 1.82)	691	57
>30 kg/m ²	1.82 (1.10, 3.03)	161	20	1.93 (1.13, 3.27)	161	20	1.93 (1.13, 3.27)	161	20
Men >65 years									
>25-30 kg/m ²	1.08 (0.91, 1.29)	447	204	1.27 (1.04, 1.53)	447	204	1.12 (0.93, 1.34)	438	198
>30 kg/m ²	1.48 (1.02, 2.16)	59	30	1.74 (1.19, 2.56)	59	30	1.52 (1.04, 2.23)	58	29

^aWeight loss from >25 kg/m² at 17 years before baseline to $19-25$ kg/m² at baseline (a loss of 5 kg/m² by difference in category medians).