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Research Article

Excess direct medical costs of severe obesity by socioeconomic status in German adults

Direkte medizinische Exzesskosten der schweren Adipositas nach sozio-ökonomischem Status bei Erwachsenen in Deutschland

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Abstract

Objective: Excess direct medical costs of severe obesity are by far higher than of moderate obesity. At the same time, severely obese adults with low socioeconomic status (SES) may be expected to have higher excess costs than those with higher SES, e.g. due to more comorbidities. This study compares excess costs of severe obesity among German adults across different SES groups.

Methods: In a subsample (N=947) of the KORA-Survey S4 1999/2001 (a cross-sectional health survey in the Augsburg region, Germany; age group: 25–74 years), visits to physicians, inpatient days in hospital, and received and purchased medication were assessed via computer-assisted telephone interviews (CATI) over half a year. Body mass index (BMI in kg/m^2) was measured anthropometrically. SES was determined via reports of education, income, and occupational status from computer-assisted personal interviews (CAPI) (used both as single indicators, and as indexed by the Helmert algorithm); due to small subsample sizes all were median-split. Data of respondents in normal weight ($18.5 \leq BMI < 25$), preobese ($25 \leq BMI < 30$), moderately (class 1:$30 \leq BMI < 35$) and severely obese (classes 2–3: $BMI \geq 35$) range were analysed by generalized linear models with mixed poisson-gamma (Tweedie) distributions. Physician visits and inpatient days were valuated as recommended by the Working Group Methods in Health Economic Evaluation (AG MEG), and drugs were valuated by actual costs. Sex, age, kind of sickness fund (statutory/private) and place of residence (urban/rural) were adjusted for, and comorbidities were considered by the Physical Functional Comorbidity Index (PFCI).

Results: Excess costs of severe obesity were higher in respondents with high SES, regardless of the SES indicator used. For instance, annual excess costs were almost three times higher in those with an above-median SES-Index as compared with those with a median or lower SES-Index (plus € 2,966 vs. plus € 1,012; contrast significant at $p<.001$). Mediation of excess costs of severe obesity by physical comorbidities pertained to the low SES-Index and the low occupational status groups: differences in costs between severe obesity and normal weight were still positive, but statistically insignificant, in the lower status groups after adjusting for the PFCI, but still positive and significant given higher SES. For example, severe obesity's excess costs were € 2,406 after PFCI-adjustment in the high SES-Index group ($p<.001$), but € 539 in the lower status group ($p=.17$). At the same time, physical comorbidities as defined by the PCFI increased with BMI and decreased with SES, however the factors BMI and SES did not significantly interact in this context.

Conclusions: To our knowledge, this is the first study to show in Germany that excess direct medical costs of severe obesity are not distributed equitably across different SES groups, do not reflect comorbidity status, and are significantly higher in those with high SES than in those with lower SES. Thus, allocation of health care resources spent on severely

obese adults seems to be in need of readjustment towards an equitable utilization across all socioeconomic groups.

Keywords: obesity, health care costs, socioeconomic status, comorbidities, Germany

Zusammenfassung

Zielsetzung: Die direkten medizinischen Exzesskosten der schweren Adipositas sind deutlich höher als die der moderaten Adipositas. Zugleich ist zu erwarten, dass (schwer) adipöse Erwachsene mit niedrigem sozioökonomischen Status (SES) höhere Exzesskosten aufweisen als solche mit höherem SES, z. B. aufgrund höherer Komorbiditäten. Diese Studie vergleicht die Exzesskosten der (schweren) Adipositas bei Erwachsenen in verschiedenen SES-Gruppen.

Methodik: In einer Teilstichprobe (N=947) des KORA-Survey S4 1999/2001 (ein querschnittlicher Gesundheitssurvey in der Region Augsburg; Altersgruppe: 25–74 Jahre) wurden Arztkontakte, Medikamentenkäufe und -erhalte sowie stationäre Krankenhaustage über ein halbes Jahr via computergestützte telefonische Interviews (CATI) erhoben. Der Body Mass Index (BMI in kg/m²) wurde anthropometrisch gemessen. Der SES wurde durch Angaben zu Bildung, Einkommen und Berufstatus aus computergestützten persönlichen Interviews (CAPI) bestimmt (sie gingen sowohl als Einzelindikatoren als auch als Helmert-Index in die Analysen ein); alle wurden wegen geringer Teilstichprobengrößen medianhalbiert. Die Daten von Teilnehmern mit Normalgewicht ($18{,}5 \leq BMI < 25$), Präadipositas ($25 \leq BMI < 30$), moderater (Grad 1:$30 \leq BMI < 35$) und schwerer Adipositas (Grade 2–3: $BMI \geq 35$) wurden mittels allgemeiner linearer Modelle mit gemischten Poission-Gamma- (Tweedie-) Verteilungen analysiert. Arztkontakte und Krankenhaustage wurden gemäß dem Vorschlag der Arbeitsgruppe Methoden der gesundheitsökonomischen Evaluation (AG MEG) bewertet, und Medikamente mit den tatsächlichen Kosten. Für Geschlecht, Alter, Krankenkasse (GKV/PKV) und Wohnort (Stadt/Land) wurde adjustiert, und Komorbiditäten mittels des Physical Functional Comorbidity Index (PFCI) berücksichtigt.

Ergebnisse: Die Exzesskosten der schweren Adipositas waren in Gruppen mit hohem SES höher, unabhängig vom verwendeten SES-Indikator. So waren diese jährlichen Exzesskosten in der Gruppe mit einem SES-Indexwert überhalb des Medians um den Faktor drei gegenüber der Gruppe mit einem medianen oder kleineren SES-Indexwert erhöht (plus € 2.966 vs. plus € 1.012; signifikanter Kontrast: $p<.001$). Die Vermittlung der Exzesskosten der schweren Adipositas durch körperliche Komorbiditäten beschränkte sich auf niedrigen SES-Index und Berufsstatus. Dabei waren die Kostendifferenziale zwischen schwerer Adipositas und Normalgewicht nach Adjustierung für den PFCI bei niedrigem SES zwar weiterhin positiv aber statistisch nicht mehr signifikant, hingegen waren sie bei höherem SES weiterhin positiv und signifikant. Hier betrugen die Exzesskosten der schweren Adipositas € 2.406 in der hohen SES-Indexgruppe ($p<.001$), jedoch € 539 in der unteren Statusgruppe ($p=.17$). Gleichzeitig waren körperliche Komorbiditäten im Sinne des PFCI positiv mit dem BMI und negativ mit dem SES assoziiert, wobei die Faktoren BMI und SES allerdings nicht signifikant interagierten.

Fazit: Die vorliegende Studie ist unseres Wissens die erste, die in Deutschland zeigt, dass die Exzesskosten der schweren Adipositas über unterschiedlichen SES-Gruppen ungleich verteilt sind, nicht den Komorbiditätsstatus reflektieren, und in hohen SES-Gruppen signifikant höher ausfallen als in niedrigeren SES-Gruppen. Es besteht offenbar Bedarf an einer besseren Allokation der Ressourcen gesundheitsbezogener Versorgung, die für (schwer) adipöse Erwachsene ausgegeben werden,

in Richtung auf eine bedarfsgerechtere Inanspruchnahme über alle sozio-ökonomischen Gruppen hinweg.

Schlüsselwörter: Adipositas, direkte Krankheitskosten, sozio-ökonomischer Status, Komorbiditäten, Deutschland

Introduction

Compared to normal weight, obesity has been shown to be associated with excess health care costs among adults in virtually all relevant studies (for reviews since 2005, see [1], [2], [3], [4], [5], [6]). Most pronouncedly, costs tend to increase with severe obesity, i. e. obesity classes II and III (for obesity classification, see [7]). Among 54- to 69-year-olds in the US, for instance, these classes result in 50% and 100% higher per-capita costs above normal weight, respectively, which compares to 25% for moderate obesity (i. e. class I) [8]. In another study on US adults aged 18 years or older, costs in class III were 81%, 65% and 47% greater than in normal weight, pre-obesity, and obesity class I, respectively [9]. Comparable data exists for Germany, where annual per-capita costs among adults aged 25 to 74 years have been estimated at € 2,572.19 in those severely obese versus € 1,080.59 in those moderately obese, comparing to € 847.60 in the normal weight group [10]. These variations in excess costs across different levels of obesity are especially relevant since the prevalence of severe obesity is growing at a faster rate than moderate obesity, including the US [11], [12]. In Germany, it can be estimated from national health monitoring data that the prevalence of moderate obesity was 1.3 times higher in 2002 than in 1985 (16.5% vs. 13.2%), whereas that of severe obesity more than doubled (6.5 vs. 3%) [13].

While it may not be surprising that severe obesity results in markedly higher excess costs both because it represents a more serious disease-related health problem than moderate obesity, and (multiple) concomitant medical conditions – i.e., (multi-)co¬morbidity – may be more likely, it is largely unknown whether these excess costs differ across different socioeconomic status (SES) groups. Apart from the well-known fact that obesity generally has a higher prevalence in lower SES groups to begin with [14], [15], it could be expected that socioeconomically disadvantated severely obese individuals have more comorbidities than higher SES groups, which under conditions of equitable health care should result in higher utilization of care. Conversely, if comorbidity is comparable, differences in costs for severely obese compared to normal weight patients (i.e., the excess costs attributable to this condition [16]) should be similar across different SES groups. Finally, the mediating role of comorbidities for excess costs should be independent of SES: *if* severely obese persons utilize health care more that those in normal weight range *because* they have comorbidities, this should – again, given equity – hold for both low and high SES groups. Against this background, this paper analyses excess direct medical annual per-capita costs of different forms of overweight (with special emphasis on severe obesity) within different SES groups in an adult population in Germany, and possible mediations of existing differences by physical comorbidity.

Methods

Population and sampling

Collection of data was conducted within the KORA- (Cooperative Health Research in the Region of Augsburg-) Survey S4 1999/2000, a representative cross-sectional health survey in the city of Augsburg and the two adjacent administrative districts, Germany (for general information on the KORA research platform, see [17]). Approval of the responsible ethics committee (Bavarian Medical Association, Munich) was secured. The target population consisted of all German residents of the region born between July 1, 1925 and June 30, 1975. A sample of N=6,640 was drawn in a two-stage sampling procedure. In addition to Augsburg city, 16 out of 70 communities from the adjacent counties were chosen by cluster sampling with probability proportional to size. Using public registry office listings, stratified random sampling was performed within each community, yielding ten strata of equal size according to gender and age. Selection within each stratum used the function RANUNI in SAS 8.1 for Windows. Fieldwork lasted from October 1999 to April 2001. The response rate was 67%, comparing well to other surveys [18]. A non-responder survey via telephone, in which 49% participated, revealed that non-responders more often had lower education (up to secondary general school: 65% vs. 54%) and fair or poor self-rated health (28% vs. 21%), were more often unmarried (34% vs. 29%) and smokers (29% vs. 26%), and more frequently reported physician contact in the last four weeks (46% vs. 38%), myocardial infarction (6% vs. 3%), and diabetes (7% vs. 4%) [18]. Ultimately, N=4,261 participated in this "main part" of the survey.

Of these, a random sample of N=1,186 with 30 nearly balanced strata by gender, age, and body mass index (BMI; see below, *Measures*) was drawn for a three-wave computer-assisted telephone interview- (CATI-) part of the survey after two, four, and six months. Ultimately, N=947 participated in all three waves (response rate: 80%). Fieldwork lasted from October 1999 to August 2001, and averaged over seven and a half months for any participant. Non-responders were more often men (23% vs. 17%), from the lowest socioeconomic stratum (23% vs. 19%), unmarried (27% vs. 17%), and smokers (29% vs. 17%), but did not differ in health care utilization or morbidity. N=5 with a BMI < 18.5 were excluded from analysis for reasons of cell count, and possible underweight-spe-

cific health problems, resulting in a sample size of N=942 for the present analysis.

Measures

Obesity

Body weight and height were assessed anthropometrically in the survey's physical examination part following international standards [17], [19]. Participants stood without shoes and heavy outer garments [20], and steelyards (SECA 709) with integrated scales (SECA 221) were used. Calibration of instruments was ensured by weekly or daily inspections using standard weights or resistors. Body mass was indexed by dividing weight in kg by (height in m)^2. Groups were defined following WHO classifications [7]: normal weight ($18.5 \leq BMI < 25$), preobesity ($25 \leq BMI < 30$), obese class I ($30 \leq BMI < 35$), obesity class II ($35 \leq BMI < 40$), and obesity class III ($BMI \geq 40$). For reasons of cell count (especially regarding class III) classes II and III were pooled. In line with WHO nomenclature [7], class I is referred to as "moderate obesity" and classes II–III as "severe obesity".

Direct medical costs

Utilization of care was assessed via self-report in the three CATI-waves. In each wave, items for physician utilization read as follows: "In the last 8 weeks, did you consult any physician?", *(if yes)* "How often did you consult a physician in the last 8 weeks?", and *(for every consultation)* "Which medical field did this physican belong to: general practitioner, internal specialist, *(for women)* gynaecologist, otorhinolaryngologist, dermatologist, dentist, or other?". For each field, the consultations were summed up across the three 8-week-periods, excluding dentists. Likewise, the number of inpatient days were estimated, using the following items in each CATI-wave:"„In the last 8 weeks, have you been hospitalised at all?" and *(if yes)* "In sum, how many days or weeks have you been hospitalised in the last 8 weeks?". Both physician consultations and inpatient days were valuated according to the recommendations of the Working Group "Methods in Health Economic Evaluation" (AG MEG) of the German Society of Social Medicine and Prevention [21], and extrapolated to 1 year. In contrast, costs for medications were determined as follows. In each CATI-wave, the following screening question was asked: "Have you received or purchased medications (with or without prescription) in the last week, irrespective of taking or applying it in this period of time?". If "yes", respective medications were assessed using the IDOM software, an instrument for collection and processing of medication data in computer-assisted interviews, which valuates these data with the prices in the drug classification by the German Drug Index of the Research Institute of the Local Sickness Funds (WIdO) [22]. Finally, total per-capita costs were defined by summing up costs for out- and inpatient use and medications per respondent. The identical method has already been used in a previous publication [10]. It has to be stressed that the monetary valuation not only of drugs, but of ambulatory medical services and hospital care as well, is based on identical unit costs across both public and private health insurance (which is not true in terms of prices). Therefore, cost differentials between subsamples of our study population cannot result from differences in the public-private insurance mix between the subsamples; instead, they always reflect differences in the volume of health care utilization.

Physical comorbidity

Physical comorbidity was assessed via the "Physical Functional Comorbidity Index" (PFCI) [23], [24], [25], which is based on the Functional Comorbidity Index (FCI) [26]. Basically, given the aim of the present and the earlier studies, it was crucial to assess individual health status of respondents on both a broad and valid basis. To this end, respondents' medical histories were drawn upon, which had been assessed by self-report for the last 12 months via the computer-aided personal interviewing (CAPI) part of the survey. Methodologically, these medical histories build on the MONICA (Multinational Monitoring of Trends and Determinants in Cardiovascular Disease) Augsburg protocol [17], [19]. Specifically, the selection of the FCI as basis for indexing comorbidities rested on two rationales. First, an alternative morbidity index employed in an earlier KORA-study [27] only represented a dichotomous index (i.e., any vs. no morbidity). Second, the FCI relates better than other indices for multimorbidity (e.g. the Charlson index [28]) to the medical histories' assessment in the KORA studies. Nevertheless, unlike the FCI, the PFCI does not include neurological diseases (such as multiple sclerosis or Parkinson's), depression, anxiety or panic disorders, visual impairments, and hearing impairments, since they were not available to us (hence, for conceptual precision, the designation *P*FCI), nor obesity (as it is the focal explanatory variable of the present analysis). All told, the PFCI takes into account the following diseases: myocardial infarction, cerebral infarction, diabetes, angina pectoris, arterial obstructive disease, cardiac insufficiency, arthrosis, attrition of vertebral column and/or intervertebral discs, osteoporosis, bronchial asthma, gastrointestinal diseases, and chronic obstructive pulmonary disease. This reduction from 18 to 12 conditions has been judged by the FCI's developer as rendering an index with acceptable validity (Dianne Groll, personal communication, April 01, 2006). Following FCI recommendations [25], the unweighted form of the index is used in the following analysis.

Socioeconomic status (SES)

Education, income and occupational status were assessed following national recommendations [29] and – besides being used as single indicators – summarized to a SES-index using the algorithm proposed by Helmert [30]. Variables are defined as follows: highest educational

level, equivalised income (net household income relative to number and age of household members, with weights of 1 for the head of the household, 0.5 for household members aged 6 years or younger, 0.65 for those between 7 and 14 years, 0.9 for those between 15 to 17, and 0.8 for those 18 or older), current or former employment status, and current or former occupational status (own or of partner). The SES-Index has a maximal range of 2–27 points and allows the following classification: lower social class (2–8 points), lower middle class (9–11 points), intermediate middle class (12–14 points), upper middle class (15–18 points), and upper social class (19–27 points). Yet, for the present analyses a median-split at 13 points had to be used due to small subsample sizes, despite taking losses in theoretical and statistical power implied by median-splitting [31]. For example, there are only N=10 respondents in the upper social class with severe obesity. This seriously jeopardizes the robustness of the mean costs estimate since even if assuming a medium effect size (e.g. 0.5), a subsample size of N=27 is necessary to determine whether the population mean equals some specified value with a test power of 0.8 (at p=.05).

Covariates

Sex, age and place of residence (urban vs. rural) were known from the sampling procedure, while type of health insurance (statutory vs. private) was assessed by self-report.

Statistical modelling

Following descriptive analysis, annual per-capita costs were analysed by generalized linear modelling as recommended in cost data analysis methodology [32]. Specifically, mixed poisson-gamma models were conducted (family=tweedie, link=log) based on the following rationales. First, the skewed distribution of the costs data was taken into account by the log link [33], and the increasing variability of costs with increasing BMI-values by dispersion modelling [34]. Second, this approach provides potentially more robust estimators than alternative models such as ordinary least squares (OLS) with normal errors, or OLS for the log normal [33][, [35]. Third, since mean costs for different subgroups based on all cases (i. e. including participants with no costs) is the primary interest (not utilization per se), a single-equation generalized linear model (GLM) was sought which allows for a non-zero probability of zero values [36], [37]. This is why a GLM with a mixed poisson-gamma (Tweedie) distribution [34], [38], [39], [40] was selected. This has been shown to compete well with two part binary/gamma models [38], and by involving only one equation it avoids the problem of post hoc adjustment for heteroscedasticity in order to remove biases in predicted means for the entire population and relevant subgroups [37]. For all analyses, SPSS Statistics 17.0 was used.

Finally, the aims of the present analysis were pursued in these GLM as follows. Following [16], any costs attributable to a given condition were defined as the difference between the costs in those affected by the condition (in the present case: preobesity, moderate obesity or severe obesity) and the costs in those without the condition (i.e. the baseline costs, here: the normal weight group). Accordingly, the analytical design implemented in GLM is as follows:

- Basically, in each GLM two factors were specified: BMI as the four groups defined above, and one of the four SES indicators, which are SES-Index (labeled SES), education (EDU), income (INC), and occupational status (OCC). Both the main effects and the interaction of the BMI- and the SES-factor were considered. Besides, sex, age, health insurance type, and place of residence were entered as covariates.
- In each model – besides the two main effects, their interaction, and the four covariates – the following contrasts were tested in line with the excess costs approach described above: “preobese vs. normal weight”, “moderately obese vs. normal weight”, and “severely obese vs. normal weight”. Specifically, each contrast was tested
  (a) overall, i. e. regardless of SES, EDU, INC, or OCC,
  (b) in regard to its interaction with the socioeconomic factor (e. g. “contrast BY SES”) to indicate whether the excess costs indicated in the contrast differed between each higher and lower socioeconomic group, and
  (c) within both the high and the low socioeconomic group (e. g. “contrast WITHIN SES-high” and “contrast WITHIN SES-low“) in order to determine if significant excess costs hold for both groups.
- Subsequently, the procedure described so far was repeated, now including the PFCI as a covariate in order to clarify whether existing excess costs are mediated by comorbidities [41].
- Finally, analyses were conducted on differences in the PFCI across BMI- and SES-subgroups (via GLM procedures corresponding to those described) in order to clarify if any differences in the BMI-PFCI-association by SES may determine costs differences.

Results

Table 1 describes the sample of N=942 participants by cross-tabulating the BMI-factor with all other variables. While overall, sex, age and place of residence are equally distributed since they served as stratification dimensions in the sampling procedure (besides BMI), a difference pertains to the fact that in the severely obese group, women represent a two-thirds majority. Furthermore, while only small differences are found for type of health insurance, respondents from lower socioeconomic groups are more strongly represented in obese vs. nonobese groups. This holds both for the SES-Index as well as for the single indicators education, income, and occupational status.

Table 1: Sample description [a, b]

	normal weight[c] N = 304	preobese N = 324	moderate obesity N = 233	severe obesity N = 81	TOTAL N = 942
women	163 (53.6%)	164 (50.6%)	111 (47.6%)	54 (66.7%)	492 (52.2%)
men	141 (46.4%)	160 (49.4%)	122 (52.4%)	27 (33.3%)	450 (47.8%)
25–34 years of age	65 (21.4%)	59 (18.2%)	39 (16.7%)	15 (18.5%)	178 (18.9%)
35–44 years of age	59 (19.4%)	63 (19.4%)	51 (21.9%)	14 (17.3%)	187 (19.9%)
45–54 years of age	56 (18.4%)	68 (21.0%)	44 (18.9%)	25 (30.9%)	193 (20.5%)
55–64 years of age	61 (20.1%)	69 (21.3%)	50 (21.5%)	14 (17.3%)	194 (20.6%)
65–74 years of age	63 (20.7%)	65 (20.1%)	49 (21.0%)	13 (16.0%)	190 (20.2%)
SES-Index (SES) ≤ median	137 (45.1%)	147 (45.4%)	139 (59.9%)	48 (59.3%)	471 (50.1%)
SES-Index (SES) > median	167 (54.9%)	177 (54.6%)	93 (40.1%)	33 (40.7%)	470 (49.9%)
education (EDU) ≤ secondary general school	133 (43.8%)	176 (54.3%)	155 (66.8%)	51 (63.0%)	515 (54.7%)
education (EDU) ≥ intermediate school	171 (56.2%)	148 (45.7%)	77 (33.2%)	30 (37.0%)	426 (45.3%)
equivalised income (INC) ≤ median	146 (50.3%)	163 (52.6%)	137 (61.4%)	48 (62.3%)	494 (54.9%)
equivalised income (INC) > median	144 (49.7%)	147 (47.4%)	86 (38.6%)	29 (37.7%)	406 (45.1%)
occupational status (OCC) ≤ foreman	118 (39.3%)	121 (37.8%)	118 (50.9%)	38 (48.7%)	395 (42.5%)
occupational status (OCC) ≥ qualified clerk	182 (60.7%)	199 (62.2%)	114 (49.1%)	40 (51.3%)	535 (57.5%)
statutory health insurance	251 (82.8%)	271 (85.8%)	202 (87.4%)	71 (88.8%)	795 (85.5%)
private health insurance	52 (17.2%)	45 (14.2%)	29 (12.6%)	9 (11.3%)	135 (14.5%)
rural place of residence	160 (52.6%)	186 (57.4%)	129 (55.4%)	48 (59.3%)	523 (55.5%)
urban place of residence	144 (47.4%)	138 (42.6%)	104 (44.6%)	33 (40.7%)	419 (44.5%)
no comorbidity (PCFI = 0)	153 (50.3%)	150 (46.3%)	87 (37.5%)	32 (39.5%)	422 (44.8%)
one comorbidity (PCFI = 1)	82 (27.0%)	92 (28.4%)	69 (29.7%)	17 (21.0%)	260 (27.6%)
multiple comorbidities (PCFI ≥ 2)	69 (22.7%)	82 (25.3%)	76 (32.8%)	32 (39.5%)	259 (15.6%)

Notes: [a] cell percentages are column percentages

[b] besides BMI, sex and age were stratification dimensions in sampling for this analysis sample, and sex, age, and place of residence in the main survey from which the sample was drawn (for details, see text). Thus, the cross-tabulations with BMI may not be viewed as reflecting the situation in the population.

[c] normal weight: 18.5 ≤ BMI < 25; preobese: 25 ≤ BMI < 30; moderately obese: 30 ≤ BMI < 35; severely obese: BMI ≥ 35

Finally, the proportions of multicomorbidity, i. e. scoring two or more conditions on the PFCI, increase with BMI.

Table 2 shows the distribution of annual direct medical costs for different subgroups. To begin with, the first column shows that overall a minority had no costs (14.7%), and even among the youngest subgroup, a similar assertion holds (25.9%). Regarding costs, overall € 1,043.03 per-capita were found on average (see second column). Outlier-trimming by excluding eight participants with costs exceeding € 20,450 reduced mean costs to € 780.99 (the cut-point of € 20,450 was chosen both because it lies in the interval characterized by an exceptionally large costs gap between a pair of adjoining participants – specifically, € 15,894.40 and € 22,818.98 –, and because it has been used before to define high utilizers in German health care, e.g. in risk adjustment schemes). However, excess cost analyses regarding obesity were not principally affected in terms of results. For instance, the mean costs of moderate and severe obesity were about 1.3 and 3.3 times higher than those of normal weight, respectively, for the sample including the outliers (€ 2,713.32 and € 1,110.52 vs. € 828.66, respectively). Without the outliers, these factors are 1.4 and 2.7 (€ 1,629.81 and € 865.77 vs. € 600.91), and thus are approximately equivalent. Along these lines, and because high utilizers eventually are part of health care as well as others, and often critical to health care costs, all following analyses include these eight outliers.

Mean cost differences across age and comorbidity groups are as expected, with highest costs in the 65- to 75-year-olds (€ 1,407.21) and especially those with two or more comorbidities (€ 1,990.60). Smaller differences are found for women vs. men, statutory vs. private health insurance, and rural vs. urban place of residence. Finally, slightly higher costs are seen in lower SES groups, regardless of SES indicator (index or single), due to slightly higher rates of those with costs exceeding € 20,450 (as indicated by the mean costs when excluding the latter cases).

Table 3 and Figure 1 show the main results of the present analysis. Table 3 shows the results from ten GLM models adjusted for sex, age, health insurance, and place of residence: two models with the BMI-factor only, without and with adjustment for the PFCI (I.(a) and I.(b)), and eight models with the BMI-factor and one of the four SES-factors, respectively, which again either do not (II.(a), III.(a), IV.(a) and V.(a)) or do adjust for the PFCI (II.(b), III.(b), IV.(b) and V.(b)). To begin with, the BMI-main effect is significant in both "BMI-factor only"-models I.(a) and I.(b) (p<.001). Specifically, in both cases the only significant contrast to normal weight is seen for severe obesity. Numerically, these excess costs are estimated at € 1,873.36 when not adjusting for PFCI and at € 1,339.38 after including the PFCI. These results basically replicate those reported previously [10] but now rest upon mixed poisson-gamma GLM instead of OLS and binary/gamma models.

More specifically related to the research questions of the present paper, models II.(a) and II.(b) which include the factors BMI and SES-Index can be summarized as follows. First, without adjusting for the PFCI, not the SES main effect but its interaction with the BMI-factor is significant. As the interactions of the three contrasts (preobesity, moderate obesity, and severe obesity vs. normal weight, respectively) indicate, all three cost differentials vary significantly across the two SES groups. Concerning severe obesity (i.e. the only category of overweight which had shown significant excess costs in model I.(a)), it is associated with higher excess costs in the higher SES-group (€ 2,965.83) than in the lower (€ 1,011.99). As shown in Figure 1.II.(a), upper graph, these differentials translate to mean costs of € 2,018 in the severely obese low SES-group (vs. € 1,006 in the respective normal weight group), and € 3,607 in the severely obese high SES-group (vs. € 641). After adjusting for the PFCI in model II.(b), two changes occur. On one hand, the SES-main effect becomes significant in that the overall estimated difference between high vs. low SES changes from € 127.04 (€ 1,167.42 – € 1,040.38) to € 298.40 (€ 1,161.95 – € 863.55) (not shown in the table). Closer inspection of this effect reveals that this is largely due to the fact that the estimated costs of moderate obesity in the low-SES group are reduced by the PFCI in this model (from € 944 to € 798; see Figures 1.II.(a) and 1.II.(b)). Finally, excess costs of severe obesity are mediated by the PFCI in the lower but not in the higher SES-group. While in the latter these excess costs are still highly significant (€ 2,406.33, p<.001), they are largely reduced in those with lower SES (€ 538.62, p=.170; see also Figure 1.II.(b)).

Regarding the three single indicators of socioeconomic position, results are largely equivalent to those for the index among the models with no adjustment for the PFCI. This includes that regardless of the indicator used, excess costs of severe obesity are found both in the low and the high status groups, and are significantly higher in the groups with higher social status (especially in the case of single indicator "education").

Adjustment for the PCFI renders more differential results. While excess costs of moderate and severe obesity are still higher in groups with higher socioeconomic position, the only case in which comorbidities significantly mediate the excess costs of severe obesity in the lower status group (i.e. like in the model with the SES-Index) is low occupational status, i. e. in those having foreman status or lower. Here, this excess cost estimate is reduced to € 752.12 (p=.072, from € 1,373.68, p=.005), while the respective mean differences both for below-median income and secondary general school or lower remain significant (Table 3). As Figure 1.V.(b) shows, the severely obese group with low occupational status has PFCI-adjusted estimated mean costs of € 1,677 (vs. € 925 in the normal weight group), while these are € 2,528 (vs. € 673) in the higher occupational status group.

Figure 2 summarizes the key results regarding severe obesity. As Figure 2(a) visualizes, without adjustment for comorbidities there are significant excess costs in all status groups, and they are significantly higher in the high vs. low status groups. This pattern is most pronounced

Table 2: Annual direct medical per-capita costs in different groups[a]

	N (%) with € 0	mean (€)	95%-CI lower bound	95%-CI upper bound	std. dev.	N (%) with > € 20,450	mean without those with costs over € 20,450 (€)
overall	130 (14.7%)	1,043.03	824.25	1,261.80	3,306.71	8 (0.9%)	780.99
women	56 (12.4%)	938.14	678.38	1,197.90	2,803.85	3 (0.6%)	756.55
men	74 (17.2%)	1,152.79	796.22	1,509.37	3,761.94	5 (1.1%)	806.70
25–34 years of age	42 (25.9%)	484.49	260.64	708.34	1,442.73	0 (0.0%)	484.49
35–44 years of age	29 (16.6%)	719.02	291.03	1,147.01	2,868.62	1 (0.5%)	523.80
45–54 years of age	33 (18.3%)	1,142.50	671.97	1,613.03	3,199.13	1 (0.5%)	973.33
55–64 years of age	13 (7.0%)	1,391.51	747.31	2,035.71	4,453.27	4 (2.1%)	777.95
65–74 years of age	13 (7.3%)	1,407.21	879.57	1,934.85	3,556.95	2 (1.1%)	1,117.63
SES-Index (SES) ≤ median	70 (16.0%)	1,060.16	731.52	1,388.80	3,499.47	5 (1.1%)	737.53
SES-Index (SES) > median	60 (13.6%)	1,026.05	735.52	1,316.57	3,107.81	3 (0.6%)	823.86
education (EDU) ≤ secondary general school	68 (14.1%)	1,109.74	783.27	1,436.21	3,659.14	6 (1.2%)	756.90
education (EDU) ≥ intermediate school	62 (15.7%)	961.11	682.47	1,239.74	2,816.75	2 (0.5%)	810.36
equivalised income (INC) ≤ median	70 (14.6%)	1,060.29	733.95	1,386.62	3,638.65	5 (1.0%)	733.94
equivalised income (INC) > median	60 (15.0%)	1,022.32	740.95	1,303.68	2,862.39	3 (0.7%)	837.29
occupational status (OCC) ≤ foreman	56 (15.0%)	1,120.97	739.14	1,502.80	3,755.33	5 (1.3%)	743.21
occupational status (OCC) ≥ qualified clerk	74 (14.6%)	985.42	729.17	1,241.67	2,933.96	3 (0.5%)	808.71
statutory health insurance	110 (14.7%)	1,062.31	820.90	1,303.73	3,365.51	7 (0.9%)	792.99
private health insurance	20 (15.3%)	932.76	421.56	1,443.96	2,957.44	1 (0.7%)	712.55
rural place of residence	69 (14.2%)	1,007.48	717.61	1,297.35	3,255.61	4 (0.8%)	760.56
urban place of residence	61 (15.6%)	1,087.08	752.61	1,421.54	3,372.54	4 (1.0%)	806.36
normal weight[b]	41 (14.4%)	828.66	487.66	1,169.67	2,924.69	2 (0.7%)	600.91
preobese	54 (18.0%)	790.29	527.12	1,053.45	2,316.24	1 (0.3%)	690.35
moderately obese	26 (11.7%)	1,110.52	674.79	1,546.26	3,294.33	2 (0.9%)	865.77
severely obese	9 (12.3%)	2,713.32	1,221.76	4,204.87	6,392.81	3 (4.1%)	1,629.81
no comorbidity (PCFI = 0)	81 (20.8%)	528.19	381.92	674.47	1,467.35	0 (0.0%)	528.19
one comorbidity (PCFI = 1)	32 (13.1%)	913.42	473.47	1,353.36	3,503.20	2 (0.8%)	627.00
multiple comorbidities (PCFI ≥ 2)	17 (6.9%)	1,990.60	1,396.30	2,584.90	4,722.59	6 (2.4%)	1,349.67

Notes: [a] unadjusted data
[b] normal weight: 18.5 ≤ BMI < 25; preobese: 25 ≤ BMI < 30; moderately obese: 30 ≤ BMI < 35; severely obese: BMI ≥ 35

Table 3: Annual direct medical per-capita costs by BMI and four different SES-indicators (a) unadjusted and (b) adjusted for PFCI: GLM tests [a, b, c]

source of variation	statistic	(a) unadjusted for PFCI value	(a) unadjusted for PFCI p	(b) adjusted for PFCI value	(b) adjusted for PFCI p
I. models with factor BMI only					
BMI [d]	*Wald* χ^2	105.64	<.001	71.48	<.001
contrast analysis					
"preobese vs. normal weight"	*mean difference*	€ –112.39	.481	€ –92.02	.698
"moderately obese vs. normal weight"	*mean difference*	€ 165.10	.283	€ 131.64	.463
"severely obese vs. normal weight"	*mean difference*	€ 1,873.36	<.001	€ 1,339.38	<.001
PFCI	*Wald* χ^2	–	–	80.94	<.001
II. models with factors BMI and SES-Index (SES) [e]					
SES	*Wald* χ^2	2.38	.123	11.58	.001
BMI × SES	*Wald* χ^2	20.10	<.001	19.26	<.001
contrast analysis					
"preobese vs. normal weight" BY SES	*Wald* χ^2	13.25	<.001	11.08	.001
"moderately obese vs. normal weight" BY SES	*Wald* χ^2	6.01	.014	7.11	.008
"severely obese vs. normal weight" BY SES	*Wald* χ^2	14.79	<.001	15.15	<.001
"preobese vs. normal weight" WITHIN SES-high	*mean difference*	€ 162.24	.751	€ 144.81	.999
"moderately obese vs. normal weight" WITHIN SES-high	*mean difference*	€ 391.60	.041	€ 409.14	.036
"severely obese vs. normal weight" WITHIN SES-high	*mean difference*	€ 2,965.83	<.001	€ 2,406.33	<.001
"preobese vs. normal weight" WITHIN SES-low	*mean difference*	€ –428.10	.003	€ –355.04	.008
"moderately obese vs. normal weight" WITHIN SES-low	*mean difference*	€ –62.81	.999	€ –91.33	.999
"severely obese vs. normal weight" WITHIN SES-low	*mean difference*	€ 1,011.99	.013	€ 538.62	.170
III. models with factors BMI and education (EDU) [f]					
EDU	*Wald* χ^2	3.58	.058	10.72	.001
BMI × EDU	*Wald* χ^2	15.94	.001	14.44	<.002
contrast analysis					
"preobese vs. normal weight" BY EDU	*Wald* χ^2	2.58	.108	1.35	.245
"moderately obese vs. normal weight" BY EDU	*Wald* χ^2	10.19	.001	10.90	.001
"severely obese vs. normal weight" BY EDU	*Wald* χ^2	11.28	.001	7.44	.006
"preobese vs. normal weight" WITHIN EDU-high	*mean difference*	€ 19.64	.999	€ 0.01	.999
"moderately obese vs. normal weight" WITHIN EDU-high	*mean difference*	€ 567.99	.011	€ 586.04	.009
"severely obese vs. normal weight" WITHIN EDU-high	*mean difference*	€ 3,120.87	<.001	€ 2,287.93	<.001
"preobese vs. normal weight" WITHIN EDU-low	*mean difference*	€ –258.15	.194	€ –181.25	.564
"moderately obese vs. normal weight" WITHIN EDU-low	*mean difference*	€ –102.17	.999	€ –109.28	.999
"severely obese vs. normal weight" WITHIN EDU-low	*mean difference*	€ 1,151.07	.002	€ 799.62	.010

(Continued)

Table 3: Annual direct medical per-capita costs by BMI and four different SES-indicators (a) unadjusted and (b) adjusted for PFCI: GLM tests [a, b, c]

IV. models with factors BMI and income (INC) [g]						
INC	*Wald* χ^2	1.31	.252	2.05	.152	
BMI × INC	*Wald* χ^2	13.59	.004	11.20	.011	
contrast analysis						
"preobese vs. normal weight" BY INC	*Wald* χ^2	1.31	.251	1.61	.204	
"moderately obese vs. normal weight" BY INC	*Wald* χ^2	8.71	.003	10.15	.001	
"severely obese vs. normal weight" BY INC	*Wald* χ^2	8.85	.003	3.84	.050	
"preobese vs. normal weight" WITHIN INC-high	*mean difference*	€ −7.21	.999	€ 12.27	.999	
"moderately obese vs. normal weight" WITHIN INC-high	*mean difference*	€ 507.87	.013	€ 503.54	.012	
"severely obese vs. normal weight" WITHIN INC -high	*mean difference*	€ 2,773.44	<.001	€ 1,798.77	<.001	
"preobese vs. normal weight" WITHIN INC-low	*mean difference*	€ −210.16	.465	€ −191.84	.499	
"moderately obese vs. normal weight" WITHIN INC-low	*mean difference*	€ −81.54	.999	€ −115.77	.999	
"severely obese vs. normal weight" WITHIN INC-low	*mean difference*	€ 1,194.52	.003	€ 988.39	.005	
V. models with factors BMI and occupational status (OCC) [h]						
OCC	*Wald* χ^2	0.06	.796	4.51	.034	
BMI × OCC	*Wald* χ^2	12.82	.005	14.34	.002	
contrast analysis						
"preobese vs. normal weight" BY OCC	*Wald* χ^2	8.22	.004	7.66	.006	
"moderately obese vs. normal weight" BY OCC	*Wald* χ^2	9.22	.002	10.89	.001	
"severely obese vs. normal weight" BY OCC	*Wald* χ^2	5.92	.015	7.36	.007	
"preobese vs. normal weight" WITHIN OCC-high	*mean difference*	€ 85.79	.999	€ 84.93	.999	
"moderately obese vs. normal weight" WITHIN OCC-high	*mean difference*	€ 422.30	.012	€ 422.50	.012	
"severely obese vs. normal weight" WITHIN OCC-high	*mean difference*	€ 2,266.85	<.001	€ 1,854.93	<.001	
"preobese vs. normal weight" WITHIN OCC-low	*mean difference*	€ −404.86	.020	€ −346.82	.029	
"moderately obese vs. normal weight" WITHIN OCC-low	*mean difference*	€ −158.14	.999	€ −187.80	.926	
"severely obese vs. normal weight" WITHIN OCC-low	*mean difference*	€ 1,373.68	.005	€ 752.12	.072	

Notes:
[a] adjusted for sex, age, type of health insurance (statutory vs. private), and place of residence (urban vs. rural)
[b] family: tweedie; link: log
[c] mean differences can be interpreted as cost differentials and, if positive, excess costs
[d] normal weight: 18.5 ≤ BMI < 25; preobese: 25 ≤ BMI < 30; moderately obese: 30 ≤ BMI < 35; severely obese: BMI ≥ 35
[e] SES-low: < median, SES-high: ≤ median
[f] EDU-low: ≤ secondary general school, EDU-high: ≥ intermediate school
[g] INC-low: < median, INC-high: ≤ median
[h] OCC-low: ≤ foreman, OCC-high: ≤ qualified clerk

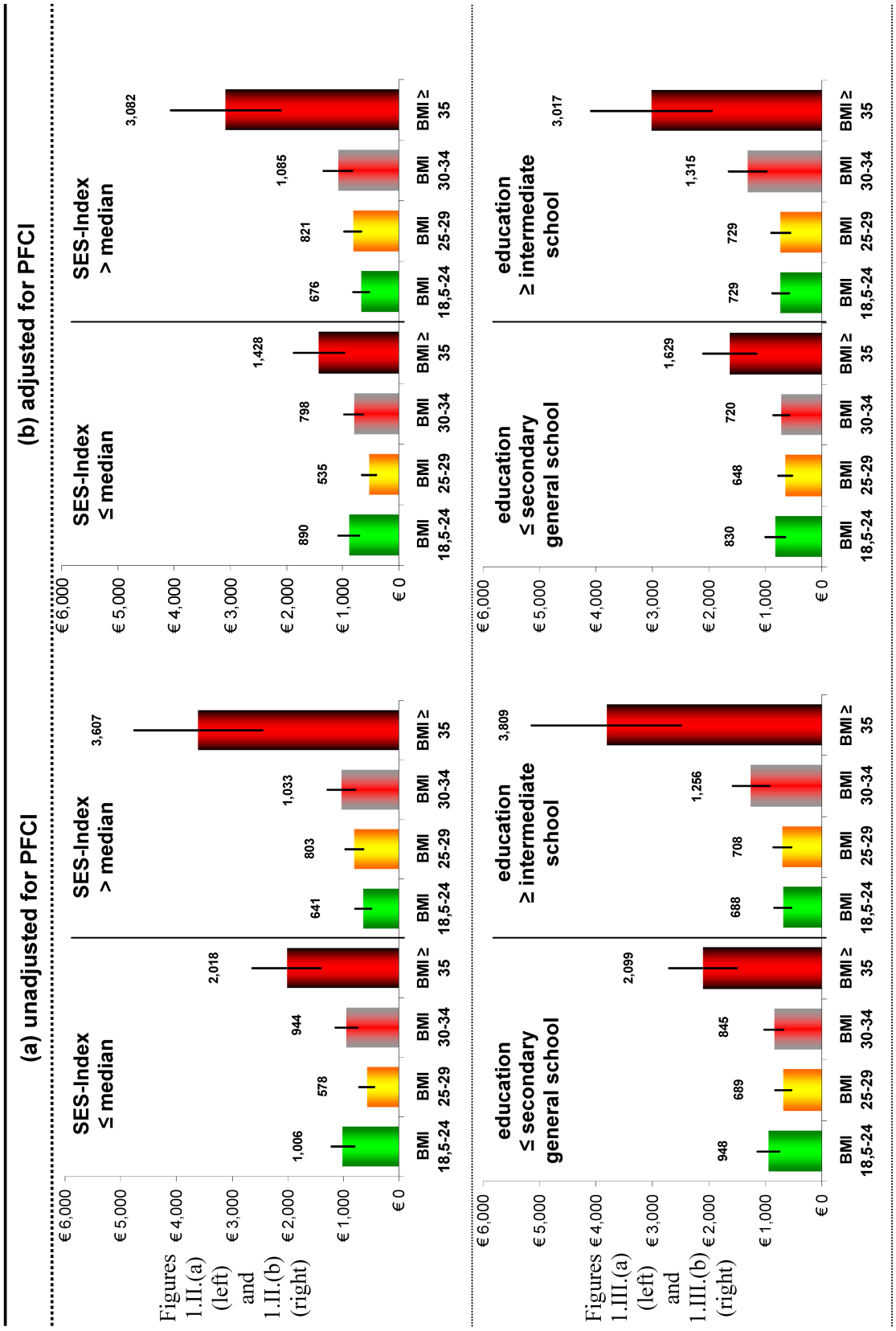
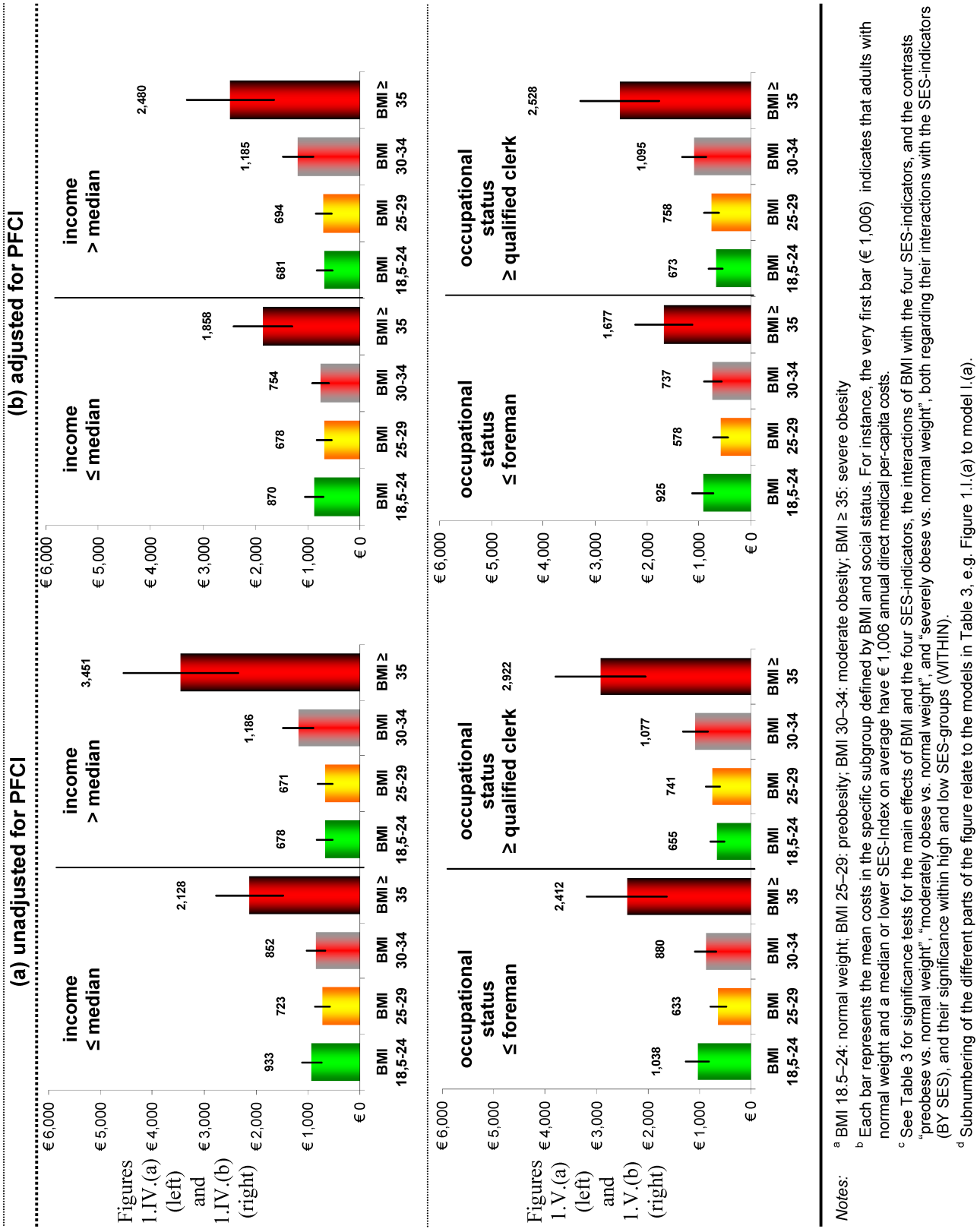


Figure 1: Annual direct medical per-capita costs by BMI and four different SES-indicators (a) unadjusted and (b) adjusted for PFCI: GLM estimates [a, b, c, d]



Notes:

[a] BMI 18.5–24: normal weight; BMI 25–29: preobesity; BMI 30–34: moderate obesity; BMI ≥ 35: severe obesity

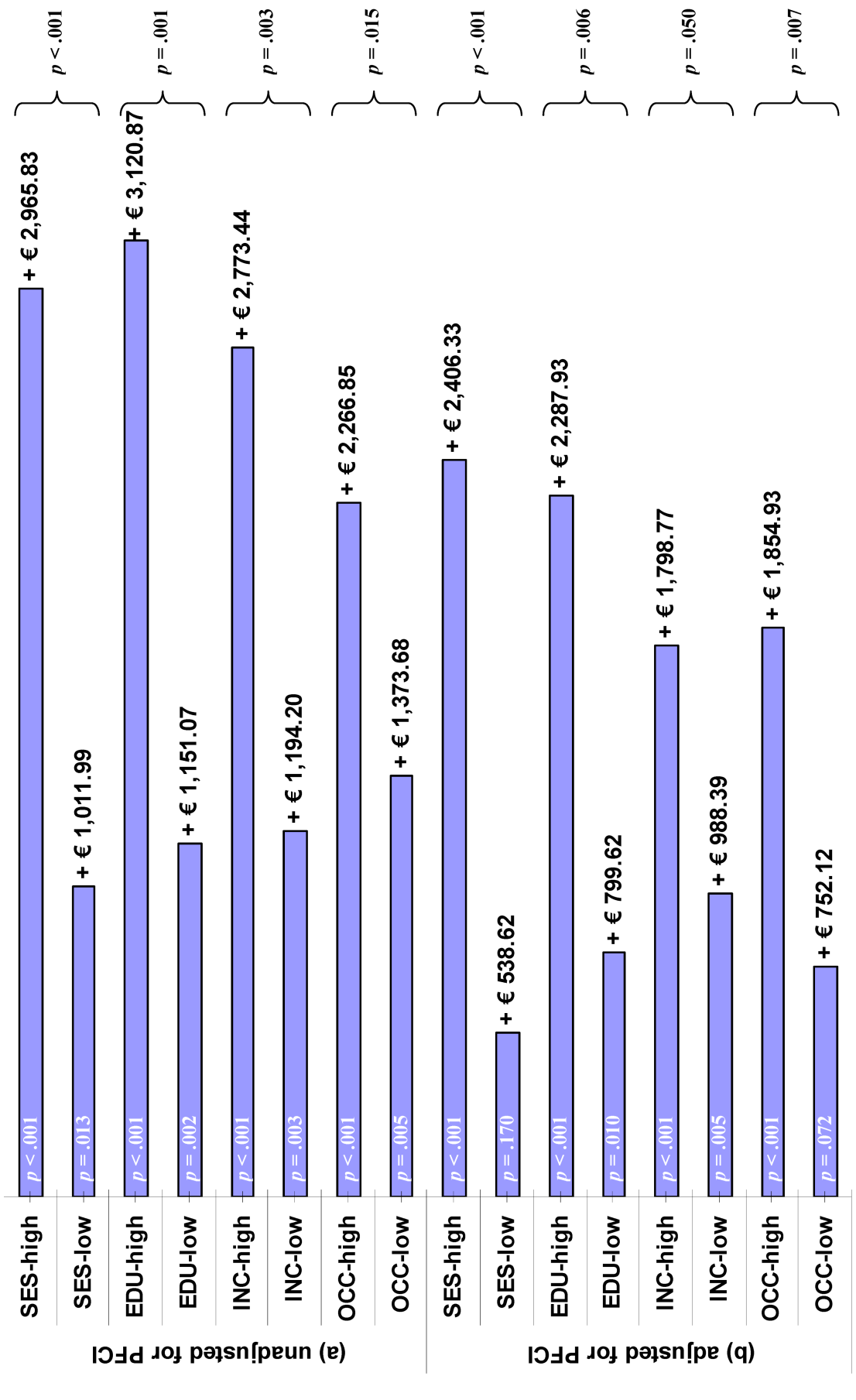
[b] Each bar represents the mean costs in the specific subgroup defined by BMI and social status. For instance, the very first bar (€ 1,006) indicates that adults with normal weight and a median or lower SES-Index on average have € 1,006 annual direct medical per-capita costs.

[c] See Table 3 for significance tests for the main effects of BMI and the four SES-indicators, the interactions of BMI with the four SES-indicators, and the contrasts "preobese vs. normal weight", "moderately obese vs. normal weight", and "severely obese vs. normal weight", both regarding their interactions with the SES-indicators (BY SES), and their significance within high and low SES-groups (WITHIN).

[d] Subnumbering of the different parts of the figure relate to the models in Table 3, e.g. Figure 1.I.(a) to model I.(a).

(Continued)

Figure 1: Annual direct medical per-capita costs by BMI and four different SES-indicators (a) unadjusted and (b) adjusted for PFCI: GLM estimates [a, b, c, d]



Notes: [a] Abbreviations: PFCI: Physical Functional Comorbidity Index, SES: SES-Index, EDU: education, INC: income, OCC: occupational status; [b] *p*-values in the bars denote the contrast "severe obesity vs. normal weight" within the social status group in question, and those at the right the interaction of this contrast by the social status factor in question

Figure 2: Excess costs of severe obesity (BMI = 35) for different SES-groups (a) unadjusted and (b) adjusted for PFCI: Summary of GLM estimates [a, b]

for the SES-index and education: excess costs of severe obesity in those with a high SES-index and high education amount to € 2,965.83 and € 3,120.87, and compare to € 1,011.99 and € 1,151.07 in those with lower status, respectively (differences between high and low status group significant at $p<.001$ and $p=.001$, respectively). As Figure 2(b) shows, adjustment for the PFCI renders decreased *and* consistently significant excess costs in all groups but those with a low SES-Index (€ 538.62) and a low occupational status (€ 752.12). In other words, physical comorbidities significantly mediate excess costs of severe obesity – if at all – in lower social status groups. Finally, to explore the possibility that the cost differentials described so far reflect differences in the association between BMI and PFCI by SES, a GLM was run on differences in the PFCI across BMI- and SES-subgroups (as a PFCI validation analysis in the KORA S4 main survey). Unexpectedly, the BMI by SES-subgroups with high costs did *not* show correspondingly high values on the PFCI. By way of example, while main effects of the factors BMI and SES-Index were significant (Wald $\chi^2=46.83$ and 27.61, respectively; $p<.001$) and indicated that comorbidities increased with high BMI and low SES, there was no interaction between these two factors (Wald $\chi^2=0.62$; $p=.891$). Thus, no evidence was found that the excess burdens of disease in the preobese, moderately obese and severely obese groups are more pronounced in those with high SES than those with lower SES (or, for that matter, vice versa).

Discussion

Drawing on earlier published data which showed that the excess direct medical per-capita costs of obesity in Germany are by and large restricted to severe (vs. moderate) obesity [10], the present analyses reveal two addenda to this general finding. First, the excess costs of severe obesity are more pronounced in individuals with comparably high SES, regardless of which SES indicator is used (SES-Index by Helmert, education, income, or occupational status). For instance, the excess costs of severe obesity are almost three times as high in those with an above-median value on the SES-Index as compared to those with median or lower SES, with similar assertions holding for education and income. In the case of occupational status, excess costs are roughly twofold in the higher status group. Second, mediation of excess costs of severe obesity by physical comorbidity only pertains to the lower SES groups. Specifically, in the cases of the SES-Index and occupational status, the difference in costs between severe obesity and normal weight is still positive but insignificant in the lower status group after adjusting for the PFCI. In contrast, it is positive and still significant in the higher status group. Conversely, excess costs of severe obesity are significant in both low and high education and income groups both before and after adjustment for the PCFI, which indicates that there is no mediation by the PFCI. Numerically, excess costs estimates of severe obesity are almost halved by PFCI-adjustment in the groups defined by low SES-Index and low occupational status (reductions of 47% and 45%, respectively), while downsized by only about one fifth (19% and 18%) in the high status groups. Regarding education, the reduction in the lower status groups is higher as well, however by a clearly smaller margin (31% vs. 27%). Regarding income, we found a 17% reduction in the low vs. a 35% in the higher status group.

Several limitations of this study have to be considered. First, the study sample only includes individuals of German nationality living in the city and region of Augsburg. Second, the KORA-Survey S4 had a nonresponse rate of 33%. While this makes extrapolations to the total population difficult, there are no indications that it biases cost differentials between the overweight groups and the normal weight reference group. Third, the study only includes about two-thirds of the total health care costs spectrum, i.e. outpatient care (general practitioners and medical specialists), medications, and inpatient care. The exclusion of, most importantly, rehabilitative care and medical aids and remedies, but also of complementary and alternative services (for which data were not available) implies a tendency to underestimate absolute costs differentials between BMI-groups; whether this also applies to relative differentials as well is difficult to judge. Also, it has to be noted that actual costs were known for medications only, while for out- and inpatient services, standard costs were used. Here, especially the use of nationwide averages of daily hospital rate does imply some imprecision, but there seems to be no obvious tendency to under- or overestimate mean cost or costs differentials. Fourth, the study is cross-sectional, and thus does not allow causal conclusions. Nevertheless, since the PCFI was included in the present analysis, so at least physical comorbidities were available and analysed as a mediator.

Fifth, due to subsample size limitations, stratification over and beyond the BMI x SES-grouping was possible neither for sex, age, statutory vs. private type of health insurance, nor urban vs. rural place of residence (i.e., the covariates in the present analyses). While this is not uncommon in cost of illness studies in the context of obesity [9], further studies should provide more indepth scrutiny of subgroups. In the present context, it has to suffice to say that results are robust against excluding the privately insured participants (which may be of special interest given current two-class medicine discussions in Germany). That is, when looking only at those participants from statutory sickness funds, the interactions both of the factors BMI and the SES-Index, and the "severe obesity vs. normal weight"-contrast with the SES-factor, were significant (Wald $\chi^2=26.19$ and 16.87, respectively; $p<.001$), and the PFCI mediated the excess costs of severe obesity in those with low SES (mean difference after adjustment: € 556,43, $p=.206$) but not those with high SES (€ 2.831,88, $p<.001$). Also, the excess costs of severe obesity were on the same level as in the analysis which included the privately insured.

Sixth, sample size and power considerations only allowed for dichotomizations of SES-indicators, thus reducing analytical sensitivity to social gradients and absolute deprivation. However, contrasting two SES-groups defined by median splits is statistically conservative, i.e. differentiating between more groups would probably more easily detect cost differentials.

Finally, while the assessment of comorbidities by the PFCI used a recognized instrument [23], [24], [25], it does not include all possible physical (co-)morbidities. This is why we recalculated the main GLM with the physical health summary measure of the SF-12 [42] instead the PFCI. This rendered comparable results: the interactions both of the factors BMI and the SES-Index, and the "severe obesity vs. normal weight"-contrast with the SES-factor, were significant (Wald χ^2=26.41 and 19.36, respectively; p<.001), and poor subjective physical health mediated the excess costs of severe obesity in those with low SES (mean difference after adjustment: € 429,23, p=.339) but not those with high SES (€ 2.370,59, p<.001). Against this background, the role of physical comorbidity for the excess costs of severe obesity seems to be fairly robust. In contrast, no such assertion is possible regarding mental comorbidities since the PFCI does not include these, and since the SF-12 mental health summary measure has been shown to be associated neither with preobesity nor obesity in this population [43].

With these limitations in mind, results can be read as follows. To begin with, the significantly higher excess costs of moderate and especially severe obesity in all groups with high vs. low SES raise the question how health care in both groups is related to need. Because the pattern of costs does not parallel the burden of comorbidities in the different subgroups, which shows increasing comorbidities associated with increasing BMI and higher SES, but no interaction, both underuse in low-SES groups and overuse by high-SES groups are possible explanations. Because information on the actual reasons of health care use were not available in the present data (and mental comorbidities not covered by the PCFI), compelling arguments for or against either one interpretation unfortunately are not viable. Possibilities are that severely obese high-SES patients may be more aware of the condition and assertive in negotiating the quality and quantity of the health care they receive, or offered more services. In addition, it is interesting that in the only other study we could find on SES-differences in excess costs of obesity, namely from Taiwan [44], excess costs of obesity have been found only in low, not high SES groups (as defined by education and income). Again, the empirical basis of our study does not allow conclusions on how to explain these differences. Among other reasons, we cannot say whether specificities of the Taiwanese compared to the German health care system – e.g., a national health insurance rooting in universalism rather than in corporatism [45], and patients who tend to use (expensive) services of (university) hospitals to the disadvantage of practices [46] – play any role here. In sum, the question whether differences in excess costs of severe obesity across SES groups actually do represent instances of the inverse care law [47] has to remain unanswered until more conclusive studies (possibly including supraindividual variables such as health care system parameters) are available. Such research should scrutinize routine healthcare data in order to account for the main diagnoses and actual costs of consultations and inpatient services, and provide empirical data on appropriate health care costs for different levels of overweight in longitudinal designs. Furthermore, the issue remains why in the present study excess costs of severe obesity were significantly mediated by comorbidities only in groups defined by a median or below-median value on the SES-Index or a low occupational status, but not low education or low income. First of all, the general findings that mediation was observed in lower SES-groups only is in accordance with earlier findings indicating that such groups use more services partly because they suffer from more illnesses [48]. Furthermore, besides being in agreement, by scrutinizing all four indicators, with the assertion that the sole use of indices to measure SES is not advisable [49], different SES-indicators represent different phenomena and may tap into different causal mechanisms [50]. In the present case, health care services were possibly used until comorbidities were dealt with (and then stopped) by the group with low occupational status either because there was more pressure to return to work or because their perception of opportunities to influence their own life, including health, was lower than those with high status due to lesser work control. However, since control of one's life circumstances has been argued to be responsible for effects of all three single SES indicators [50] (and thus does not truly discriminate between the three), compelling explanations for differences in mediation of excess costs of severe obesity by comorbidity across SES-indicators remain to be determined.

Conclusions

Excess costs of severe obesity in German adults are higher in those with high SES than in those with lower SES, regardless of whether the SES-index or single indicators were used. In addition, these excess costs are mediated by comorbidities only in those with low SES defined either by a median or lower SES-Index, or low occupational status. At the same time, physical comorbidities increase with BMI and decrease with SES, but the factors BMI and SES did not significantly interact in this regard. Economically, if the trend that prevalences of severe obesity increase more steeply in groups with high social risks [15] will continue in the future, this may reduce increases in health care costs driven particularly by severe obesity. Regarding equity issues, as far as we know the present study is the first to show in Germany that excess direct medical costs of severe obesity are not distributed equitably across different SES groups, do not reflect comorbidity status, and are significantly higher in those with high SES than in those with lower SES. Thus,

allocation of health care resources spent on severely obese adults seems to be in need of readjustment towards an equitable utilization across all socioeconomic groups [51].

Notes

KORA Study Group

The KORA Study Group consists of H.-E. Wichmann (speaker), A. Peters, C. Meisinger, T. Illig, R. Holle, J. John, and co-workers who are responsible for the design and conduct of the KORA studies.

Conflicts of interest

None.

Acknowledgements

This research uses data from the KORA Survey S4 1999-2001, a project conducted by the research platform KORA (Cooperative Health Research in the Region of Augsburg). KORA was initiated and financed by the Helmholtz Center Munich – German Research Center for Environmental Health (formerly: GSF – National Research Center for Environment and Health), Neuherberg, Germany, which is funded by the German Federal Ministry of Education and Research and by the State of Bavaria. Julia Hartmann, Hannelore Nagl and Andrea Wulff are acknowledged for their contribution to data administration and management.

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Please cite as
von Lengerke T, John J, Mielck A, KORA Study Group. Excess direct medical costs of severe obesity by socioeconomic status in German adults. GMS Psychosoc Med. 2010;7:Doc01.
DOI: 10.3205/psm000063, URN: urn:nbn:de:0183-psm0000635

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Published: *2010-04-20*

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