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Impact of Waist Circumference Difference on Health-Care Cost among Overweight and Obese Subjects: The PROCEED Cohort

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ABSTRACT

Objective: To estimate the incremental effect of waist circumference (WC) on health-care costs among overweight and obese subjects after adjusting for body mass index (BMI).

Methods: A prospective study. The subjects were members of Internet panels in the United States (US) and Germany. 10,816 individuals (United States: n = 5410; Germany: n = 5406) aged 30–70 years with BMI scores between 20 and 35 kg/m^2 were recruited and grouped by category: healthy weight (BMI 20–24.9 kg/m^2), overweight (BMI 25–29.9 kg/m^2), and obese (BMI 30–35 kg/m^2). Within the overweight and obese categories, the individuals were stratified by sex and within those subgroups, characterized as above or below the median WC. The subjects self-reported weight, WC, and health-care resource use at baseline, 3 months, and 6 months using online questionnaires. Over 65% of the recruited subjects completed all surveys. Resource utilization was translated into health-care costs by multiplying unit costs from national sources in each country. Annualized health costs were summarized for subjects with low and high WC within the overweight and obese categories. A two-part model generated predicted annual costs because of the WC difference controlling for BMI, demographic, and lifestyle variables among the overweight and obese subjects.

Results: When BMI and other characteristics are constant, annual health-care costs are 16% to 18% higher in Germany and 20% to 30% higher in the United States for the subjects with a high WC compared with subjects with a low WC.

Conclusions: Targeting people with a high waist circumference for weight management whether they are overweight or obese may maximize cost-efficacy.

Keywords: health-care costs, health conditions, obesity, waist circumference.

Introduction

Obesity remains a critical and common health problem in the United States. Numerous clinical studies have shown that obesity is associated with increased mortality [1] and morbidity [2–5], and decreased quality of life [6] as well as increased disability [7,8] and increased health-care costs [9,10]. Although obesity is usually defined by measurements of body mass index (BMI) [11], recently, it has been suggested that diseases may be associated more with abdominal obesity (AO) than with BMI-defined obesity [12]. While links between AO and diabetes and coronary heart disease risk are well established [13], the costs associated with AO are less documented. Most large prospective studies have evaluated the association between BMI, waist circumference (WC), and health [13–16], but none of these studies have explored the relationships with AO on health-care utilization and costs. A large Danish cohort study reported an association between high WC at baseline and subsequent health costs among an older population [17]. Quantifying the impact of AO on health-care costs would help refine the evaluation of the burden of obesity and may facilitate the effective targeting of intervention. In addition, performing this research in both the United States and one European country would provide a more informative result, independently of an individual health-care system.

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In 2005, we conducted a pilot study of normal, overweight, and obese individuals [18] to ascertain the effects of BMI and AO/WC on diseases and health-care costs. The results suggested a higher prevalence of diseases among those with higher WCs within a particular BMI category and showed that subjects with AO had higher resource use and costs compared to subjects without AO [18]. However, results were mixed when the analysis was reconsidered using WC categories based on AO cutpoints (defined by adult treatment panel [ATP] III or International Diabetes Federation [IDF]) within each category of BMI [19]. Therefore, this full phase study was designed to examine the effect of WC in the overweight and obese groups using cutpoints determined from the natural distribution of WC. Specifically, analyses were designed to make comparisons within BMI categories by WC subgroups by sex [i.e., overweight above and below the median WC; obese above and below the median WC].

Hence, the objective of this study is to estimate the incremental effect of increasing WC on health-care costs for overweight and obese patients with the same BMI (after adjustment for patient-specific characteristics, such as lifestyle and demographic factors), in both the United States and Germany.

Methods

Study Design

The PRospective Obesity Cohort of Economic Evaluation and Determinants (PROCEED) Full Phase Study is a prospective

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cohort study in the United States and Germany that collected self-reported health and health-care utilization data on normal weight ($20 \geq$ BMI < 25 kg/m^2), overweight ($25 \geq$ BMI < 30 kg/m^2), and obese ($30 \geq$ BMI ≤ 35 kg/m^2) individuals followed up for 6 months via the Internet. The BMI cutoff points were selected based on well-established definitions for overweight and obesity [20]. Within each BMI category, recruitment was further stratified by sex to accomplish equal sex ratio (i.e., 50% males and 50% females) within each BMI category.

Sample Size

The sample size was determined by formal sample size calculations, based on US pilot study data, accounting for expected retention. A two-sided *t* test of costs would have 80% power to detect a statistical difference if prescription costs are $141 higher in the high WC subgroup than the low WC subgroup of the overweight subjects (difference of $407 within the obese subjects) assuming a common standard deviation ($1117) and alpha (0.05). The normal weight group (control group) size was not based on statistical considerations and was chosen to provide a qualitative reference only.

Recruitment was stratified by BMI and sex to accomplish a 50% male–female ratio within each BMI category, such that each country would include the following at baseline:

- 200 participants (100 males; 100 females) with $20 \geq$ BMI < 25 kg/m^2 (control);
- 4000 participants (2000 males; 2000 females) with $25 \geq$ BMI < 30 kg/m^2 (overweight);
- 1200 (600 males; 600 females) participants with $30 \geq$ BMI ≤ 35 kg/m^2 (obese).

Data Collection

The study subjects were identified from existing large Web-based research panels in the United States and Germany. The panel members were Internet users who had voluntarily registered with the panel. For this study, a random sample of existing panel members who met the age, country, and participation criteria were invited to participate via email. The email directed the panelist to the online screening questionnaire to determine study eligibility. The panelists were selected for inclusion if they met the eligibility criteria: between the ages of 30 and 70 years (inclusive); able to provide consent; had Internet access; able to read English (US participants) or German (German participants); weighed less than the scale limit of 130 kg (286 pounds); provided weight and WC measurements at screening and baseline; had $20 \geq$ BMI ≤ 35 kg/m^2; and if female, were not pregnant.

The flow of data collection is illustrated in Figure 1. As quotas were met in each BMI category for each sex, recruitment into that category was stopped. For the subjects who met the inclusion criteria in the screening survey, scales and tape measures were provided at no cost to the participants within 2 weeks of screening to standardize the tools used for weight and waist measurement assessment. Then, these eligible subjects were sent email invitations to participate in the baseline survey. Eligibility was reconfirmed based on the weight and WC reported using the study supplies. The eligible subjects completed the baseline survey and two quarterly surveys.

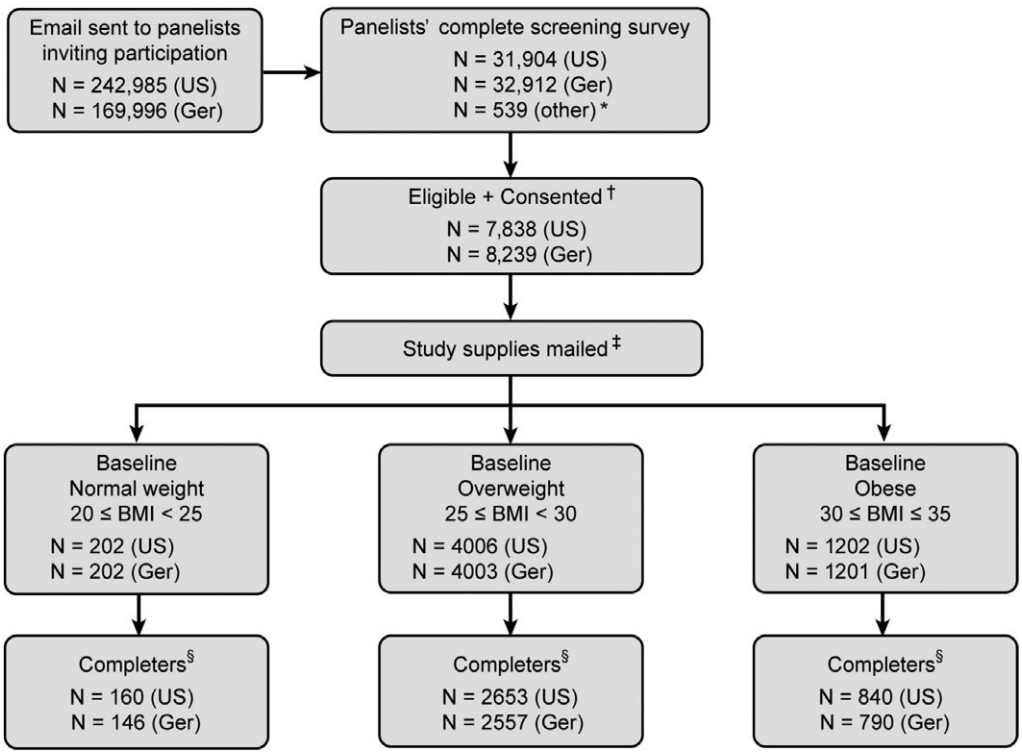


Figure 1 Subject recruitment and retention. *Did not report country or reported a country other than the United States or Germany. †Panelists who completed screening survey and met study criteria and consented to participate. ‡760 participants did not receive study supplies because supplies ran out (0.26% in the United States and 0.35% in Germany). §Completers are subjects who completed all three assessments (baseline, month 3, and month 6). BMI, body mass index; Ger, Germany; US, United States.

To validate the body measurements, in-home visits were made to a random subsample of the respondents using the same approach as described in the PROCEED Pilot Study [18]. At baseline, the overall difference between the self-reported and the measured weight was <0.5 kg (correlations between 0.96 and 0.98) and 0.10 cm for WC (correlations between 0.87 and 0.88).

To ascertain the primary reasons for lost to follow-up, a survey was conducted at the completion of the PROCEED 6-month follow-up period. Those individuals who did not respond to the month 6 survey were contacted by telephone and a brief interview was conducted to collect information on health status, recent resource use, and reason for discontinuation. A Web-based survey was also offered for the respondents who did not have time for or who were unwilling to participate in a telephone interview.

The participants received "points" equivalent to US$10 for each completed assessment and the equivalent of US$5 "bonus" points if they completed all the assessments. Points were redeemable for merchandise through the research panel.

The study was approved by RTI International's institutional review board and the German Ethics Committee of the Technical University of Munich.

Outcome Measures

Key outcomes were health-care consumption including pharmaceutical use and inpatient and outpatient care. Health-care resource use during the previous 3 months was assessed based on self-reported responses to questions about hospitalizations (number, length of stay, reason), emergency room or surgery visits, health-care provider visits, outpatient procedures (surgery, diagnostic, treatment, and laboratory), prescription medication use, and rehabilitation care. Thus, the subjects who completed the baseline questionnaire and follow-up surveys at months 3 and 6 provided data over a 9-month period.

Costing Methods

Health-care costs were derived by multiplying self-reported resource use by unit costs. In the United States, unit costs were derived from these sources.

- Inpatient costs: Healthcare Cost and Utilization Project Nationwide Inpatient Sample [21] and Williams [22]. All costs were converted to 2006 US dollars using the medical consumer price index.
- Outpatient costs: Uniform Data System for Medical Rehabilitation [23], Medicare Physician Fee Schedule [24], Resource-based Relative Value Scale [25], and the Florida Agency for Health Care Administration [26].
- Prescription costs: Red Book [27]. Cancer medication costs were not included.

German unit costs were derived from these sources:

- Statutory Health Insurance from official statistics for hospitals (2005) [28];
- German Diagnosis Related Group system (2005) [28];
- Rehabilitation and average point value of outpatient medical services (2005) [28];
- Medications paid by the Statutory Health Insurance (2005) [28].

Costs were not included for the following: cancer, cold medications, and three medications unavailable in Germany; weight loss and cosmetic outpatient surgeries; and consultations with nonphysicians.

For the respondents who completed all the assessments, the total costs were then annualized by multiplying 9-month costs by a constant 1.33.

Statistical Methods

Analyses were performed on the subset of completers (i.e., subjects who completed all the assessments including baseline, month 3, and month 6). To assess the effect of WC on health-care utilization costs within the BMI categories, the annualized total health-care utilization costs and each cost component (inpatient, outpatient, and prescription drug costs) were summarized for the subjects in five mutually exclusive categories: 1) normal BMI; 2) overweight with low WC; 3) overweight with high WC; 4) obese with low WC; and 5) obese with high WC. The normal BMI category provided a qualitative reference. Very few subjects with normal BMI had AO. High WC and low WC were determined based on sex-specific sample medians within each of the overweight and obese groups in each country (listed in Table 1), an approach recommended by the advisory board of clinicians. The sample median WCs were calculated using the baseline data for the subjects who completed all the assessments.

To estimate the incremental effect of increasing WC on health-care costs for the patients with the same BMI in the United States and Germany, we implemented a two-part model [29,30] in each country in which the probability of incurring health-care costs was combined with the estimated cost of service. This analysis was performed using the combined overweight and obese sample in each country. In both parts of the model, same demographic and lifestyle factors expected to be associated with health-care costs were prespecified as covariates so that estimates of the effects of WC and BMI on health-care costs are adjusted for these factors. Besides BMI and WC (both as continuous variables), the covariates included in the model were sex, age, race, education level, health insurance, smoking status, alcohol consumption, and medical conditions (depression and cancer). Separate models were developed for prescription drug cost, outpatient costs, inpatient costs, and total health-care utilization costs.

In part 1 of the two-part model, the probability that a subject will use a health-care service (i.e., prob [Cost > 0]) over a 1-year

Table 1 Median waist circumference (in cm) by body mass index category and sex

	Normal BMI $20 \leq BMI < 25$			Overweight $25 \leq BMI < 30$			Obese $30 \leq BMI \leq 35$		
Population	PROCEED all	PROCEED completers	National survey	PROCEED all	PROCEED completers	National survey	PROCEED all	PROCEED completers	National survey
US			NHANES			NHANES			NHANES
Males	90	90	89	100	100	100	112	112	111
Females	80	79	81	91	91	92	102	101	103
Germany			GNHIS			GNHIS			GNHIS
Males	89	88	88	99	99	98	111	111	109
Females	79	79	76	90	90	87	101	101	98

BMI, body mass index; GNHIS, German National Health Examination and Interview Survey 1998; NHANES, National Health and Nutrition Examination Survey 2003–2004.

period was estimated using a logistic regression model. Next, the part 2 model was developed using only those patients who had non-zero costs. An estimation of the expected annual costs was generated using ordinary least squares regression against the set of relevant covariates. Finally, expenditures for a population with a given set of patient characteristics were estimated by multiplying the probability of incurring the expense by the estimated cost.

Estimations were made at the midpoint BMI (27.5 in the overweight group, 32.5 in the obese group) for a subject representing the 25th and 75th percentile of the sex-specific WC distributions within the overweight and obese groups with all other characteristics set to the average of the study sample in each country. For the differences in costs between the high and low WC groups, 95% confidence intervals and *P*-values were calculated using variances estimated by bootstrapping [31] from 1000 bootstrapped samples. Analyses were generated using SAS software, version 9.1 of the SAS System for Unix. Copyright © 2007 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA (SAS Institute Inc., Cary, NC).

Role of the Funding Source

The study was conducted by RTI Health Solutions and Sanofi-aventis Recherche et Développement (S-A) and funded by S-A.

Results

Recruitment and Response Rates

Figure 1 illustrates the number of subjects completing each stage of the recruitment process. In April 2007, email invitations were sent out to a total of 412,981 panelists in the United States and Germany, and 65,355 panelists responded to the invitation and were screened. Of those screened, 16,077 were eligible and consented to participate in the study. An additional 13,935 subjects were qualified, but the recruiting quota had been met; data collection ceased once enough participants were recruited to meet the target sample sizes. In addition, 9387 subjects suspended (i.e., decided to stop before going through the survey questionnaire) and 8711 subjects did not agree to participate in the study. The remaining subjects (n = 17,245) were screened out mostly because they were overweight, underweight, and did not report their weight, height, or WC. Of the 16,077 that were eligible and consented in the screening survey, a total of 10,816 responded to the invitation to complete the baseline survey, were confirmed as eligible, and completed the baseline questionnaire (n = 5410 in the United States; n = 5406 in Germany) after they received the study scales and tape measures.

Of the baseline cohort, the response rate was 79% for the 3-month assessment and 72% for the 6-month assessment. Sixty-eight percent in the United States (n = 3653) and 65% in Germany (n = 3493) completed both follow-up surveys and are included in the analyses.

Baseline Characteristics

Median WC values for the control/healthy, overweight, and obese groups are shown in Table 1. The values were remarkably similar across countries for each sex.

Table 2 show the demographic and baseline characteristics of the US and German completers by BMI category and WC sub-

Table 2 Baseline demographic characteristics in the United States and Germany*

		Overweight (BMI 25–29.9 km/m^2)		Obese (BMI 30–35 km/m^2)	
	Normal BMI (%)	Gender specific median WC category (%)		Gender specific median WC category (%)	
		≤WC median	>WC median	≤WC median	>WC median
United States					
Sample size	160	1374	1279	437	403
Mean age in years	49.2	48.9	52.0	51.1	51.8
30–39	(26)	(24)	(18)	(16)	(16)
40–49	(29)	(34)	(27)	(28)	(25)
50–59	(21)	(20)	(22)	(33)	(31)
60–70	(24)	(22)	(32)	(23)	(28)
Gender (% male)	(56)	(52)	(53)	(54)	(53)
Race or ethnic origin (% Caucasian)	(94)	(92)	(95)	(95)	(94)
Current smoker	(30)	(19)	(23)	(16)	(26)
With alcohol intake (>1 drink/week)	(49)	(42)	(40)	(33)	(33)
Education (at least one university degree)	(49)	(50)	(42)	(43)	(36)
With health insurance coverage	(93)	(91)	(91)	(90)	(88)
BMI: mean; SD	23.2; 1.3	27.1; 1.3	28.1; 1.2	31.6; 1.3	32.7; 1.4
WC: mean; SD	85.6; 9.5	89.6; 7	102.5; 7.1	101.3; 7.7	114.5; 6.7
Germany					
Sample size	146	1326	1231	409	381
Mean age (in years)	43.2	44.3	47.9	45.4	47.9
30–39	(39)	(34)	(22)	(29)	(21)
40–49	(34)	(38)	(33)	(41)	(36)
50–59	(21)	(20)	(32)	(23)	(32)
60–70	(6)	(7)	(13)	(8)	(10)
Gender (% male)	(51)	(51)	(53)	(53)	(54)
Race or ethnic origin (% Caucasian)	(100)	(99)	(99)	(99)	(99)
Current smoker	(52)	(33)	(36)	(35)	(46)
With alcohol intake (>1 drink/week)	(50)	(49)	(47)	(40)	(40)
Education (at least one university degree)	(36)	(29)	(26)	(23)	(21)
With health insurance coverage	(97)	(100)	(99)	(99)	(98)
BMI: mean; SD	22.8; 1.3	27.0; 1.2	28.0; 1.3	31.7; 1.3	32.6; 1.5
WC: mean; SD	83.9; 8.6	89.7; 6.5	101.3; 6.2	100.4; 7.1	113.3; 6.8

*Based on subjects who completed surveys at 0, 3, and 6 months.
BMI, body mass index; WC, waist circumference.

group. The mean age across the entire cohort was 48 years; in both countries, more than 90% of the subjects were Caucasian. Forty-five percent of the subjects in the United States and 27% of the subjects in Germany reported having at least a university-level education. About 91 % of the US subjects and 99% of the German subjects reported having some form of health insurance. In the overweight group, the low WC group is younger than the high WC group. In both the overweight and obese groups, the lower WC groups have a lower percentage of smokers and a higher percentage with a university or higher degree. It is also noteworthy that there is not much difference in mean BMI but a large difference in mean WC. Our data suggested that only 30–50% of the variation in WC can be explained by BMI (results not shown in the table). Baseline demographic characteristics and prevalence of selected conditions were compared with noncompleters and national survey data and are discussed later.

Health-Care Utilization and Costs

Over the entire study period, approximately 90% of the respondents in both countries used at least one health-care service, thus incurring a cost. Table 3 illustrate the annualized health-care utilization costs for the United States and Germany by BMI category and WC subgroup. In both countries, the pattern of use indicated higher health-care utilization in the higher WC subgroup compared with the lower WC subgroup in both the overweight and obese groups. A somewhat higher proportion of the subjects incurred costs, and average costs were higher for the subgroup with a higher WC compared with subjects in the low WC subgroup for each BMI category. This observation was made for total health-care costs and each cost component (inpatient, outpatient, and prescription costs). The greatest differential was observed in the proportion of subjects using prescriptions.

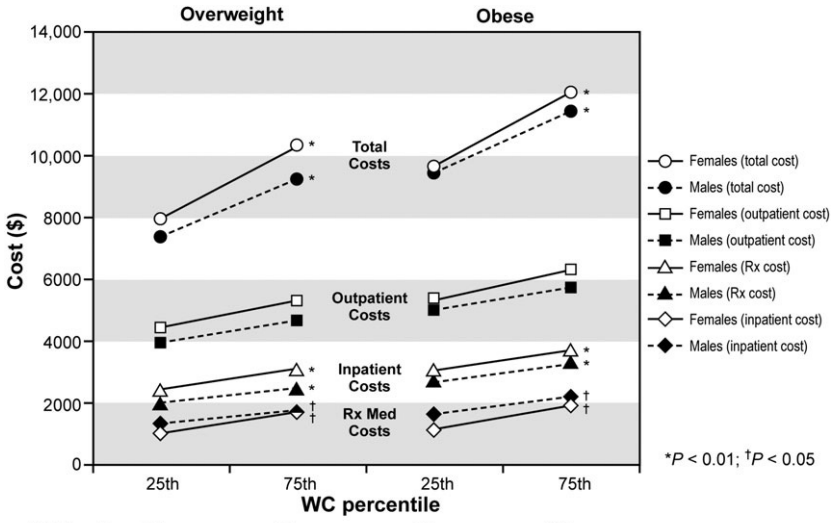
Predicted Annual Health-Care Costs

Figure 2 shows expected annual health-care costs based on US subjects at prespecified BMI and WC, adjusted for age, sex, education level, race, health insurance status, smoking status/history, and alcohol consumption. For the subjects who are overweight or obese, expected prescription drug costs are significantly higher for the subjects above the median WC compared with the subjects below the median. The overweight females in the 75th percentile of the WC distribution (i.e., the median of the high WC group) are predicted to generate $3096 in annual prescription costs versus $2430 for females in the 25th percentile (i.e., the median of the low WC group) holding BMI and other characteristics constant ($P < 0.001$). The overweight males in the 75th percentile of WC are expected to have $2496 versus $1972 in annual prescription costs for males in the 25th percentile ($P < 0.001$). Consistent differences across WC levels were observed for the obese subjects (females: $P < 0.001$; males: $P < 0.001$). Similar patterns were observed for inpatient costs (overweight females: $P = 0.042$, overweight males: $P = 0.037$; obese females: $P = 0.045$, obese males: $P = 0.041$). Outpatient costs are expected to be higher for the overweight or the obese subjects with higher WC compared with the subjects with WC below the sample median, but predicted differences were not statistically significant at the $P = 0.05$ level (at BMI = 27.5 or at BMI = 32.5: females $P = 0.072$; males $P = 0.066$). Total estimated costs were significantly higher for the overweight subjects with high WC compared with the subjects with low WC (difference among females = $2394, $P = 0.003$; among males = $1923, $P = 0.002$). The differences in predicted annual costs between the obese subjects in the 75th versus the 25th percentile of the WC distribution were $2418 for the females ($P = 0.003$) and $1970 for the males ($P = 0.002$).

Table 3 Annualized health-care utilization costs for the United States and Germany by waist circumference (WC) and body mass index (BMI)*

Population	Normal BMI (US$)	Overweight ≤ WC median (US$)	Overweight > WC median (US$)	Obese ≤ WC median (US$)	Obese > WC median (US$)
United States					
Sample size	160	1,374	1,279	437	403
% with any annual costs	89	89	90	92	93
Total annualized cost mean (SD)	6,578 (19,189)	6,904 (16,703)	10,027 (24,215)	10,317 (31,510)	12,486 (23,622)
% with any annual inpatient costs	13	13	15	18	21
Annual inpatient cost mean (SD)	730 (3,138)	1,364 (10,854)	1,894 (12,893)	1,491 (7,667)	2,370 (14,125)
% with any annual outpatient costs	86	85	87	87	89
Annual outpatient cost mean (SD)	4,197 (15,043)	3,556 (9,850)	5,121 (14,521)	6,029 (29,908)	6,147 (15,252)
% with any annual prescription drug costs	69	73	80	81	86
Annual prescription drug cost mean (SD)	1,651 (2,517)	1,984 (2,539)	3,012 (3,629)	2,796 (2,995)	3,969 (4,284)
Germany					
Sample size	146	1,326	1,231	409	381
% with any annual costs	86	89	91	89	93
Total annualized cost mean (SD)	1,751 (3,785)	1,874 (3,719)	2,506 (4,670)	2,373 (4,177)	3,229 (7,051)
% with any annual inpatient costs	14	14	18	18	20
Annual inpatient cost mean (SD)	408 (1,793)	549 (1,905)	894 (3,020)	777 (2,661)	1,140 (4,467)
% with any annual outpatient costs	84	87	90	87	91
Annual outpatient cost mean (SD)	1,029 (2,059)	962 (2,452)	1,102 (2,134)	1,085 (2,182)	1,361 (2,758)
% with any annual prescription drug costs	55	58	70	68	73
Annual prescription drug cost mean (SD)	314 (664)	363 (734)	510 (822)	512 (766)	728 (1,030)

*Based on subjects who completed surveys at 0, 3, and 6 months.



US	Differences between subject at BMI 27.5 with WC at 75th vs. 25th percentile (US$)	Differences between subject at BMI 32.5 with WC at 75th vs. 25th percentile (US$)
Total Costs		
Females	2394 (832, 3956)	2418 (838, 3998)
Males	1923 (693, 3152)	1970 (706, 3234)
Outpatient Costs		
Females	913 (-80, 1906)	927 (-80, 1934)
Males	722 (-47, 1491)	744 (-48, 1537)
Inpatient Costs		
Females	671 (26, 1316)	812 (19, 1605)
Males	488 (29, 946)	610 (25, 1196)
Rx Med Costs		
Females	667 (488, 845)	684 (500, 867)
Males	525 (384, 665)	562 (412, 711)

Figure 2 Predicted annual healt care costs in the United States. Within the overweight and obese groups, predictions were made at the BMI midpoint (27.5 and 32.5, respectively) for the subjects representing the 75th and 25th quartiles of the sex-specific WC distributions. Other characteristics were set to average for the United States cohort: 21% 30–39 years, 31% 40–49 years, 23% 50–59 years, 25% 60–70 years; 93% Caucasian; 44% university degree or higher; 90% with health insurance; 22% current, 33% former smoker; 40% drinking ≥ 1 alcoholic beverage/week. *P*-values correspond to the comparisons of costs between high WC and low WC. Numbers in parentheses represent 95% confidence intervals. BMI, body mass index; US, United States; WC, waist circumference.

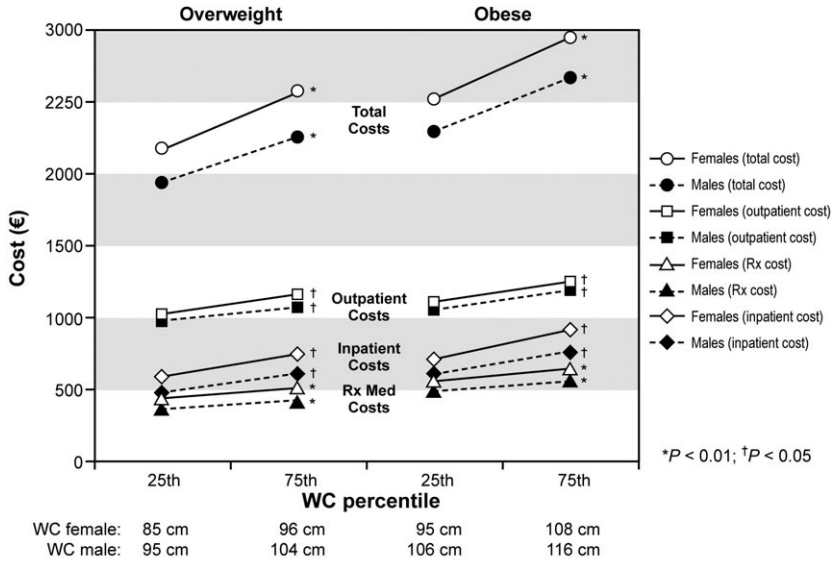
In Germany (Fig. 3), all components of predicted health-care costs were significantly higher for the subjects above the median WC compared with the subjects below the median both for the overweight and the obese. Predicted annual prescription costs were €516 for the females in the 75th percentile of WC and €445 for the females in the 25th percentile ($P = 0.002$), with BMI and other characteristics held constant (for males: €423 vs. €366; $P < 0.001$). The same pattern was found in the United States, with absolute values greater in the obese than the overweight and greater in the females than in the males. Differences in predicted annual costs in the overweight subjects at the 75th versus 25th percentile of the WC distribution were €393 for the females ($P = 0.005$) and €316 for the males ($P = 0.004$). Among the obese subjects, differences were €432 for the females and €358 for the males ($P = 0.005$; $P = 0.004$).

In both countries, the subjects with a midpoint BMI of 27.5 whose WC was at the high end of the distribution among the overweight subjects had a similar WC to the obese subjects with a midpoint BMI of 32.5 whose WC distribution was at the low end for that category. Furthermore, predicted health-care costs were similar for these subjects with differing BMIs but similar WCs.

Discussion

The goal of PROCEED was to determine the effect of WC on health-care costs—in particular, prescription medication costs—after adjusting for BMI and other potentially confounding variables. When BMI and other characteristics are held constant, annual health-care costs of the subjects with a high WC are 16% to 18% (€300–€400) higher in Germany and 20% to 30% ($1900–$2400) higher in the United States compared with the subjects with a lower WC. In the overweight and the obese female and male subjects in Germany and the United States, a higher WC was associated with significantly higher total health-care costs as well as inpatient, outpatient, and pharmaceutical costs. The exception was outpatient costs among the overweight subjects in the United States where the results approached but did not reach statistical significance ($P = 0.07$). These results confirm the importance of evaluating WC in addition to BMI and suggest that targeting people with a high WC for weight management whether they are overweight or obese may maximize cost-efficacy.

The higher health-care costs observed were reflections of the higher disease prevalence among the subgroups with a higher WC [32–34]. The association between high WC indicating AO, and cardiovascular disease and insulin resistance is well established [18,35–40]. Despite this known association, little is known how or if this association translates into higher health-care utilization and costs. Cornier and colleagues initially documented the link between health-care costs and a high WC, but the population was small (n = 424) and nongeneralizable (from one city in the United States) [12]. More recently, Højgaard and colleagues reported, in a sample of 31,849 subjects aged 50–65 years and residing in Denmark, that a high WC at baseline was associated with increased health-care costs over a 7-year period [41]. Our



Germany	Differences between subject at BMI 27.5 with WC at 75th vs. 25th percentile (Euros)	Differences between subject at BMI 32.5 with WC at 75th vs. 25th percentile (Euros)
Total Costs		
Females	393 (95, 691)	432 (104, 761)
Males	316 (83, 549)	357 (93, 622)
Outpatient Costs		
Females	131 (-14, 277)	144 (-16, 305)
Males	108 (-5, 221)	122 (-7, 250)
Inpatient Costs		
Females	160 (9, 311)	207 (8, 405)
Males	117 (10, 225)	157 (9, 305)
Rx Med Costs		
Females	71 (23, 119)	81 (25, 137)
Males	58 (24, 91)	71 (29, 113)

Figure 3 Predicted annual health care costs in Germany. Within the overweight and obese groups, predictions were made at the BMI midpoint (27.5 and 32.5, respectively) for the subjects representing the 75th and 25th quartiles of the sex-specific WC distributions. Other characteristics were set to average for the German cohort: 31% 30–39 years, 36% 40–49 years, 24% 50–59 years, 9% 60–70 years; 98% Caucasian; 25% university degree or higher; 99% with health insurance; 38% current, 29% former smoker; 45% drinking ≥ 1 alcoholic beverage/week. *P*-values correspond to the comparisons of costs between high WC and low WC. Numbers in parentheses represent 95% confidence intervals. BMI, body mass index; WC, waist circumference.

study expands what is known about WC and health-care costs by using a large population with a wider age range from two different countries, the United States and Germany. Thus, it provides insight that higher costs occur across all components of health care.

One limitation of the current study is that the survey did not collect the extensive details required to estimate the cost of cancer treatments (e.g., stage of disease, type and line of therapy, concurrent regimens). We note that cancer rates for the subjects who completed the survey followed the same trend as for the other conditions (i.e., higher cancer rates were seen in the above median WC subgroups in the obese group in both countries and the overweight group in the United States) (data not shown). We surmise that the inclusion of drug costs for cancer would have reinforced the patterns already observed but may have skewed the overall results with extreme cost values.

Another limitation of the current study is that the participants had to have Internet access. The advantage and validity of Internet recruitment and data collection methods have been documented in previous studies [33,42]. The current study sample was compared with data from available national probability-based surveys for each BMI group in each country using the US 2003–2004 National Health and Nutrition Examination Survey [43] and the 1998 German National Health Examination and Interview Survey (GNHIS) [44]. The US PROCEED cohort is very similar to the National Health and Nutrition Examination Survey (NHANES) cohort with regard to most demographic characteristics (i.e., education level, marital status, and income level) and selected health and behavioral characteristics (i.e., hypertension, high cholesterol, diabetes, and smoking), except for higher proportion of White subjects and a slightly higher mean age in the PROCEED cohort than in the NHANES cohort (by 3.1 years in the normal weight group, 1.6 years in the overweight group, and 3.6 years in the obese group). The German PROCEED cohort, on average, is younger than the GNHIS cohort (1.6 years mean difference in normal weight group, 4.2 years in overweight group, and 5.2 years in obese group), has a higher proportion (>10% point difference) of participants with higher education ("abitur" in German), and has a higher proportion of single participants. The percentage with an apprenticeship ("lehre" in German) is similar in PROCEED and the GNHIS. Percentages of hypertension, high cholesterol, and diabetes are very similar to GNHIS data. Despite differences in some characteristics, the PROCEED cohort is generally comparable to the US and German general populations. In addition, it is important to realize that the PROCEED sample contains a sufficient range of key demographics, such as age, race, and education level, so that statistical models can be developed to account for these characteristics.

The use of distribution-based WC cutpoints may also lessen the generalizability of these results to other populations. However, within the normal, overweight, and obese groups of the PROCEED cohort, the distribution of WC values are comparable with national survey data in the United States and in Germany. Observed WC measures in this naturalistic cohort were similar between countries and may be useful to describe the

relationship between actual WC measures and health-care resource use and cost. We noted that the median WC values in the overweight females were higher than the ATP III criteria for AO and lower in the overweight males.

The cost analysis was performed on the subset of completers, which means the subjects who completed the baseline and months 3 and 6 surveys. Among the baseline participants, 68% in the United States and 65% in Germany completed all the assessments and were included in analysis. The baseline demographic characteristics (i.e., sex, age, education, income, and employment status) and prevalence of selected conditions (i.e., hypertension, dyslipidemia, diabetes, depression, coronary heart disease, and cancer) were compared for the completers against the noncompleters in each BMI category and country. No difference was consistently found across the BMI groups or the countries.

In addition, a lost-to-follow-up survey was conducted to ascertain the reason for nonresponse. Approximately 10% to 15% of the noncompleters did not complete the follow-up survey because they discontinued from the Web panel. Approximately 20% to 30% of the nonresponders answered one or a few questions in the follow-up survey but did not finish all questions. Over 30% of the nonresponders completed the lost-to-follow-up survey. The most prevalent reasons cited for not completing the PROCEED survey in both the United States and Germany was that the subject became too busy or did not have time (37% and 45%, respectively). Eleven percent of the US and 16% of the German cohorts reported being hospitalized in the past 12 months, which is comparable with the completers.

It is now well established that obesity is a heterogeneous condition and that not every overweight/obese individual is at high risk of complications. The present study adds further evidence that at any given BMI value, individuals with an elevated WC have greater health-care costs. Although experimental data will be needed to test this hypothesis, given scarce health-care resources and the fact that more than half of the population in industrialized countries are overweight and obese, it is reasonable to suggest that the subgroup of overweight/obese individuals with a high WC may benefit the most from approaches that aim at weight loss and loss of abdominal fat. Of course, intervention studies are needed to specifically examine this issue.

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