Obesity, Health Services Use, and Health Care Costs Among Members of a Health Maintenance Organization

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Background: Obesity is an independent risk factor for a variety of chronic diseases and is therefore a potential source of avoidable excess health care expenditures. Previous studies of obesity and health care costs have used group level data, applying estimates of population-attributable risks to estimates of US total costs of care for each obesity-related disease.

Objective: To quantify the association between body mass index (BMI) and health services use and costs stratified by age and use source at the patient level, a level of detail not previously reported.

Methods: In 17,118 respondents to a 1993 health survey of members of a large health maintenance organization, we ascertained through computerized databases all hospitalizations, laboratory services, outpatient visits, outpatient pharmacy and radiology services, and the direct costs of providing these services during 1993.

Results: There was an association between BMI and annual rates of inpatient days, number and costs of outpatient visits, costs of outpatient pharmacy and laboratory services, and total costs (P=.003). Relative to BMI of 20 to 24.9, mean annual total costs were 25% greater among those with BMI of 30 to 34.9 (rate ratio, 1.25; 95% confidence interval, 1.10-1.41), and 44% greater among those with BMI of 35 or greater (rate ratio, 1.44; 95% confidence interval, 1.22-1.71). The association between BMI and coronary heart disease, hypertension, and diabetes largely explained these elevated costs.

Conclusion: Given the high prevalence of obesity and the associated elevated rates of health services use and costs, there is a significant potential for a reduction in health care expenditures through obesity prevention efforts.

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Obesity clearly has been shown to be an independent risk factor for a variety of diseases, including cardiovascular disease, diabetes, colon cancer, and gallbladder disease. A substantial fraction of adults are at increased risk for morbidity and mortality as a result of being above a healthy weight. Total direct costs of obesity-associated diseases have been estimated to be $45.8 billion in 1990, approximately 6.8% of all health care expenditures in the United States, with increased annual costs of care at each level of increased body mass index (BMI).

We undertook this study to quantify the association between body fatness as measured by BMI and various categories of inpatient and outpatient health services use and cost of providing these health services in a large health maintenance organization. Unlike previous studies, the unit of analysis was the patient, and we therefore had the unique ability to stratify and control for sociodemographic variables, comorbidities, alcohol consumption, and cigarette smoking, a particularly important potential confounding variable.

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RESULTS

DEMOGRAPHICS

Characteristics of the study population by level of BMI are presented in Table 1. The sex distribution varied by BMI with no clear pattern across BMI categories. Proportions of respondents who were white or a race other than black, Hispanic, or Asian were similar across BMI categories. However, proportions of Asian respondents decreased as BMI increased and proportions of black and Hispanic respondents increased with BMI. The highest and lowest BMI categories were associated with the lowest mean ages (BMI of 20-24.9, 50.7 years; BMI of ≥35, 48.6 years). The associations between BMI and sex, race, and age were all statistically significant.
SUBJECTS AND METHODS

STUDY SAMPLE

We included respondents to a membership health survey conducted in March 1993 among members of the Kaiser Permanente Medical Care Program in the Northern California Region (KPNC). The KPNC is a private, nonprofit, prepaid group practice program with more than 2.4 million members, approximately 25% of the population in areas served. Health plan members are similar to the general population with respect to sociodemographic characteristics, with the exception of a slight underrepresentation of the extremes of income.8

The membership health survey, an age-sex-stratified random sample survey, elicited information on chronic and acute illnesses during the previous 12 months, use of prescription and over-the-counter drugs, height and weight, race or ethnicity, educational level, alcohol consumption, and cigarette smoking. Questionnaire items were generally obtained from the National Health Interview Survey9 and the California Behavior Risk Factor Survey.10 A reminder postcard was sent several weeks after the initial mailing, followed by up to 2 subsequent survey packet mailings. Excluding ineligible respondents (eg, no longer a health plan member), the overall survey response rate was 38.2% (9728/33 888). Response rates varied by age and sex, with the lowest rates among men age 20 to 30 years (40%) and the highest rates among men and women 65 years and older (80%) (N. P. Gordon, ScD, unpublished data, July 1994).

We eliminated study subjects with missing or implausible height and weight combinations (N=610) and a BMI of less than 20 (N=1715) and women who gave birth during the 6 months after our study (N=285), leaving 17 118 subjects for analysis. Body mass index was calculated as weight in kilograms divided by the square of height in meters.

(P<.001). There was a clear, positive association between BMI and each of the 6 comorbidities, with the prevalence generally increasing with BMI, particularly for diabetes and hypertension (P<.001).

OUTPATIENT AND INPATIENT USE COUNTS

The annual rate of all outpatient visits varied significantly (P<.001, adjusted for age and sex) by BMI, with rates increasing with BMI (Table 2). Compared with respondents with BMI of 20 to 24.9, those with BMI of 30 to 34.9 (hereafter referred to as moderately overweight) experienced a 17% higher outpatient visit rate, and those with BMI of 35 or greater (hereafter referred to as severely overweight) experienced a 24% higher rate. The association between BMI and outpatient visits varied by age (test for age × BMI interaction, P<.001), with the trend strongest for the youngest (20-39 years) and middle (40-59 years) age groups. There was no association among those 75 years or older (P=.47).

There was a strong association between BMI and annual hospital days, adjusted for age and sex; relative to respondents with BMI of 20 to 24.9, there was a decreased inpatient use for those with BMI of 25 to 29.9, increasing to 34% and 74% higher rates among the moderately and severely overweight, respectively (Table 2). As for outpatient visits, there was a significant age × BMI interaction with respect to annual hospital days (P<.001). The association appeared strongest for those age 40 to 59, where the rates among the moderately and severely overweight groups were 2.21 (95% confidence intervals [CI], 1.85-2.63) and 2.30 (95% CI, 1.85-2.86) times, respectively, that among respondents with BMI of 20 to 24.9. A J-shaped pattern of use was apparent among those age 60 to 74 years and 75 years and older, with the minimum rates among respondents with BMI of 25 to 34.9.

OUTPATIENT COSTS

With the exception of surgery (P=.96) and radiology services (P=.24), there was a significant association between BMI and each category of outpatient costs (Table 3). Relative to respondents with BMI of 20 to 24.9, costs generally increased with BMI, mostly among those with BMI of greater than 30, particularly for outpatient visits and laboratory services. Pharmacy costs, however, were significantly increased among those with BMI of 25 to 29.9 as well as those in the higher BMI categories; relative to BMI of 20 to 24.9, pharmacy costs were 23%, 60%, and 78% higher in each increasing BMI cat-
measurements, and $4.00 or less for the complete blood cell counts and urinalyses), our analyses are unlikely to be much affected. Inpatient laboratory, pharmacy, and radiology services were not ascertained at the individual level due to the lack of such databases during the study, but costs for such services are included in the average cost of an inpatient stay.

**SOURCES OF COST INFORMATION**

Costs for the units of health services use were obtained primarily from a computerized cost management information system, which integrates regional use databases with the health plan’s general ledger to provide fully allocated costs by department, medical center, patient, or procedure. Because this system was not fully operational during 1993, we used the 1994 database to obtain unit costs. Thus, cost estimates presented herein are in 1994 dollars and reflect average costs across the facilities in the KPNCR during 1994. Costs were obtained for each unit of use by a standard step-down accounting method. Most program expenses, including those attributable directly to provision of the service, the overhead associated with the operation of a medical facility, and the indirect costs associated with administering the medical care program, were allocated to these unit costs. Costs were aggregated to services within departments as follows: inpatient stays by Diagnostic Related Groups, outpatient surgery by Diagnostic Related Groups, outpatient visits by specialty, radiology services by relative value unit, and laboratory services by relative value unit. Costs for authorized claims and referrals were determined from the billing information. Outpatient pharmacy costs were calculated as the actual cost to the KPNCR for each prescription dispensed, plus an average dispensing and overhead cost per prescription. The costs of prescriptions dispensed in 1993 were adjusted to 1994 dollars using the medical care services component of the Consumer Price Index.

**STATISTICAL ANALYSIS**

The association between use or costs and BMI was assessed in general using fitting log linear models, which provided point and interval estimates of rate ratios (RR) adjusted for age, sex, and other potential confounders. Data that can be typified by a counting process such as number of outpatient visits and hospital days were analyzed using a Poisson regression approach, which allowed for unequal follow-up and overdispersion (ie, variance greater than the mean). We used a similar generalized linear modeling approach to the cost analyses, but we specified a normal distribution for the dependent variable and a constant variance, which was generally appropriate for the analyses of specific types of costs. Estimation for cost and use models was performed using maximum likelihood. In general, we used Wald tests to obtain significance probabilities for the differences in cost and use across BMI categories. We used the obesity classification system proposed by Bray,2 which categorizes disease risk by BMI categories of 5 units in width across the BMI range. Unlike the classification by Bray,2 our highest BMI category is greater than 35, necessary because of sample size limitations accompanied by unstable age-specific estimates for BMI of greater than 40.

Sensitivity analyses examined the potential impact of outliers and the distributional assumptions of the analysis of use and cost. With a few exceptions noted below, the exclusion of outliers (>99th percentile) had no impact on our primary analyses. By examining alternative distributional assumptions in our cost models, we found our results in general were not sensitive to this specification, most likely related to our large sample size.

**TOTAL COSTS**

There was a strong association between BMI and total costs ($P<.001), with a slight J-shaped pattern (Table 4). Relative to respondents with BMI of 20 to 24.9, there was a 25% and a 44% elevation among the moderately and severely overweight groups, respectively, adjusted for age and sex. Mean annual total costs among those with BMI of 25 to 29.9 were slightly less (5%) than among those with BMI of 20 to 24.9, but not significantly. The association did not differ by age (test for age × BMI interaction, $P=.24$), but the BMI effect appeared weakest among those older than 75 years and strongest among those age 40 to 59 years (Table 4).

Adjustment for race, alcohol consumption, current smoking, and educational level resulted in no appre-
No. (%) of respondents | 20-24.9 | 25-29.9 | 30-34.9 | ≥35
--- | --- | --- | --- | ---
No. (%) of respondents | 8225 (48.0) | 6003 (35.1) | 1994 (11.6) | 896 (5.2)
Female | 53.5 | 42.0 | 52.8 | 70.6
Race | | | | 
Black | 4.3 | 6.7 | 8.8 | 10.9
White | 75.4 | 76.6 | 77.2 | 74.7
Hispanic | 3.3 | 3.9 | 4.2 | 5.0
Asian | 6.9 | 3.8 | 1.6 | 1.0
Other | 10.1 | 9.1 | 7.8 | 8.4
Mean (SD) age, y | 50.7 (17.2) | 53.9 (15.6) | 52.7 (14.6) | 48.6 (13.3)
Comorbidities | | | | 
Diabetes | 3.7 | 7.4 | 12.2 | 15.3
Hypertension | 17.7 | 29.4 | 36.7 | 39.4
High cholesterol level | 12.6 | 18.6 | 19.5 | 14.0
Heart disease | 9.9 | 14.8 | 16.8 | 16.9
Depression | 12.8 | 13.5 | 16.4 | 22.4
Musculoskeletal pain | 21.2 | 24.1 | 28.3 | 30.6
No. of comorbidities | | | | 
0 | 50.2 | 40.1 | 32.6 | 30.0
1 | 29.9 | 29.4 | 28.8 | 28.2
2 | 13.6 | 18.1 | 21.9 | 23.3
≥3 | 6.3 | 12.4 | 16.7 | 18.4

*Respondents are members of the Kaiser Permanente Medical Care Program in the Northern California Region. Unless otherwise indicated, data are given as percentage of respondents.

Table 2. Relative Rates of Outpatient Visits and Inpatient Days Associated With Body Mass Index, by Age*

| Age, y | 20-24.9 | 25-29.9 | 30-34.9 | ≥35 | P |
--- | --- | --- | --- | --- | --- |
### Outpatient Visits
20-39 | 4.33 (0.11) | 1.05 (0.98-1.12) | 1.10 (0.99-1.22) | 1.41 (1.25-1.57) | <.001
40-59 | 5.23 (0.14) | 1.06 (1.01-1.13) | 1.28 (1.20-1.38) | 1.34 (1.22-1.47) | <.001
60-74 | 7.96 (0.18) | 1.05 (1.00-1.11) | 1.11 (1.03-1.20) | 1.05 (0.92-1.19) | .04
≥75 | 10.21 (0.31) | 0.95 (0.87-1.03) | 1.02 (0.88-1.19) | 0.81 (0.52-1.27) | .47
All | 6.09 (0.08) | 1.04 (1.01-1.07) | 1.17 (1.11-1.22) | 1.24 (1.17-1.32) | <.001
### Inpatient Days
20-39 | 0.15 (0.02) | 0.74 (0.60-0.91) | 1.45 (1.12-1.87) | 0.93 (0.64-1.36) | <.001
40-59 | 0.24 (0.03) | 1.21 (1.03-1.41) | 2.21 (1.85-2.63) | 2.30 (1.85-2.86) | <.001
60-74 | 0.84 (0.11) | 0.74 (0.64-0.86) | 1.18 (0.97-1.43) | 1.82 (1.40-2.38) | <.001
≥75 | 1.71 (0.22) | 0.61 (0.47-0.79) | 0.84 (0.55-1.28) | 1.46 (0.55-3.91) | .002
All | 0.48 (0.04) | 0.78 (0.72-0.85) | 1.34 (1.20-1.49) | 1.74 (1.50-2.02) | <.001

*Age-specific rate ratios are sex adjusted; rate ratios for all ages are adjusted for sex and age. Rates are determined per person per year. Unless otherwise indicated, data are given as rate ratios (95% confidence interval).
†Referent group for rate ratios, given as mean (SE).

Significant and slightly U shaped (Table 5). After controlling for these 3 diseases, there was no association between total cost and high cholesterol level or musculoskeletal pain, and the addition of these variables did not alter the pattern of the BMI association. Similarly, the comorbidity-adjusted BMI association was unaltered with the additional control for depression, although depression was independently and significantly associated with total cost. Additional control for interactions among these diseases or for total number of comorbidities resulted in no appreciable change to this pattern of RR for BMI. This analysis was somewhat sensitive to extreme values of total cost; with elimination of...
outliers, the pattern of association was less U shaped, and adjusted costs among those with BMI of 25 to 34.9 were not significantly lower than among those with BMI of 20 to 24.9.

COMMENT

In summary, there was a clear association between BMI and annual rates of outpatient visits and inpatient days; annual cost of outpatient visits; radiology, laboratory, and pharmacy services; and total cost of care, both inpatient and outpatient. There was a slight J shape in the association with total costs, driven by the inpatient costs association.

Because the 6 comorbidities studied herein are to a large extent intermediate along the causal pathway between increased BMI and increased health services use and cost, statistical control for such diseases in estimating the association between BMI and health services cost and use constitutes overadjustment. Therefore, neither our estimates nor those from other studies are adjusted for comorbidities. Our multiple regression analysis, which was performed to determine which diseases accounted for the variation in costs by BMI, indicates that given the presence of 1 or more of these comorbidities, high BMI does not appear to be strongly associated with increased costs. However, this does not imply that BMI is unrelated to increased costs. The higher incidence of disease drives increased costs among the high BMI groups. Therefore, to stratify or adjust and, in a sense, equalize high and low BMI groups with respect to such a disease when measuring BMI effects on costs would lead to an underestimate of association.

It is important, however, to attempt to determine what diseases may account for variation in costs by

<table>
<thead>
<tr>
<th>Services</th>
<th>Body Mass Index</th>
<th>20-24.9†</th>
<th>25-29.9</th>
<th>30-34.9</th>
<th>≥35</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient Visits</td>
<td>1.00</td>
<td>1.02 (0.96-1.07)</td>
<td>1.14 (1.06-1.23)</td>
<td>1.25 (1.14-1.38)</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Surgery</td>
<td>1.00</td>
<td>0.99 (0.84-1.17)</td>
<td>1.01 (0.79-1.29)</td>
<td>1.09 (0.78-1.54)</td>
<td>.96</td>
<td></td>
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<tr>
<td>Radiology</td>
<td>1.00</td>
<td>0.68 (0.29-1.56)</td>
<td>1.40 (0.60-3.25)</td>
<td>1.73 (0.75-3.97)</td>
<td>.24</td>
<td></td>
</tr>
<tr>
<td>Pharmacy</td>
<td>1.00</td>
<td>1.23 (1.15-1.32)</td>
<td>1.60 (1.48-1.74)</td>
<td>1.78 (1.60-1.99)</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>1.00</td>
<td>0.97 (0.84-1.12)</td>
<td>1.24 (1.04-1.48)</td>
<td>1.85 (1.52-2.24)</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>1.00</td>
<td>0.99 (0.88-1.13)</td>
<td>1.21 (1.03-1.42)</td>
<td>1.37 (1.11-1.68)</td>
<td>.003</td>
<td></td>
</tr>
<tr>
<td>Inpatient services</td>
<td>1.00</td>
<td>0.83 (0.72-0.96)</td>
<td>1.33 (1.12-1.57)</td>
<td>1.70 (1.34-2.15)</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>1.00</td>
<td>0.95 (0.85-1.06)</td>
<td>1.25 (1.10-1.41)</td>
<td>1.44 (1.22-1.71)</td>
<td>.001</td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Relative Rates of All Health Services Use Costs Associated With Body Mass Index*

*Data are given as rate ratios (95% confidence interval), adjusted for age and sex.
†Referent group for rate ratios.

Table 4. Relative Rates of Total Outpatient and Inpatient Health Services Use Costs Associated With Body Mass Index, by Age*

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Body Mass Index</th>
<th>20-24.9†</th>
<th>25-29.9</th>
<th>30-34.9</th>
<th>≥35</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient Costs</td>
<td>20-39</td>
<td>811 (24)</td>
<td>1.11 (0.99-1.25)</td>
<td>1.18 (1.00-1.39)</td>
<td>1.47 (1.26-1.73)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>40-59</td>
<td>1382 (202)</td>
<td>0.94 (0.86-1.35)</td>
<td>1.44 (1.00-2.07)</td>
<td>1.62 (1.08-2.43)</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>60-74</td>
<td>1888 (162)</td>
<td>1.04 (0.91-1.18)</td>
<td>1.10 (0.92-1.32)</td>
<td>1.09 (0.81-1.47)</td>
<td>.73</td>
</tr>
<tr>
<td></td>
<td>≥75</td>
<td>2190 (78)</td>
<td>0.95 (0.84-1.07)</td>
<td>1.11 (0.92-1.33)</td>
<td>0.71 (0.32-1.54)</td>
<td>.34</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>1406 (82)</td>
<td>0.99 (0.88-1.13)</td>
<td>1.21 (1.03-1.42)</td>
<td>1.37 (1.11-1.68)</td>
<td>.003</td>
</tr>
<tr>
<td>Inpatient Costs</td>
<td>20-39</td>
<td>160 (24)</td>
<td>1.03 (0.61-1.72)</td>
<td>1.57 (0.90-2.74)</td>
<td>1.48 (0.76-2.88)</td>
<td>.32</td>
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<tr>
<td></td>
<td>40-59</td>
<td>370 (43)</td>
<td>1.33 (0.90-1.96)</td>
<td>2.16 (1.47-3.17)</td>
<td>2.11 (1.32-3.35)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>60-74</td>
<td>1198 (139)</td>
<td>0.86 (0.67-1.17)</td>
<td>1.33 (0.97-1.83)</td>
<td>1.88 (1.27-2.77)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td>≥75</td>
<td>2270 (239)</td>
<td>0.59 (0.39-0.89)</td>
<td>0.98 (0.59-1.64)</td>
<td>0.29 (0.00-95.6)</td>
<td>.09</td>
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<tr>
<td></td>
<td>All</td>
<td>684 (45)</td>
<td>0.83 (0.72-0.96)</td>
<td>1.33 (1.12-1.57)</td>
<td>1.70 (1.34-2.15)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Total Costs</td>
<td>20-39</td>
<td>970 (38)</td>
<td>1.10 (0.95-1.27)</td>
<td>1.24 (1.03-1.51)</td>
<td>1.48 (1.22-1.79)</td>
<td>&lt;.001</td>
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<tr>
<td></td>
<td>40-59</td>
<td>1752 (208)</td>
<td>1.03 (0.77-1.37)</td>
<td>1.59 (1.19-2.12)</td>
<td>1.72 (1.23-2.40)</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>60-74</td>
<td>3086 (224)</td>
<td>0.99 (0.85-1.14)</td>
<td>1.18 (0.98-1.42)</td>
<td>1.38 (1.06-1.80)</td>
<td>.02</td>
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<tr>
<td></td>
<td>≥75</td>
<td>4460 (277)</td>
<td>0.77 (0.63-0.95)</td>
<td>1.04 (0.78-1.39)</td>
<td>0.53 (0.10-2.83)</td>
<td>.06</td>
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<tr>
<td></td>
<td>All</td>
<td>2090 (97)</td>
<td>0.95 (0.85-1.05)</td>
<td>1.25 (1.10-1.41)</td>
<td>1.44 (1.22-1.71)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

*Adjusted rate ratios are explained in the first footnote to Table 2. Costs are determined per person per year. Unless otherwise indicated, data are given as rate ratios (95% confidence interval).
†Referent group for rate ratios, given as mean (SE).
BMI, and we therefore fitted statistical models that included comorbidities as independent variables in addition to BMI, age, and sex. Statistical control for these obesity-associated comorbidities did not entirely remove or explain the association between BMI and cost of care, but the estimated effects in the moderately and severely overweight groups were essentially eliminated, suggesting that much of the increased use in these groups can be attributed to diabetes, CHD, and hypertension. The model estimates provide age-sex-adjusted measures of strength of association between total cost and these 3 comorbidities, the strongest association being with CHD, followed by diabetes and hypertension. This ordering of impact on total costs is in agreement with that of the US total costs of care for each of the 3 diseases.4

The J-shaped inpatient cost association, seen most clearly in the older ages, is in contrast to a study based on the 1981-1989 Netherlands Health Interview Survey, which found no difference in the likelihood of hospitalization in the previous year when subjects with BMI of 25 to 34.9 were compared with those with BMI of 20 to 24.9.11 In addition, Wolf and Colditz4 reported direct costs of care strictly increasing with BMI. However, a study of health care expenditures by third-party providers found the lowest probability of expenditure during 5 years to be in the midrange of BMI.7 In addition, the trend in our results agrees with the analysis of indirect costs associated with BMI performed by Wolf and Colditz4 and based on the 1988 National Health Interview Survey. Their analyses show U- or J-shaped associations between BMI and work-loss days, restricted activity days, and bed days. They note that this finding is subject to bias due to the effects of uncontrolled confounding variables such as smoking and preexisting disease, which would be more evident at older ages.6

We were able to study the potential confounding of smoking, alcohol consumption, educational level, and race, and found no appreciable effects. Similar to findings by Wolf and Colditz,8 with this study design we could not determine if increased cost in the lower BMI group was due to preexisting disease leading to low BMI and increased use. Elimination of subjects with cancer and human immunodeficiency virus, diseases known to result in weight loss, resulted in a slightly less pronounced J shape, suggesting this shape is in part attributable to preexisting disease. Stratified analyses of inpatient costs categorized by Major Diagnostic Categories, the standard industry groupings of Diagnostic Related Groups, show that the J-shaped inpatient cost pattern is driven by a variety of diagnoses, including diseases and disorders of the respiratory, circulatory, digestive, musculoskeletal, and connective tissue systems, lending support to the theory that low BMI accompanied by high costs is due to preexisting illness. In addition, the J shape was in part driven by extreme values of total cost, most likely among the most severely ill, again perhaps indicating weight loss due to illness.

Using health plan membership counts, age- and sex-specific obesity prevalence estimates (BMI ≥27.8 for men and ≥27.3 for women), excess total cost estimates from this study, and cost information from the health plan’s general ledger, we estimate that in 1994, the cost of obesity in the KPNCR was $220 million, or approximately 6% of the total cost of health care for all members. This is in close agreement with previous estimates of 5.3% of total US health expenditures due to obesity based on 1986 data,8 and more recently 6.8% using 1990 data.9

The World Health Organization has proposed an obesity classification system with the 2 highest categories BMI at 30 to 40 and greater than 40. For comparison with other studies, we obtained age-sex–adjusted estimates for total costs using the World Health Organization BMI categories. Compared with respondents with BMI of 20 to 24.9, those with BMI of 30 to 40 experienced 25% higher total costs (RR, 1.25; 95% CI, 1.12-1.41), and those with BMI of greater than 40 experienced 78% higher mean annual costs (RR, 1.78; 95% CI, 1.41-2.24) (data not shown).

Although we were unable to measure BMI among the nonrespondents to the survey, we compared age-sex-specific health services use with that of respondents, and in general we found few differences. However, among those older than 60 years, the annual rate of inpatient days among nonrespondents was approximately twice that among respondents, indicating that the extremely ill were less likely to participate. Given the known associations between obesity and chronic disease, exclusion of the most severely ill could tend to result in conservative estimates of the association between obesity and health care costs. Using an outpatient diagnosis and procedures database implemented in 1994, we found no significant differences between respondents and nonrespondents in the prevalence of obesity indicated as a significant health problem during the 2 years following the study. In addition, among survey respondents, we found no meaningful differences between our study group and those with missing BMI (384 women and 197 men) in age-sex–specific mean annual outpatient visits and inpatient days. In summary, age-sex-specific comparisons of health services use and a crude measure of obesity prevalence indicate that nonresponse is not likely to be a source of appreciable bias in our analyses.

### Table 5. Relative Rates of Total Cost of All Health Services Use Associated With Body Mass Index Adjusted for Comorbidities

<table>
<thead>
<tr>
<th>Comorbidity-Unadjusted Rate Ratio (95% Confidence Interval)</th>
<th>Comorbidity-Adjusted Rate Ratio (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index</td>
<td></td>
</tr>
<tr>
<td>20-24.9</td>
<td>1.00</td>
</tr>
<tr>
<td>25-29.9</td>
<td>0.95 (0.85-1.04)</td>
</tr>
<tr>
<td>30-34.9</td>
<td>1.25 (1.10-1.41)</td>
</tr>
<tr>
<td>&gt;35</td>
<td>1.44 (1.22-1.71)</td>
</tr>
<tr>
<td>Comorbidities</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.72 (1.56-1.89)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.17 (1.07-1.29)</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>2.38 (2.15-2.63)</td>
</tr>
</tbody>
</table>

* Rates are adjusted for sex and age. Rates are determined per person per year. Ellipses indicate data are not applicable.

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A possible limitation is that our determination of BMI was derived from self-reported heights and weights. A validation study involving a chart review of a random sample of 111 study subjects who had an outpatient visit within 2 months of the survey date showed that weight was in general underreported by an average of 2.45, 2.05, and 3.27 kg among groups with BMIs of less than 30, 30 to 34.9, and 35 or greater, respectively. There was no difference between medical chart and self-reported height. With respect to misclassification of BMI into our 4 categories, medical chart and self-reported BMI category agreed for 87.4% of respondents. Given this relatively high level of agreement, our estimates are unlikely to be much affected, and given that BMI was generally underreported, they are likely to be conservative.

A variety of studies of reliability and validity of self-reported chronic conditions have generally found these conditions to be underreported. However, these self-reports are most accurate for chronic diseases that require physician visits and hospitalization and therefore are useful for studies involving the cost of medical care. We have minimized misclassification by using self-reported and computerized pharmacy information to ascertain comorbidity status, and we have used our diabetes registry, which has high sensitivity (90.0%) and specificity (97.5%).

Because of database limitations, we used a different time to ascertain use of outpatient radiology and pharmacy services. Because this interval overlaps with the primary study by 3 months and extends only 9 months later, the bias in estimation of the 1993 annual rates is most likely small. Similarly, as described above, database limitations resulted in some missing data for outpatient laboratory services. Exclusion of these 3 potentially problematic cost components resulted in no change in our estimates of association between BMI and total cost.

The prevalence of obesity in the United States has been increasing; comparison of national estimates based on the 1988-1991 National Health and Nutrition Survey with those from the 1976-1980 survey show an 8% increase in prevalence of obesity. Such increases will likely be accompanied by increased prevalence of obesity-related diseases, resulting in higher total health care expenditures attributable to obesity. This trend in obesity prevalence is likely due to factors such as diet, physical activity levels, social and demographic trends, and other health behaviors, some of which are clearly modifiable. Given the high prevalence of obesity and the clearly elevated disease risks and increased use of health services, there is great potential for a reduction in health care expenditures through efforts in weight reduction and prevention of weight gain.

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