International Journal of Obesity (2004) 28, 1365–1373

0307-0565/04 $30.00
www.nature.com/ijo

PAPER

Effects of weight gain on medical care costs

PJ Elmer[1], JB Brown[1]*, GA Nichols[1] and G Oster[2]

[1]Center for Health Research, Kaiser Permanente Northwest, Portland, OR, USA; and [2]Policy Analysis Inc., Brookline, MA, USA

OBJECTIVE: To examine in middle-aged adults the effect of medical care costs of large, rapid weight gain compared to weight maintenance.
DESIGN: Retrospective cohort study for a 3-y time period.
SETTING AND PARTICIPANTS: Population-based sample ($N = 15174$) of men and women members of a large managed care organization, aged 35–65 y, with a body mass index (BMI) $>25\,kg/m^2$ at baseline. Health-care utilization and costs were measured at baseline and over the 3-y follow-up period.
RESULTS: Mean age at baseline was 49.7 y and mean BMI was $31.5\,kg/m^2$. During the 3-y follow-up period, 40.8% were classified as weight maintainers (± 4 pounds), 45.3% gained 5–19 pounds, and 13.9% gained ≥ 20 pounds. A weight gain of ≥ 20 pounds was significantly associated with increased total medical care costs in all subgroups evaluated. Among all subjects, for those who gained ≥ 20 pounds compared to those who maintained weight, the adjusted 3-y increase in costs was $561. Among the subgroup with baseline comorbidities, the adjusted 3-y change in total medical care costs was $711. Multivariate analyses showed no significant differences between those who gained 5–19 pounds and those who maintained weight. Baseline BMI and comorbidities were also significant predictors of change in medical care costs, independent of weight gain.
CONCLUSION: A large 3-y weight gain (≥ 20 lb) in middle-aged overweight and obese adults is associated with a correspondingly larger increase in total medical care costs compared to weight maintainers. The prevention of large weight gains holds promise for significantly reducing future medical care costs. Future studies should examine the causes of rapid weight gain and evaluate approaches to prevent and reverse such weight gain.
International Journal of Obesity (2004) **28,** 1365–1373. doi:10.1038/sj.ijo.0802774
Published online 31 August 2004

Keywords: medical care costs; BMI; weight gain

Introduction

The prevalence of overweight and obesity has been growing at an alarming rate in the US in recent years.[1,2] More than 60% of US adults are either overweight (body mass index (BMI) $>25\,kg/m^2$) or obese (BMI $>30\,kg/m^2$).[1,3,4] Furthermore, the prevalence of severe obesity (BMI $>40\,kg/m^2$) has increased by nearly 200% since 1990.[1,2,5]

The health consequences of this trend are potentially staggering.[6,7] Overweight and obesity are leading causes of preventable morbidity and mortality.[8] Excess body weight is an important risk factor for coronary heart disease (CHD); hypertension; hyperlipidemia; type 2 diabetes; left ventricular hypertrophy; colon, endometrial, and postmenopausal breast cancer; and musculoskeletal disorders.[6,9,10] Obesity is also related to a host of other chronic debilitating conditions, including sleep apnea, asthma, and other breathing problems; complications of pregnancy; and depression.[11]

Weight gain is associated with adverse changes in blood lipids, insulin, glucose, and blood pressure,[12,13] as well as worsening of other chronic conditions. Even modest increases in body weight are associated with significant increases in chronic disease risk. A weight gain of 10–20 pounds is associated with a 1.25 relative risk of heart disease in women and a 1.65 relative risk in men.[14,15] A gain of 20–40 pounds increases the risk of CHD even more dramatically, by 1.75 for women and 2.65 for men.[14,15] A weight gain of 11–18 pounds doubles the risk of developing type 2 diabetes relative to persons who maintain their weight, while those who gain 40 pounds or more have a fourfold higher risk of developing this disease.[1,16]

The economic consequences of obesity are enormous in terms of both direct and indirect costs, and these costs are rising as the prevalence of obesity increases.[17–19] In 1995, the

*Correspondence: Dr JB Brown, Center for Health Research, Kaiser Permanente Northwest, 3800 N. Interstate Avenue, Portland, OR 97227-1110, USA.
E-mail: jonathan.brown@kpchr.org
Received 13 May 2003; revised 8 February 2004; accepted 8 February 2004; published online 31 August 2004

total costs attributable to obesity were estimated at $99 billion and by 2000 had risen to $117 billion.[7,20,21] Obesity has also been shown to be predictive of higher future health-care costs, especially among those with BMI > 30 kg/m^2.[22–24]

With more than half the adult population now overweight or obese, implementing recommendations to reduce obesity will be expensive. For these reasons, in this study, we evaluated the impact of rapid weight gain (*vs* weight maintenance) on health-care utilization and costs in middle-aged adults who were classified as overweight or obese. Here, we consider two main questions in overweight and obese individuals: (1) what is the relationship between large, rapid weight gain over a 3-y period and change in health-care costs and (2) does this relationship depend on baseline comorbidities or BMI. Few, if any, studies have evaluated the costs associated with weight gain in either the short term or long term. Understanding the costs of weight gain may help health systems develop and prioritize obesity treatment and prevention initiatives.[7,21] Preventing obesity and helping individuals who are already obese maintain weight by preventing further weight gain are two key strategies for addressing the national obesity epidemic.[25] For these reasons, in this study, we evaluated the impact of rapid weight gain (*vs* weight maintenance) on health-care utilization and costs in middle-aged adults who were classified as overweight or obese.

Methods

Study design

Using a retrospective cohort study design, we examined the relationship between weight gain (*vs* weight maintenance) and medical care utilization and costs over a 3-y period (1996–1999). Study subjects were members of Kaiser Permanente, Northwest Division (KPNW), a long-established, not-for-profit, group-model health maintenance organization that provides comprehensive, prepaid coverage to about 20% of the population in the greater Portland, Oregon, metropolitan area (or about 400 000 persons during the period of study). Our economic perspective was that of the health plan. Thus, we did not ascertain the use of medical services for which the health plan did not pay. Demographically, subscribers resemble the area population as a whole.[26]

All members of KPNW have access to a complete range of clinical services. The organization maintains electronic databases containing comprehensive information on membership, outpatient visits, inpatient admissions, pharmacy dispenses, laboratory tests, and outside claims and referrals. All of these databases are linked through a unique health record number that is assigned to each member at the time of initial enrollment in the health plan. Height and weight are part of the electronic medical record. Weight is routinely measured at most ambulatory care visits on digital scales (which are calibrated biannually). Height is an optional data field and is not available for all members. Age and gender were obtained from health plan membership records.

Study population

We identified all KPNW members aged 35–64 y in 1996 who had full health plan eligibility in both 1996 and 1999 ($n = 114\,139$) (Figure 1). We excluded 14 098 persons who, any time between 1996 and 1999, had an ambulatory visit or inpatient discharge diagnosis of cancer, AIDS, eating disorders, end-stage renal disease (ESRD) or kidney dialysis, chronic obstructive pulmonary disease (COPD), emphysema, congestive heart failure, stroke, or pregnancy (see Appendix A1 for the list of ICD-9-CM codes). We then excluded all persons (72.7%) who did not have weight measurements for both 1996 and 1999 ($n = 49\,673$) and an electronically recorded measurement of height (thereby permitting calculation of BMI) ($n = 23\,034$). These exclusions fell more heavily on persons without arthritis, asthma, depression, diabetes, heart disease, hypertension or hyperlipidemia at baseline (78.4% excluded) than on those with one or more of these diseases (52.9% excluded).

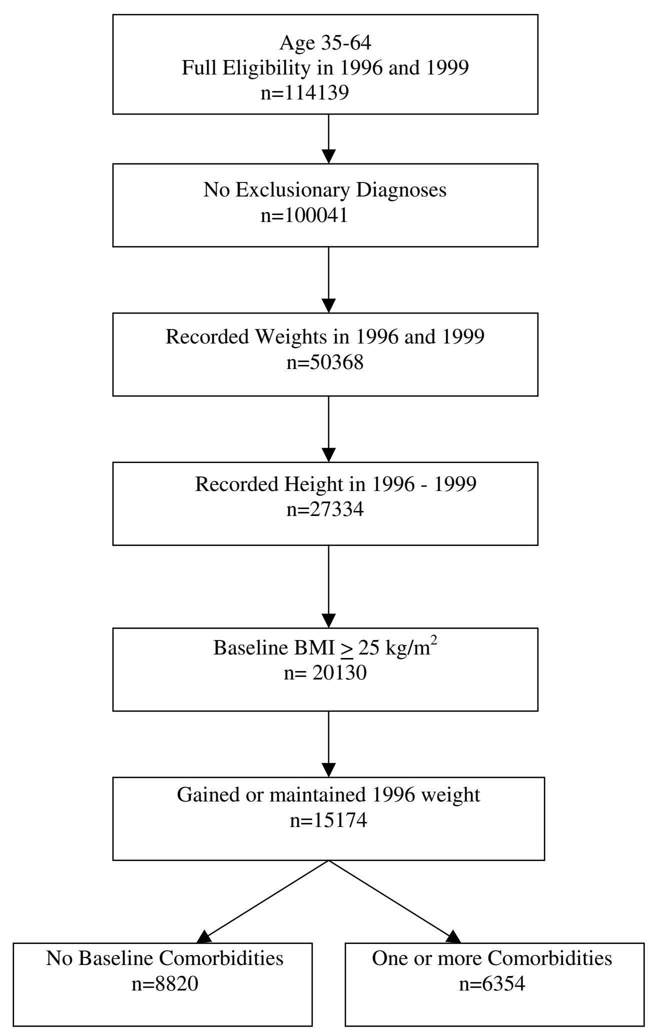

Figure 1 Population selection.

We next restricted the population to those who had a BMI $\geq 25\,kg/m^2$ at baseline. Finally, since our interest was in the relationship between weight gain (*vs* weight maintenance) and future health-care utilization and costs, we excluded all persons whose body weight in 1999 was less than that in 1996 ($n = 4956$). Figure 1 shows the number of persons remaining after application of each of these exclusion criteria. The final study sample contained 15 174 persons.

Utilization data and costs

For each study subject, we obtained all information over the 3-y study period (1997–1999) on: (1) ambulatory visits to primary care, specialty care, and emergency department clinicians; (2) admissions to acute-care hospitals; (3) pharmaceuticals and supplies dispensed by KPNW outpatient pharmacies; and (4) ambulatory services provided by non-KPNW professionals and institutions. Our economic perspective was that of the health plan. Thus, we did not attempt to ascertain the use of medical services for which the health plan did not pay.

Unit costs were assigned to measures of utilization using methods described previously.[27,28] For services provided in hospitals owned by KPNW, inpatient costs were estimated from the HMO's annual Medicare Cost Report. For outpatient visits to KPNW clinicians, we used cost coefficients obtained by an internal 1993 study that estimated aggregate visit costs based on salaries by specialty, clinician type (MD, physician assistant, or nurse practitioner), minutes per visit by specialty, overhead costs per specialty, and per-visit cost of laboratory services per specialty. To calculate visit costs, we multiplied the relevant coefficient by the total number of visits of that type. We based the costs of services provided by outside providers, including non-KPNW hospitals, on the amount actually paid to these vendors. We calculated the costs of drugs and related supplies at the retail cost of each compound and dosage, as of the date of purchase. All costs are expressed in 1999 dollars, based on the US Medical Price Index.[29]

Analytic methods

The primary outcome measure of interest was the change in annual medical care costs (in constant 1999 dollars) between 1996 and 1999. Our primary predictor of change in medical care costs was body weight change over this period. We categorized subjects into those who gained 20 or more pounds (high weight gain), those who gained 5–19 pounds (moderate weight gain), and those who maintained their weight within ± 4 pounds. These categories were chosen to provide a reasonable distribution of cell sizes across the categories and to reflect meaningful categories of weight change from a clinical and public health perspective.[9,16,30] Increases in body weight in the range of 5–19 and >20 lbs have been shown to have a clinically meaningful impact on conditions such as CHD, hypertension, hyperlipidemia, and diabetes, and on the pain and immobility associated with arthritis.[9,16,31,32]

We first studied bivariate associations between weight change and changes in medical service utilization and medical care cost, both in the aggregate and by categories of care (pharmacy, inpatient, and outpatient). We also crosstabulated changes in cost by initial BMI and weight-change category. In these analyses, we used either Pearson's χ^2 test or Fisher's least-significant-difference test to rule out chance associations.

To obtain adjusted estimates of the relation of weight gain to cost growth, we estimated two multivariate ordinary-least-squares regression models. In both models, the dependent variable was change in annual cost, and our three weight-change categories were specified as two dummy variables, using weight maintainers as the reference group. In Model 1, we included age, gender, baseline weight, and baseline costs as covariates. In regression Model 2, we also added comorbidities present at baseline (asthma, diabetes, hyperlipidemia, arthritis, hypertension, ischemic heart disease, and depression) as additional covariates. Baseline comorbidities were ascertained from KPNW's electronic medical records for the year 1996 using the ICD-9-CM codes listed in Appendix A1. Of the 15 174 person study sample, 6354 had at least one baseline comorbidity.

Model 1 was estimated for three groups of study subjects: (1) those with baseline comorbidities, (2) those without baseline comorbidities, and (3) both groups combined. Model 2 was estimated for groups 1 and 3.

Statistical analyses were performed using SAS Version 6.12 (SAS Institute, Cary, NC, USA).

Results

Baseline population characteristics

The study population consisted of 15174 persons (Table 1). The mean age at baseline was 49.7 y, and 58.2% of study subjects were women. The mean BMI in 1996 was $31.5\,kg/m^2$; 50.2% had a BMI ≥ 25 and $<30\,kg/m^2$, and 8.2% had a BMI $>40\,kg/m^2$. Between 1996 and 1999, 13.9% of the population gained ≥ 20 lbs, 45.3% gained 5–19 lbs, and 40.8% maintained their weight within ± 4 lbs. Persons who gained ≥ 20 lbs were younger and more likely to have been obese (BMI $>30\,kg/m^2$) at baseline.

Descriptive results (bivariate analyses)

Table 2 describes 3-y changes in medical care utilization (per 1000 persons) by weight-change group. Pharmaceutical dispenses increased for all weight-change categories, but grew twice as much in the group that gained ≥ 20 pounds compared to those who maintained their weight. While primary care visits decreased across all weight-change groups, specialty care visits increased about equally for all groups. Hospital admissions decreased overall, with no

Table 1 Characteristics of study population, in total and by weight change status

	Gained 20+ lbs	*Gained 5–19 lbs*	*Maintained*	*Total*
Number of subjects (*N*)	2116	6868	6190	15 174
Percent of subjects	13.9	45.3	40.8	100.0
Age category[a] *(y)*				
35–44	38.2%	28.0%	24.2%	27.9%
45–54	41.9%	43.1%	41.1%	42.1%
55–64	19.9%	28.9%	34.8%	30.0%
Mean baseline age[a] (y)	47.5	49.6	50.7	49.7
Gender[a]				
Male	35.6%	41.7%	44.0%	41.8%
Female	64.4%	58.3%	56.0%	58.2%
Baseline BMI category[a] *(kg/m^2)*				
25.0–29.9	35.8%	51.3%	54.0%	50.2%
30.0–34.9	30.0%	29.1%	27.7%	28.7%
35.0–39.9	18.6%	12.3%	11.6%	12.9%
40.0+	15.6%	7.3%	6.7%	8.2%
Mean baseline BMI[b] (kg/m^2)	33.5	31.2	31.0	31.5
Mean baseline body weight[a] (lbs)	212	197	194	198

[a]Columns are significantly different, $P<0.001$. [b]Columns are significantly different, $P<0.001$ except 'Gained 5–19 lbs' and 'Maintained' where $P<0.01$.

Table 2 Mean (s.e.m.) at baseline and follow-up, and change in medical care utilization (per 1000 subjects) over 3 y, by weight change status

	Gained 20+ lbs	*Gained 5–19 lbs*	*Maintained*	*Total*
Baseline				
1996 Utilization				
Dispenses/1000[a]	17205 (445)	13154 (189)	12525 (192)	13462 (132)
Visits/1000				
Primary care[a]	3617 (70)	3118 (33)	3018 (33)	3147 (22)
Specialty care[a]	7942 (204)	6356 (90)	6295 (97)	6552 (63)
Total visits[a]	11560 (238)	9474 (105)	9313 (111)	9699 (74)
Admissions/1000[b]	60 (6)	42 (3)	32 (3)	40 (2)
1999 Utilization				
Dispenses/1000[a]	24155 (560)	17812 (243)	16516 (232)	18168 (166)
Visits/1000				
Primary care[a]	3411 (60)	2861 (28)	2812 (29)	2918 (19)
Specialty care[a]	8759 (206)	7347 (99)	7319 (104)	7533 (68)
Total visits[a]	12170 (234)	10208 (112)	10132 (117)	10451 (77)
Admissions/1000[b]	38 (5)	27 (2)	27 (2)	29 (2)
Change in utilization[c]				
Dispenses/1000	**6950 (359)**	**4658 (155)**	**3991 (143)**	**4706 (104)**
Visits/1000				
Primary care	**−206 (69)**	**−257 (33)**	**−206 (35)**	**−229 (23)**
Specialty care	**817 (225)**	**991 (107)**	**1,024 (108)**	**981 (73)**
Total visits	**610 (247)**	**734 (118)**	**819 (119)**	**752 (80)**
Admissions/1000	**−22 (8)**	**−15 (4)**	−5 (3)	**−11 (2)**

[a]Columns are significantly different, $P<0.001$. [b]Columns are significantly different, $P<0.05$. [c]Bolded figures are significantly different from zero within weight change groups, $P<0.01$.

statistically significant differences across weight-change categories.

Total medical care costs increased by $336 per person between 1996 and 1999 (Table 3). Pharmaceutical costs increased the most among those who gained the most weight, but outpatient and inpatient costs changed inversely with weight gain. As a result, in these unadjusted data, total medical care costs increased more among those who maintained their weight ($434) than among those experiencing a moderate ($261) or large ($286) weight gain.

We also examined the effect of baseline BMI category on the relationship between weight change and change in

Table 3 Mean (s.e.m.) at baseline and follow-up, and change in medical care costs (per person) over 3 y, by weight change status

	Gained 20+ lbs	*Gained 5–19 lbs*	*Maintained*	*Total*
Baseline				
1996 Costs ($1999)				
Pharmacy[a]	$667 (24)	$502 (13)	$462 (10)	$509 (8)
Outpatient[a]	$1788 (40)	$1440 (17)	$1406 (18)	$1475 (12)
Inpatient[a]	$995 (92)	$627 (43)	$498 (38)	$625 (28)
Total[a]	$3450 (119)	$2569 (54)	$2366 (50)	$2609 (36)
1999 Costs ($1999)				
Pharmacy[a]	$1108 (36)	$752 (15)	$688 (15)	$776 (11)
Outpatient[a]	$1821 (39)	$1522 (18)	$1518 (18)	$1562 (12)
Inpatient[a]	$807 (80)	$556 (34)	$594 (37)	$607 (24)
Total[a]	$3736 (114)	$2830 (49)	$2800 (50)	$2945 (34)
Change in costs ($1999)[b]				
Pharmacy[a]	**$441 (27)**	**$250 (12)**	**$226 (11)**	**$267 (8)**
Outpatient	$33 (41)	**$82 (19)**	**$112 (20)**	**$87 (13)**
Inpatient[c]	−$188 (118)	−$71 (53)	$96 (52)	−$18 (36)
Total	**$286 (140)**	**$261 (63)**	**$434 (61)**	**$336 (43)**

[a]Columns are significantly different, $P<0.001$. [b]Bolded figures are significantly different from zero within weight change groups, $P<0.001$, except total costs for the total population, where $P<0.05$. [c]Columns are significantly different, $P<0.05$.

health-care costs. At baseline, per-person total costs increased with increasing BMI category (25–29.9, 30–34.9, 35–39.9, 40+) kg/m^2 by $2317, $2643, $3047, and $3586 respectively. Changes in 3-y costs were also positively associated with baseline BMI, except for persons with BMIs greater than 40 kg/m^2 ($294, $369, $460, and $276 respectively).

Adjusted results (multivariate analyses)

The multivariate analyses are displayed in Table 4. The first set of models, Models 1A–C, included age, gender, baseline BMI, and baseline costs, along with weight-change category. A second set of models, Models 2A and 2C, added seven comorbidities present at baseline. We performed analyses for three population groups: the total study sample, persons without comorbidities at baseline, and persons with baseline comorbidities. In contrast to the bivariate analyses, the multivariate analyses (Models 1 and 2) showed a large and statistically significant association between weight gain and cost increase for persons who gained 20 or more pounds. In the full model (Model 2A), over the 3-y period those who had large weight gain incurred $561 more in medical costs than weight maintainers. When only persons with baseline comorbidities were included in the analyses (Model 2C), those who had large weight gain incurred $711 more in medical costs than weight maintainers. Multivariate analyses revealed no significant difference in costs for persons with moderate increases in weight compared with weight maintainers. Adjusted R^2 for the models ranged between 0.41 and 0.49, except for Model 1C (adjusted $R^2 = 0.28$).

Each of the baseline comorbidities showed strong and significant associations with increases in cost. In the full model estimated on all study subjects (Model 2A), baseline diabetes predicted the greatest amount of cost increase ($1379), followed by depression ($1119) and asthma ($1117). Although, individually, baseline ischemic heart disease, hypertension, and hyperlipidemia were not strong predictors of change in costs, in the aggregate these cardiovascular variables accounted for $1243 in new costs.

Age and gender were significant predictors of change in costs only for individuals without baseline comorbidities. Baseline BMI was a significant predictor of 3-y change in total costs for all individuals (those with and without baseline comorbidities). In the fully adjusted model (2A and 2C), baseline BMI was associated with $30 of cost increase per unit of BMI. This result is equivalent to a $450-dollar cost increase between a baseline BMI of 25 kg/m^2 and a baseline BMI of 40 kg/m^2. No interaction between baseline BMI and a ≥20-pound weight gain was observed (data not shown), which suggests that baseline BMI and postbaseline weight gain are separately and independently associated with a 3-y increase in costs. The addition of baseline comorbidities in the full model (2A and 2C) reduced the coefficients for age, baseline BMI, and gender, while the adjusted R^2 increased only slightly.

Baseline costs were significantly and negatively associated with 1996–1999 changes in cost.

Discussion

We analyzed the effect of weight gain versus weight maintenance over a 3-y period on changes in medical care utilization and costs among middle-aged members of a large managed care organization who were overweight or obese at baseline. We categorized the population according to whether they maintained their body weight, gained between 5 and 19 lbs, or gained ≥20 lbs over the 3-y study period.

Table 4 Multivariate analyses of change in costs

(a) Model 1: Without baseline comorbidities

	Model 1A, all subjects (n = *15174;* R^2 = *0.41)*			*Model 1B, no baseline comorbities* (n = *8820;* R^2 = *0.28)*			*Model 1C, one or more baseline comorbidites,* (n = *6354;* R^2 = *0.48)*		
Variable	*Parameter estimate*	*Standard error*	*P-value*	*Parameter estimate*	*Standard error*	*P-value*	*Parameter estimate*	*Standard error*	*P-value*
Intercept	−$778	$296	0.009	−$219	$326	0.502	$1245	$575	0.030
Baseline age (y)	$26	$4	0.001	$20	$5	0.001	$4	$8	0.589
Female gender	$167	$67	0.013	$213	$71	0.003	$56	$127	0.657
Baseline BMI (kg/m^2)	$51	$6	0.001	$29	$7	0.001	$46	$11	0.001
Baseline costs ($)[a]	−$0.77	$0.01	0.001	−$0.77	$0.01	0.001	−$0.81	$0.01	0.001
Weight change									
Gained 5–19 pounds	−$9	$71	0.898	$22	$75	0.765	−$42	$133	0.755
Gained 20 pounds	$619	$104	0.001	$417	$113	0.001	$790	$187	0.001

(b) Model 2: With baseline comorbidities as predictors

	Model 2A, all subjects (n = *15174;* R^2 = *0.43)*			*Model 2C, one or more baseline comorbidites* (n = *6354;* R^2 = *0.49)*		
Variable	*Parameter estimate*	*Standard error*	*P-value*	*Parameter estimate*	*Standard error*	*P-value*
Intercept	$255	$304	0.402	$925	$589	0.116
Baseline age (y)	$13	$4	0.003	$2	$9	0.840
Female gender	$120	$68	0.001	−$52	$131	0.691
Baseline BMI (kg/m^2)	$30	$6	0.001	$30	$11	0.006
Baseline costs ($)[a]	−$0.81	$0.01	0.001	−$0.83	$0.01	0.001
Comorbidities						
Arthritis	$384	$142	0.007	$501	$186	0.007
Asthma	$1117	$147	0.001	$1169	$196	0.001
Depression	$1119	$109	0.001	$1191	$158	0.001
Diabetes	$1379	$117	0.001	$1442	$156	0.001
Ischemic heart disease	$536	$177	0.003	$649	$220	0.003
Hypertension	$457	$91	0.001	$534	$136	0.001
Hyperlipidemia	$250	$112	0.025	$287	$149	0.054
Weight change						
Gained 5–19 pounds	−$4	$70	0.950	−$50	$132	0.707
Gained 20 pounds	$561	$103	0.001	$711	$186	0.001

[a]1999 dollars.

After accounting for age, gender, baseline BMI, baseline comorbidities, and baseline costs, we found a strong positive relationship between large weight gain ($\geq$20 lbs) and increase in annual medical care costs over a 3-y period. Baseline BMI was also strongly and independently associated with cost increase, as were baseline comorbidities and cost during the baseline year. The effect of high weight gain on costs was only slightly attenuated (about 10%) by including comorbidities present at baseline that are known to be associated with obesity. Thus, weight gain prevention initiatives may be equally cost saving when applied to diseased and nondiseased patients. Coefficients on baseline BMI, however, diminished considerably after comorbidity variables were added to the models. This confirms results from other studies, indicating that diabetes, depression, asthma, and cardiovascular disease account for much of the longer-term impact of BMI on future health-care costs.[19,20,33]

Our bivariate and multivariate analyses provided some conflicting results. It is likely that regression to the mean in the bivariate data is responsible for a considerable amount of the difference observed between analyses. Typically, medical care costs exhibit a very skewed frequency distribution, with long tails at the high cost end of the distribution. Higher than average costs in a baseline year usually presage lower costs in subsequent years, especially when the baseline costs are many times the average. Multivariate models that include baseline cost as a covariate are able to correct for this regression to the mean. In our models, the amount of the correction is shown by the highly statistically significant negative coefficient on baseline cost.

Several limitations of these analyses should be noted. Although we used data from a large managed care plan representative of the larger population in the Northwest region of the United States, data availability limited the sample included in these analyses. To evaluate change in weight over the 3-y period, at least one measured weight was required in both 1996, the baseline year, and in 1999, the follow-up year, plus a recorded height. Of the original eligible adult population, only 27% had the required weight and height data (22% of those without any of the baseline comorbidities included in our multivariate models and 47.1% of those with at least one of these conditions). Those who did not have weights available for both time points were younger, more likely to be male, and had significantly fewer ambulatory health-care visits compared to those with complete data (1.1 *vs* 4.2 contacts per year in 1996, 3.0 *vs* 7.5 contacts per year in 1999) (data not shown). A majority (57%) of persons with incomplete data did not have any ambulatory care visit in 1996.

Although weight is commonly measured in the ambulatory setting, it may be more frequently measured for encounters for chronic conditions compared to encounters for acute conditions, and persons with chronic conditions may be more likely to be overweight or obese.[9,10] Thus, our total-sample results may overestimate the economic effects of weight gain by over-representing persons with pre-existing medical problems. However, readers can employ our regression results for the sub-samples with and without pre-existing comorbidities to construct estimates for specific populations of interest.

Although we included important covariates in our multivariate models (baseline BMI, comorbities, costs, age, and gender), data were not available for alcohol use, smoking, or physical activity, factors that could be related to weight gain. We cannot rule out that these factors may have affected the association between weight gain and change in health-care cost.

In the sample selection process for this study, we attempted to reduce bias or confounding due to illness-related weight change, especially weight loss. We excluded subjects who lost weight during the study period or who had a diagnosis of cancer, AIDS, ESRD or kidney dialysis, COPD, congestive heart failure, or stroke, all diseases associated with wasting. We did not exclude patients with such conditions as diabetes, hypertension, or hypercholesterolemia, but rather conducted separate multivariate analyses to evaluate the effects of weight gain in those with and without these preexisting conditions. Nevertheless, other forms of confounding may remain. For example, most of the short-term cost increase that we observed was related to pharmaceutical utilization, presumably from a combination of new prescriptions and increased dosages for existing prescriptions. A variety of medications can cause weight gain in some individuals, including antidepressants, steroids, and antihyperglycemic agents,[34] all of which are used for treatment of the chronic conditions that we included as covariates in the multivariate analyses. More complex yet are the relationships between weight gain and disease incidence and progression. Weight gain may contribute to the development of arthritis, for example, but arthritis may also contribute to weight gain and obesity by discouraging physical activity. Our results should not be interpreted as indicating that all of the increased costs associated with large weight gain in the short term could be prevented.

Our results confirm several previous reports that future medical care costs are higher for those who are initially classified as overweight or obese.[19,21,24] For example, in a study of adults in the Pacific Northwest over a 9-y period, future medical care costs were higher for those who were overweight, and especially in those who were classified as obese (BMI $>30\,kg/m^2$). These higher costs included pharmacy costs, particularly medications for diabetes and cardiovascular diseases, as well as outpatient and inpatient costs.[21] Similarly, in a study of Japanese adults examining changes in health-care costs over a 4-y period, costs were 9.8% higher for those with a baseline BMI 25–29.9 kg/m^2 and 22.4% higher in those with a BMI $>30\,kg/m^2$.[24] In a Midwest managed care population, short-term medical care costs, calculated as mean annual patient charges over an 18-month period, were 1.9% higher for each increase in BMI unit.[35]

Although previous epidemiologic studies have demonstrated that longer-term weight gain is associated with increased levels of lipids, blood pressure, glucose, and insulin;[12,13] an increased incidence of hypertension, hyperlipidemia, and diabetes;[36] and increased cardiovascular mortality;[15,37,38] few, if any, studies have described the association of weight gain, *per se*, with health-care costs.

In response to the growing obesity epidemic and the attendant health complications, in 2001 the US Surgeon General issued a call to action to mobilize resources for the prevention and treatment of obesity.[7] National guidelines recommend obesity treatment for persons who are overweight with BMI $>25\,kg/m^2$. Aggressive and sustained treatment is emphasized for those with higher BMI levels or with risk factors for CVD and other conditions.[7] As for many, weight loss is difficult to maintain,[7] the prevention of weight gain may be an important treatment strategy. It has been stressed that weight maintenance for the obese as well as the nonobese would prevent further increases in the prevalence of severe obesity and would also prevent new cases of obesity in those who are in the healthy weight range.[25] However, with more than half the adult population now overweight or obese, implementing recommendations to reduce obesity will be expensive. For these reasons, in this study, we evaluated the impact of short-term weight gain (*vs* weight maintenance) on health-care utilization and costs in middle-aged adults who were classified as overweight or obese. Our results indicate that medical care costs—particularly those for prescriptions—increase correspondingly when large weight increases occur over the short term. This raises the possibility that preventing rapid, substantial weight gain may prevent the increases in medical care costs that we observed. By showing that rapid weight gain is significantly related to new medical expenses in the relatively short run (3 y), the economic case for systematic weight-gain prevention is much strengthened.

These results have important implications for the development of obesity treatment and prevention strategies in the health-care setting. Results from this study indicate that preventing weight gain may result in substantial cost savings, and targeting those at risk for rapid and large weight gains seems warranted. Data on the costs of weight gain may help insurers and health-care systems to prioritize and evaluate investments in weight gain prevention. National health organizations and policy groups have stressed the need for concerted research efforts into the causes, prevention, and treatment of obesity.[7,9,39–42] In this regard, further information about factors associated with large and rapid weight gain are needed in order to identify those at risk for these rapid weight gains and for developing intervention approaches for preventing weight gain and promoting weight maintenance.

References

1 Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA* 2002; **288**: 1728–1732.

2 Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. *JAMA* 2002; **288**: 1723–1727.

3 National Institutes of Health. *NHLBI Morbidity & Mortality: 2000 Chart Book on Cardiovascular, Lung, and Blood Diseases*. NHLBI: Bethesda, MD; 2000.

4 Mokdad AH, Ford ES, Bowman BA. Diabetes trends in the US:1990–1998. *Diabetes Care* 2000; **23**: 1278–1283.

5 Freedman DS, Khan LK, Serdula MK, Galuska DA, Dietz WH. Trends and correlates of class 3 obesity in the United States from 1990 through 2000. *JAMA* 2002; **288**: 1758–1761.

6 Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA* 1999; **282**: 1523–1529.

7 US Department of Health and Human Services. *The Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity*. US Department of Health and Human Services, Public Health Service, Office of the Surgeon General: Rockville, MD; 2001. Available from: US GPO, Washington.

8 McGinnis JM, Foege WH. Actual causes of death in the United States. *JAMA* 1993; **270**: 2207–2212.

9 National Institutes of Health National Heart Lung and Blood Institute. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults: The EVIDENCE Report*. NHLBI: Bethesda, MD; 1998.

10 Mokdad AH, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The continuing epidemics of obesity and diabetes in the United States. *JAMA* 2001; **286**: 1195–1200.

11 Clinical guidelines on the identification, evaluation, and treatment of overweight obesity in adults: executive summary. Expert panel on the identification, evaluation, and treatment of overweight in adults. *Am J Clin Nutr* 1998; **68**: 899–917.

12 Norman JE, Bild D, Lewis CE, Liu K, West DS. The impact of weight change on cardiovascular disease risk factors in young black and white adults: the CARDIA study. *Int J Obes Relat Metab Disord* 2003; **27**: 369–376.

13 Curtis AB, Strogatz DS JSRT. The contribution of baseline weight and weight gain to blood pressure change in African Americans: The Pitt County Study. *Ann Intern Med* 1998; **8**: 497–503.

14 Willett WC, Manson JE, Stampfer MJ, Colditz GA, Rosner B, Speizer FE, Hennekens CH. Weight, weight change, and coronary heart disease in women: Risk within the 'normal' weight range. *JAMA* 1995; **273**: 461–465.

15 Galanis DJ, Harris T, Sharp DS, Petrovitch H. Relative weight, weight change, and risk of coronary heart disease in the Honolulu Heart Program. *Am J Epidemiol* 1998; **147**: 379–386.

16 Ford ES, Williamson DF, Liu S. Weight change and diabetes incidence: findings from a national cohort of US adults. *Am J Epidemiol* 1997; **146**: 214–222.

17 Allison DB, Zannolli R, Narayan KM. The direct health care costs of obesity in the United States. *Am J Public Health* 1999; **89**: 1194–1199.

18 Quesenberry Jr CP, Caan B, Jacobson A. Obesity, health services use, and health care costs among members of a health maintenance organization. *Arch Intern Med* 1998; **1585**: 466–472.

19 Oster G, Edelsberg J, O'Sullivan AK, Thompson D. The clinical and economic burden of obesity in a managed care setting. *Am J Manag Care* 2000; **6**: 681–689.

20 Wolf AM, Colditz GA. Current estimates of the economic cost of obesity in the United States. *Obes Res* 1998; **6**: 97–106.

21 Thompson D, Edelsberg J, Colditz GA, Bird AP, Oster G. Lifetime health and economic consequences of obesity. *Arch Intern Med* 1999; **159**: 2177–2183.

22 Thompson D, Brown JB, Nichols GA, Elmer PJ, Oster G. Body mass index and future healthcare costs: a retrospective cohort study. *Obes Res* 2001; **9**: 210–218.

23 Gorsky RD, Pamuk E, Williamson DF, Shaffer PA, Koplan JP. The 25-year health care costs of women who remain overweight after 40 years of age. *Am J Prev Med* 1996; **12**: 388–394.

24 Kuriyama S, Tsuji I, Ohkubo T, Anzai Y, Takahashi K, Watanabe Y, Nishino Y, Hisamichi S. Medical care expenditure associated with body mass index in Japan: the Ohsaki Study. *Int J Obes Relat Metab Disord* 2002; **26**: 1069–1074.
25 Koplan JP, Dietz WH. Caloric imbalance and public health policy. *JAMA* 1999; **282**: 1579–1581.
26 Hornbrook MC, Goodman MJ. Adjusting health benefit contributions to reflect risk. In: Hornbrook MC (ed) *Advances in Health Economics and Health Services Research*. JAI Press Inc.: Greenwich, CT; 1991. pp 41–76.
27 Brown JB, Nichols GA, Glauber HS, Bakst AW. Type 2 diabetes: Incremental medical care costs during the first eight years after diagnosis. *Diabetes Care* 1999; **22**: 1116–1124.
28 Brown JB, Pedula KL, Bakst AW. The progressive cost of complications in type 2 diabetes mellitus. *Arch Intern Med* 1999; **159**: 1873–1880.
29 US Department of Labor. *US medical price index*, http://www.bls.gov/search. Internet 2002.
30 Fine JT, Colditz GA, Coakley EH, Moseley G, Manson JE, Willett WC, Kawachi I. A prospective study of weight change and health-related quality of life in women. *JAMA* 1999; **282**: 2136–2142.
31 Dattilo AM, Kris-Etherton PM. Effects of weight reduction on blood lipids and lipoproteins: a meta-analysis. *Am J Clin Nutr* 1992; **56**: 320–328.
32 Neaton JD, Grimm Jr RH, Prineas RJ, Stamler J, Grandits GA, Elmer PJ, Cutler JA, Flack JM, Schoenberger JA, McDonald R *et al*. Treatment of Mild Hypertension Study (TOMHS): Final results. *JAMA* 1993; **270**: 713–724.
33 Heithoff KA, Cuffel BJ, Kennedy S, Peters J. The association between body mass and health care expenditures. *Clin Ther* 1997; **19**: 811–820.
34 Strowig SM, Aviles-Santa ML, Raskin P. Comparison of insulin monotherapy and combination therapy with insulin and metformin or insulin and troglitazone in type 2 diabetes. *Diabetes Care* 2002; **25**: 1691–1698.
35 Pronk NP, Goodman MJ, O'Connor PJ, Martinson BC. Relationship between modifiable health risks and short-term health care charges. *JAMA* 1999; **282**: 2235–2239.
36 Lewis CE, Jacobs Jr DR, McCreath H, Kiefe CI, Schreiner PJ, Smith DE, Williams OD. Weight gain continues in the 1990s: 10-year trends in weight and overweight from the CARDIA study. Coronary Artery Risk Development in Young Adults. *Am J Epidemiol* 2000; **151**: 1172–1181.
37 Dyer AR, Stamler J, Greenland P. Associations of weight change and weight variability with cardiovascular and all-cause mortality in the Chicago Western Electric Company Study. *Am J Epidemiol* 2000; **152**: 324–333.
38 Lee IM, Manson JE, Hennekens CH, Paffenbarger Jr RS. Body weight and mortality: a 27-year follow-up of middle-aged men. *JAMA* 1993; **270**: 2823–2828.
39 National Institutes of Health. *NHLBI Strategic Plan to Address Health Disparities*, US Department of Health and Human Services; NHLBI: Bethesda, MD; 2000.
40 National Institutes of Health. *Report of the Task Force on Behavioral Research in Cardiovascular, Lung, and Blood Health and Disease*. NHLBI: Bethesda, MD; 1988.
41 National Institutes of Health. *NHLBI Strategic Plan*, US Department of Health and Human Services; NHLBI: Bethesda, MD; 2000.
42 National Institutes of Health. *NHLBI Task Force Report on Research in Prevention of Cardiovascular Disease*, US Department of Health and Human Services; NHLBI: Bethesda, MD; 2001.

Appendix A1

ICD-9-CM codes for exclusionary diagnoses:

Malignant cancers	140.00–209.99
AIDS	279.1–279.9
Eating disorders	307.1, 307.5, 307.51, 307.59
ESRD/dialysis	584.6–584.9, 585, 586
COPD	492.8
Emphysema	496
Congestive heart failure	428.0, 428.1, 428.9, 402.91
Stroke	430.0–437.1
Pregnancy	V22.0–V22.2, V23.0–V23.9

ICD-9-CM codes for comorbidity diagnoses:

Asthma	493.xx
Diabetes	250.xx
Hyperlipidemia	272.0–272.4
Arthritis	714.0–715.9x
Hypertension	401.1, 401.9
Ischemic heart disease	410.0–414.9x
Depression/dysthymia	296.2, 296.3, 296.82, 296.9, 300.4, 309.0, 309.1, 311