Original Article
EPIDEMIOLOGY/GENETICS

Obesity

Is Overweight and Class I Obesity Associated with Increased Health Claims Costs?

Truls Østbye[1,2], Marissa Stroo[1], Eric L. Eisenstein[1,3], Bercedis Peterson[4] and John Dement[1]

Objectives: Evaluate the relationship between body mass index (BMI) and health claims costs over the last decade, assess the strength and nature of the relationship between BMI and costs, and identify comorbidities that may drive any increased costs.

Methods: Using 2001-2011 claims data for employees participating in annual health appraisals, annual paid claims costs were calculated. One-part negative binomial models were fit to evaluate the relationship between BMI and costs, controlling for age, gender, race/ethnicity, and calendar year period.

Results: The relationship between increasing BMI and increasing health claims costs is gradual and starts already at a BMI of 19. The nature of the relationship did not change notably over time. The most important obesity-related comorbidities, expressed as percent increase in cost per BMI unit, was cardiovascular disease (males 10.53, 95% CI [6.46, 14.77], females 4.27, 95% CI [1.25, 7.38), while cardiovascular agents (7.23, 95% CI [6.08, 8.39]) were the most important driver of pharmacy costs.

Conclusion: In contrast to recent evidence relating to effects on mortality, we observed a gradual increase in health claims costs starting at the low end of the recommended BMI range.

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Introduction

There is general agreement that very high body mass is associated with both increased morbidity and mortality. Earlier studies using medical claims data (1-6) or population based longitudinal survey data (6-11) support an overall association between higher levels of body mass and higher morbidity and mortality. However, a recent comprehensive systematic review concluded that "mortality" is not increased for adults in the overweight (body mass index, BMI 25-29.9) and obese type I (BMI 30-34.9) categories: mortality was only significantly increased for individuals in the obese type 2 category (BMI 35-39.9) and above (12). It should be noted that lately the methods used in the mortality review have been questioned (13).

Since that systematic review addressed only the relationship between BMI and mortality, two related questions remain. First, is the relationship between body mass and "morbidity" different from the relationship between body mass and mortality, especially in the overweight and obese type I categories (i.e., do people in the overweight and obese type I groups have similar rates of morbidity compared to those in the recommended category)? Second, in spite of the fact that overall health care costs are increasing (14), might changes in lifestyle and treatments of obesity's resulting chronic diseases in the past decade have reduced the relative morbidity and morbidity costs for individuals in the overweight and obese type I categories (i.e., are these costs now more similar to the costs in the recommended category)? In other words, do costs start to increase linearly already at a BMI around 25 (1,2,4) or do the increased costs not become significant until a BMI of around 35 (12)?

We have previously developed and implemented a model health and safety surveillance system for a large employee population: the Duke Health and Safety Surveillance System (DHSSS). Duke is self-insured for employee medical coverage, and health insurance benefits include a wide range of services including inpatient and outpatient, pharmacy, and mental health services provided through several vendors. Over 90% of eligible employees participate in a Duke health care plan. A key feature of this system is the ability to link annually updated data from multiple sources at the individual level and thus define both health risk profiles and health outcomes. Using the DHSSS, comprehensive data on morbidity, and costs associated with claims can be analyzed. This provides unique opportunities to consider the relationship between various risk factors or health problems and subsequent health care utilization among a broad and diverse set of employees working for the second largest employer in North Carolina.

[1] Department of Community and Family Medicine, Duke University Medical Center, Durham, North Carolina, USA. Truls Østbye (truls.ostbye@duke.edu) [2] Duke-NUS Graduate Medical School, Singapore [3] Duke Clinical Research Institute, Durham, North Carolina, USA [4] Department of Biostatistics and Bioinformatics, Duke University Medical Center, Durham, North Carolina, USA

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The first objective of these analyses is to evaluate whether the relationship between BMI and health claims costs have changed over the last decade, particularly whether the association between overweight and obesity type I and health claims costs has decreased relative to the recommended BMI category over this period (after adjusting for key potential sociodemographic confounders).

The second is to assess the strength and nature of the relationship between BMI and morbidity, as measured by overall claims costs (inpatient, outpatient, and pharmacy). The third objective is to identify which of the major diagnostic categories usually associated with obesity are the main drivers of any such increased costs among those overweight and obese.

Methods

Study population definition

All data used for these analyses were obtained from the DHSSS (15). The study cohort included those employees who participated in one of the Duke health plans for 12 continuous months in a given follow-up year (2001-2011) and completed at least one health risk appraisal (HRA) during the same year. All inpatient and outpatient medical claims as well as pharmacy claims were abstracted for employees included in the study sample. Employee demographic variables were obtained using annual human resources data, also available in the DHSSS.

Selected variables from the HRAs were also abstracted and merged with the study file by employee and follow-up year. Self-reported weight and height were used to calculate the BMI. Smoking status (Never, Former, Current, or Unknown) was also determined from HRA responses.

Obesity-related disease comorbidities: Hypertension and type II diabetes

Type II diabetes and hypertension are common comorbidities associated with obesity, and we investigated their association obesity and costs more closely. Cases of diabetes and hypertension were identified using criteria specified by the National Committee for Quality Assurance in the 2008 Healthcare Effectiveness Data and Information Set (HEDIS). HEDIS 2008 criteria were used given the time frame covered by the claims and eligibility data. Detailed HEDIS case definitions based on ICD-9, CPT, and National Drug (NDC) codes can be found in the published reference 16).

Categorization of medical and pharmacy costs

All costs analyses were based on tabulations of health plan paid costs obtained from the line item health claims. All costs were adjusted to 2011 dollars using the BLS Medical Care Consumer Price Index (17). Broad categories of expenditures included yearly medical (inpatient and outpatient) costs, pharmacy costs, and total costs (pharmacy plus medical). Medical costs were further categorized by Major Diagnostic Category (MDC) and drug costs were further categorized by general therapeutic class based on the NDC using Redbook classifications. These costs did not include costs paid by the employee out of pocket.

Stratified analyses and multivariate analyses

The cohort was categorized into three time periods (2001-2004, 2005-2008, and 2009-2011) and BMI was categorized into six categories (19-24, 25-29, 30-34, 35-39, 40+) for presentation of raw data by BMI category. We were primarily interested in investigating mean annual medical and pharmacy costs and the relationships between BMI and these costs, taking into account age, gender, race/ethnicity (white and non-white), and calendar time period, while accounting for the skewed distribution of medical costs data and variance that increases with mean costs (18). General linear models with various distributions functions (normal, log-transformed, gamma, and negative binomial) and link functions (identity and log) were fit in the baseline models.

We also investigated two-part models that used a logistic model to predict the probability of any health care costs followed by a negative binomial model to predict costs conditional on nonzero costs (19). A one-part negative binomial model using a log link function was selected as it provided the best fit based on model Akaike information criterion (AIC), without evidence of overdispersion. A log link function implies a multiplicative rather than additive relationship with BMI and is typically preferred when the goal is to understand the effects of individual covariates on total costs (18). Additionally, estimates based on a multiplicative relationship should allow results from our study to be better generalized to other health plans as a constant increase in cost per BMI unit would not be expected to apply universally across health plans with different benefit structures, deductibles, and copays.

We began negative binomial model building through construction of baseline models that included BMI, age, gender, race/ethnicity (white and non-white), and calendar year period. While our final models were based on generalized estimated equations (GEE), we evaluated model parameters first in non-GEE models due to superior model diagnostics based on likelihood rather than GEE quasi-likelihood. These non-GEE models showed little evidence of over or under dispersion and were therefore considered adequate for model parameter selection and investigation of the functional form for both age and BMI.

We initially investigated the functional form for age and BMI by comparison of model AIC for separate models that entered BMI as either a categorical or continuous variable. Model AIC was only marginally improved when age and BMI were included as categorical variables; therefore, we choose less complex models that included BMI and age as continuous variables, with age centered at the population mean (44 years) to minimize potential collinearity with follow-up calendar time. Higher order polynomials (cubic and quadratic) for age and BMI were also evaluated in the models; however, addition of these terms did not result in an improvement in model fit and were not included in the final model. We also investigated interactions of BMI with age, gender, race/ethnicity, and calendar year period in each model and these terms were retained if they were significant based on model Type III Wald statistics ($P < 0.05$). For models where interaction terms including gender were significant, we present gender-stratified multivariate models [this is also justified by previously reported gender differences in obesity prevalence (20) and in the mental and physical health consequences of overweight and obesity (5,21)]. Parameters included in the final models for medical and pharmacy costs were retained in subsequent analyses by subcategory analyses on MDC or drug class.

Our data includes 37,221 person-years of health claims experience contributed by 17,703 individuals. In order to account for potentially correlated outcome data, all models were based on use of GEE. We evaluated both an exchangeable and unstructured correlation structure in the GEE models. A few GEE models for subanalyses by MDC category failed to converge. Non-GEE results for these categories are presented with variance adjusted by the scaled deviance to partially account for increased model dispersion due to correlated outcome data. All statistical analyses were conducted using SAS 9.3.

Results

The final study sample was 73.2% female, 59.3% Caucasian, and 31.9% Black/ African American. The mean age was 44 years (SD = 10.9 years), and the mean BMI was 28.5 (SD = 6.6). Table 1 presents the demographic characteristics for the study sample overall and by time period. Using the HEDIS criteria for diabetes and hypertension, the prevalence of both diseases increased gradually by BMI category. For diabetes, the prevalence increased from 1.6% (BMI 19-24) and 3.9% (BMI 25-29) to 7.7% (BMI 30-34), 13.7% (BMI 35-39), and 16.6% (BMI 40+). Similarly, for hypertension the prevalence increased from 5.4% (BMI 19-24) and 13.5% (BMI 25-29) to 19.6% (BMI 30-34), 25.6% (BMI 35-39), and 30.6% (BMI 40+).

Figures 1a and 1b show the unadjusted mean annual health care (a) and pharmacy (b) costs by BMI unit as well as the costs in each time period (2001-2004, 2005-2008, and 2009-2011). Costs associated with medical and pharmacy claims increased gradually with BMI category, starting already in the recommended category, in all of the time periods evaluated, but the overall shape of the trajectory of the relationship did not appear to change significantly over time.

Multivariate models

All baseline covariates (age, gender, race/ethnicity, and calendar year period were significantly associated with medical and pharmacy costs ($P < 0.001$) after GEE adjustment for correlated data. Higher order polynomial terms for age and BMI failed to significantly improve model fit and were not included in the final models for

TABLE 1 Demographic characteristics of study population by time period

	Study follow-up time period			
	2001-2004	2005-2008	2009-2011	Overall
Individuals (*N*)	5,903	10,154	9487	17,703
Person-years (*N*)	8,344	15,560	13,317	37,221
Mean age (SD)	42.4 (10.2)	44.3 (10.9)	44.7 (11.2)	44.1 (10.9)
Mean age (SD) by BMI category (kg/m^2)				
19-24	40.6 (10.7)	42.1 (11.4)	42.5 (12.0)	41.9 (11.5)
25-29	43.2 (10.2)	45.1 (10.7)	45.7 (11.0)	44.8 (10.7)
30-34	44.1 (9.6)	46.3 (10.4)	46.7 (10.7)	46.0 (10.4)
35-39	43.3 (9.7)	45.6 (9.7)	46.4 (10.4)	45.4 (10.0)
40+	42.3 (9.4)	45.1 (9.8)	45.5 (9.7)	44.7 (9.8)
Percent male	27.9	27.4	25.5	26.8
Race/ethnicity (%)				
Caucasian	61.9	59.7	57.5	59.3
Black or African American	31.8	31.1	32.8	31.9
All other	6.7	9.2	9.7	8.8
HRA cigarette smoking status (%)				
Never	68.4	69.6	70.3	69.6
Former	11.0	21.5	22.6	19.5
Current	11.6	8.6	7.2	8.8
Unknown	9.0	0.2	0.0	2.1
Mean BMI (kg/m^2) (SD), overall	28.6 (6.3)	28.3 (6.7)	28.8 (6.8)	28.5 (6.6)
Mean BMI (kg/m^2) (SD), by race/ethnicity				
Caucasian	27.2 (5.6)	27.2 (6.1)	27.8 (6.3)	27.4 (6.1)
Black or African American	31.2 (6.6)	31.7 (6.9)	31.9 (6.7)	31.7 (6.7)
All Other	24.4 (4.4)	24.6 (4.9)	24.9 (5.1)	24.7 (4.9)
Mean BMI (kg/m^2) (SD), by gender				
Male	27.5 (6.7)	27.4 (5.3)	27.7 (5.4)	27.5 (5.2)
Female	28.5 (6.7)	28.7 (7.1)	29.2 (7.2)	28.9 (7.0)
HEDIS diabetes prevalence (%)	4.3	5.6	7.2	5.9
HEDIS hypertension prevalence (%)	13.5	13.4	16.8	14.6

SD, standard deviation.

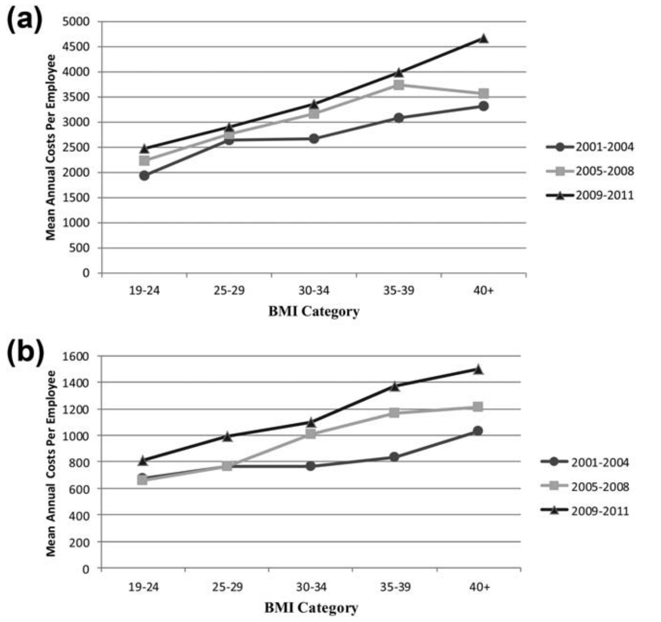

Figure 1 Unadjusted mean annual medical and pharmacy costs by BMI category (19-24, 25-29, 30-34, 35-39, and 40+) and time period (2001-2004, 2005-2008, and 2009-2011).

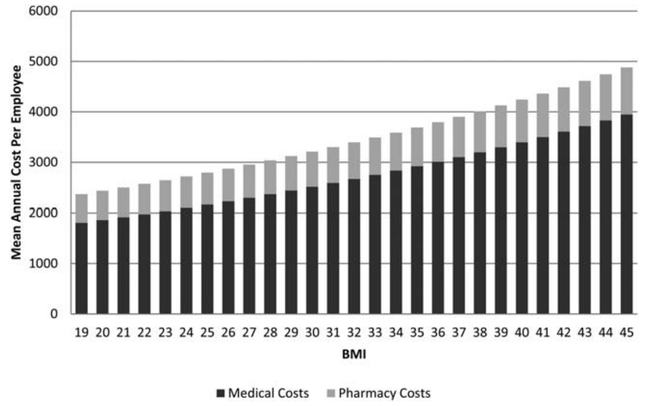

Figure 2 Model population mean medical (dark gray) and pharmacy (light gray) costs. Estimates are centered at the population mean age (44 years).

medical and pharmacy costs. No significant interactions between BMI and age, race, or calendar year period were observed in models for medical and pharmacy costs. While the prevalence of obesity was higher among African-Americans included in our study, the increased health care costs per unit increase in BMI were not significantly different by race/ethnicity. An interaction term for BMI and time period was not significant in the medical or pharmacy costs models ($P > 0.05$) suggesting that the slope of the relationship between BMI and health care costs has remained reasonably stable over the study period. Our evaluation of choice of correlation structure for the GEE analyses did not find meaningful differences in results based on use of an exchangeable, autoregressive, or exchangeable structure; therefore, results are presented assuming an exchangeable correlation structure.

The statistical models were based on 36,741 person-years of follow-up among those with a BMI $\geq$19. Figure 2 presents the mean annual medical and pharmacy costs per employee by BMI unit. There was a clear relationship between BMI and health care costs, beginning at 19 and gradually increasing as BMI increases. Mean annual medical costs for those with a BMI of 45 ($3,946) more than doubled the costs for those with a BMI of 19 ($1,805), while pharmacy costs climbed from $563 annually to $934 for those with a BMI of 45.

Significant associations with BMI were found for 13 of the 18 MDCs evaluated (see Table 2 for details). The MDCs for myeloproliferative diseases and the circulatory system had the highest percent increase per BMI unit for males (10.67, 95% CI [8.97, 12.39] and 10.53, 95% CI [6.46, 14.77], respectively) and for females the largest percent change per BMI unit was in the liver and pancreas MDC (7.43, 95% CI [5.01, 9.90]), followed by the endocrine, nutritional and metabolic MDC (6.63, 95% CI [4.90, 8.39]). While myeloproliferative diseases and diseases of the liver and pancreas had the largest percent increase in costs by unit of BMI gain, the actual paid medical costs of these diseases was quite low across all gender stratified BMI categories ranging from a mean of $2 to $243 annually for myeloproliferative diseases and from $19 to $99 annually for the liver and pancreas category.

Women had higher overall medical costs in all BMI categories (ranging from an annual mean per female employee of $2,456-$4,022 compared to $1,677-$3,452 for males), but a higher overall percent change in medical costs per BMI unit was observed in males (3.93 vs. 2.18%). Table 2 presents the mean annual paid medical costs per employee by gender, MDC and BMI category, and the results from the multivariate model (stratified by gender) of increase in medical costs per unit increase in BMI.

Significant associations with BMI were found for eleven drug classes (see Table 3 for details). The drug class with the largest percent change per BMI unit was cardiovascular agents (7.23, 95% CI [6.08, 8.39]), followed by the electrolytic, caloric, and water balance drug class (7.02, 95% CI [6.42, 7.64]). Women had a slightly higher mean annual pharmacy costs compared to men ($740-$1,293 vs. $645-$1,274). For men and women combined, there was a 1.97% increase in pharmacy costs for each unit increase in BMI. As there was no significant interaction with gender for pharmacy costs, percent change per unit of BMI change by gender was not assessed. Table 3 presents the mean annual paid pharmacy costs by MDC and BMI category, and the results from the multivariate model for changes in pharmacy costs per unit increase in BMI, overall and for each of the obesity-related MDCs.

Figure 3 presents the significant medical (3a) and pharmacy (3b) costs associated with BMI by gender. Our statistical models used BMI as a continuous linear variable; therefore, the results by BMI category in Figure 3 were generated from the models using predictions based on the midpoints for each BMI category. For both men and women, cardiovascular diseases were associated with the largest actual dollar increase per gain in BMI unit (from an annual mean of $127 for BMI 19-24 to $1,041 for BMI 40+ in males, and from $194 to $466 for the same groups in females). The pharmacy costs for cardiovascular agents in men saw the greatest cost increase with

TABLE 2 Mean annual paid medical costs[1] per employee by gender, major diagnostic category (MDC) and BMI category, and percent change in costs by unit of BMI change

		Males ($n = 5{,}181$), mean					Females ($n = 12{,}324$), mean					Percent change per unit BMI (95% CI)	
MDC	Category description	19-24 ($n = 1{,}816$)[3]	25-29 ($n = 2{,}401$)	30-34 ($n = 1{,}124$)	35-39 ($n = 383$)	40+ ($n = 233$)	19-24 ($n = 4{,}836$)	25-29 ($n = 4{,}226$)	30-34 ($n = 2{,}929$)	35-39 ($n = 1{,}693$)	40+ ($n = 1{,}412$)	Males	Females
MDC 1	Nervous system	88	57	101	218	206	98	178	183	192	161	6.85 (2.33-11.58)	3.90 (2.51-5.31)
MDC 2	Eye	54	66	74	102	57	67	78	103	100	73	3.28 (−0.26 to 6.95)	0.74 (−0.41 to 1.89)
MDC 3	Ear, nose, mouth and throat	59	106	165	156	348	87	109	139	176	171	8.45 (6.29-10.66)	4.15 (3.18-5.12)
MDC 5	Circulatory system	208	319	603	656	640	181	321	413	454	652	10.53 (6.46-14.77)	4.27 (1.25-7.38)
MDC 7	Liver, pancreas	39	54	56	36	19	30	43	75	75	99	−1.37 (−6.4 to 3.93)	7.43 (5.01-9.90)
MDC 8	Musculoskeletal	273	399	521	484	715	402	491	565	759	877	2.92 (0.33-5.58)	3.46 (2.39-4.54)
MDC 10	Endocrine, nutritional and metabolic	37	160	103	175	167	59	86	119	219	255	6.01 (1.68-10.51)	6.63 (4.90-8.39)
MDC 11	Kidney and urinary tract	51	75	156	376	43	45	94	103	123	53	6.35 (−1.32 to 14.61)	1.83 (0.28-3.41)
MDC 12	Male reproductive	50	67	62	11	27	0	0	0	0	0	−4.35 (−8.07 to −0.49)	-
MDC 13	Female reproductive	0	0	0	0	0	221	289	272	291	359	-	1.84 (0.89-2.79)
MDC 17	Myeloproliferative diseases[2]	89	70	57	2	243	48	88	55	40	79	10.67 (8.97-12.39)	2.22 (1.36-3.09)
MDC 18	Infectious and parasitic[2]	15	23	9	8	34	25	17	28	26	43	3.18 (1.90-4.49)	5.27 (4.46-6.08)
MDC 19	Mental diseases and disorders	55	65	67	69	63	85	72	58	60	82	3.42 (0.37-6.56)	1.03 (−0.60 to 2.15)
All	All MDC categories combined	1,677	2,079	2,755	3,222	3,452	2,456	3,169	3,262	3,793	4,022	3.93 (2.32-5.57)	2.18 (1.72-2.65)

TABLE 3 Mean annual paid pharmacy costs[a] per employee by major drug class and BMI category[c] and percent change in costs by unit of BMI change

Drug class description	Males, mean					Females, mean					Percent change per unit BMI (95% CI)
	19-24	25-29	30-34	35-39	40+	19-24	25-29	30-34	35-39	40+	
Anti-infective agents	209	87	145	210	58	64	82	58	73	100	−1.34 (−2.61 to −0.06)
Antihistamines and Comb.	7	10	13	9	17	19	22	25	21	27	2.36 (1.27-3.47)
Cardiovascular agents	59	123	189	208	225	38	83	129	166	176	7.23 (6.08-8.39)
Central nervous system	81	127	152	167	186	186	205	229	235	267	2.84 (1.76-3.93)
Diagnostic agents	8	5	8	12	11	7	6	9	14	20	4.62 (1.59-7.75)
Electrolytic, caloric, water[b]	7	2	3	3	9	1	2	5	9	13	7.02 (6.42-7.64)
Eye, ear, nose throat	13	16	21	17	13	18	22	23	23	20	1.06 (0.14-1.99)
Gastrointestinal drugs	43	83	84	78	97	78	103	128	141	119	2.74 (1.69-3.79)
Hormones and synthetic substances	31	67	127	238	364	93	92	137	209	271	4.38 (3.49-5.29)
Respiratory tract agents	4	7	8	12	4	8	11	14	17	19	2.89 (1.12-4.69)
Other and unclassified	28	48	42	47	99	16	33	36	31	36	5.02 (3.40-6.66)
All Classes Combined	645	744	954	1,107	1,274	740	899	999	1,188	1,293	1.97 (1.26-2.68)

MDC, major diagnostic category.
[a]All costs are adjusted to 2011 dollars. Costs by MDC Category are presented only for categories significantly associated with BMI ($P < 0.05$) in the multivariate models adjusting for age, gender, race/ethnicity, and calendar time period.
[b]GEE models for these subcategories failed to achieve convergence of GEE parameter estimates. Results for non-GEE models are presented.
[c]Individual's BMI was allowed to change over the follow-up period and each individual is counted in each BMI category where they contributed data.

BMI gain (from $42 to $184) and for women the greatest dollar increase was for hormones (from $87 to $213).

Discussion

Morbidity associated with overweight and obesity is costly, and the associated costs start increasing already at the lower end of the recommended weight category. When investigating the relationship between BMI and healthcare claims costs over time, we did not see a significant change in this relationship from 2001 to 2011, suggesting that the overall costs associated with treatment of conditions related to overweight and obesity have not significantly changed during this time period. There was a gradual increase in medical and pharmacy costs by increasing BMI category, starting in the overweight category, and also with each unit rise in BMI, starting as low as at a BMI of 19. While women had higher medical and pharmacy costs, both overall and in each BMI category, BMI had a larger effect on medical costs in men.

Our findings are consistent with previous work that shows a linear relationship between BMI and morbidity and health care costs (1-5,7), and show that the trend for morbidity is different from the trend for mortality reported by Flegal et al. (12). A study from 2005 on the costs of healthcare for obese individuals showed an 81% increase compared to those with a BMI in the recommended category, and also showed significant differences in expenditures by obesity class (11). In our sample, we show combined medical and pharmacy costs for individuals with a BMI of 45 to be more than double that for those with a BMI of 19. Wang et al. (4) found 11 MDC categories significantly associated with BMI, with the highest increase in costs by BMI unit gain in the musculoskeletal category followed by the circulatory system category. In our sample, there were 13 MDC categories significantly associated with BMI, with the circulatory system category as the leading driver of increased costs.

While we observed large gender differences in overall medical costs related to the cardiovascular system, this may be due to the age of our sample. Previous literature supports a lag effect in development of cardiovascular disease among women, with manifestations of heart disease appearing after a lag time of as much as decade (22). Since our sample is composed of working age individuals, the effects of BMI on the cardiovascular system may yet appear among the women.

Given the fact that increased morbidity, or at the very least the health claims costs of excess weight, starts already at the lower end of the recommended weight range, concerted, broad, clinical and public health efforts should be vigorously pursued, both within and outside the workplace. The workplace may be particularly well suited as a place for such intervention given that they can reach large numbers of adults by targeting the more than 100 million Americans who spend most of their waking hours at work (23). Furthermore, worksites generally function as systems for communication, education, and social support, and offer a unique recurring setting for repeated contacts with program participants as well as a social environment that can influence norms and expectations (23,24).

Given that this is an employee sample, it is of interest to find out whether and to what extent excessive weight can be reduced through work site based intervention, and furthermore, whether the relationship between BMI, morbidity, and associated health claims costs can be changed through such interventions. Duke University Health System and Duke University offer several free and low cost weight and health management programs to employees (currently, a randomized study is being conducted to evaluate these interventions and the impact of the programs on health care costs).

One of the strengths of our study is the large sample size, based on a longitudinal dataset from a large employer. Although all data are

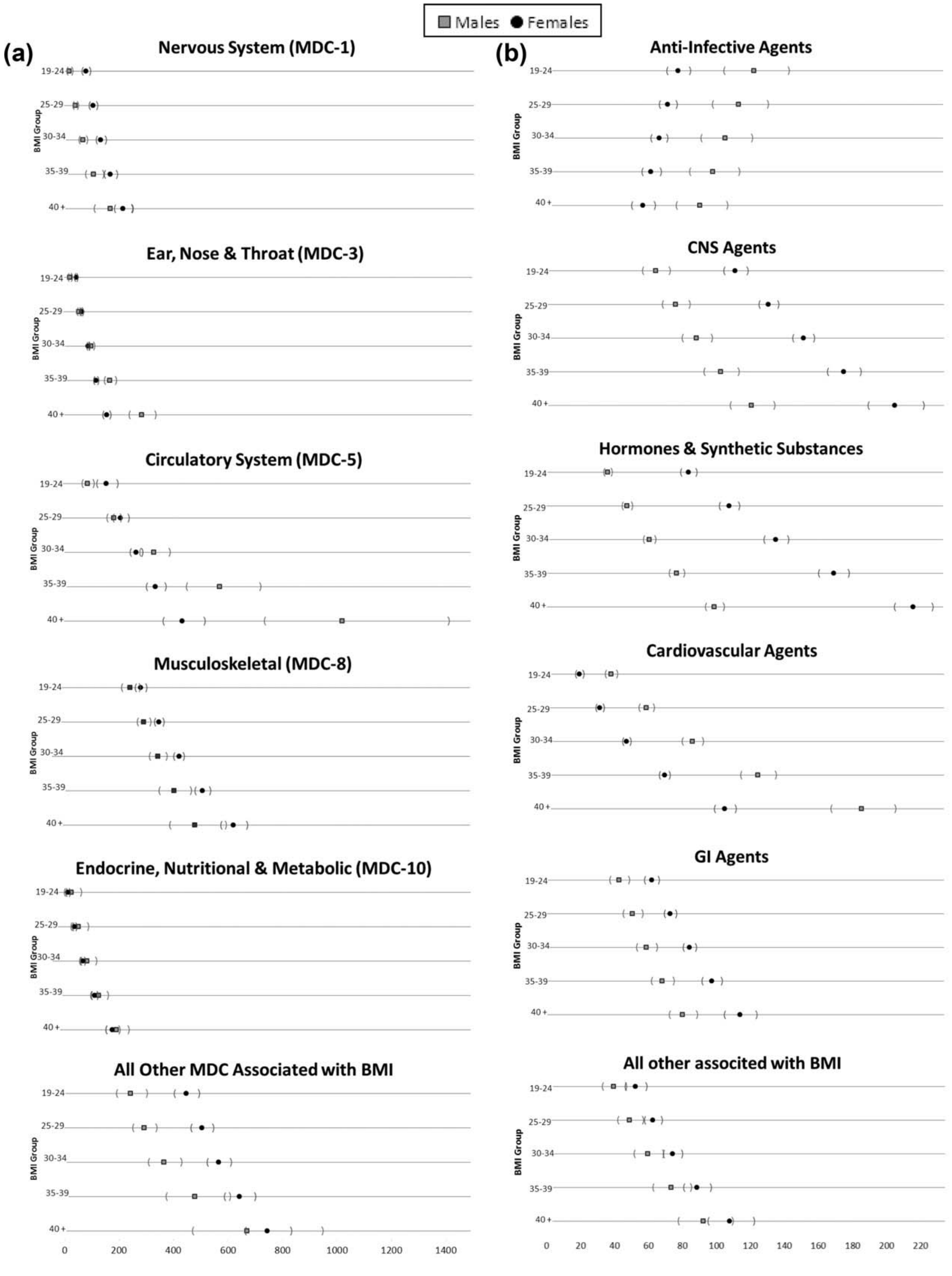

Figure 3 Medical and pharmacy costs associated with BMI by gender. Medical costs are presented for the significant major diagnostic category (MDC) categories and pharmacy costs are presented for the significant drug classes.

from this one employer, this employer is the second largest in North Carolina, and the results should be broadly generalizable to the adult working population given the breadth and diversity of the workers in terms of gender, age, race/ethnicity (32% Black), and in terms of BMI distribution.

Other strengths are the details and comprehensiveness of the data, both in terms of the type of information collected, which allows for consideration of key confounding variables, subgroup analysis by gender and type of disease group, and also the multiple time periods included. The use of both medical and pharmacy claims data further strengthens the findings. The study cohort has high rates of overweight and obesity, lending itself well to answering the study's questions.

The study also has some limitations. First, although the relationship between BMI and health claims is interesting in and of itself, health claims are only an indirect measure for morbidity. The higher claims costs in the overweight and obesity class I categories relative to recommended weight could theoretically indicate aggressive early treatment of obesity-related risk factors, suppressing any relationship between BMI and morbidity that might have been observed in the absence of such treatment. Second, most of the height and weight data were self-reported. There is a tendency to under-report weight, especially by overweight and obese individuals (25). If such bias was present in this sample, our results may be "underestimates" of the effect of BMI on health claims costs. Finally, the relatively modest number of workers in the highest obesity category (BMI $\geq$ 40) leads to higher variability (larger error bars) in the results for that group of employees. Finally, although our data were collected over a 10-year period, and the health claims costs were assessed after the BMI, conclusions regarding direct cause and effect have to be made with caution.

Conclusion

In contrast to recent evidence for no adverse association between overweight and obesity class 1 and mortality, we observed a gradual increase in health claims costs starting already at the lower end of the recommended BMI range. The nature of the relationship between increasing BMI and health claims costs has not changed notably over the last decade. The most important obesity related comorbidities responsible for this relationship appear to be first cardiovascular diseases, and second musculoskeletal and endocrine, nutritional, and metabolic diseases.

Our findings emphasize the importance of preventing workers from ever reaching the overweight and obese class 1 categories, and if already overweight or obese, workplace based and other interventions should be instituted. O

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