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Original Research Article

The Relationship Between Body Mass Index and Pain Intensity Among Veterans with Musculoskeletal Disorders: Findings from the MSD Cohort Study

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Abstract

Objective. To examine the relationship between body mass index (BMI) and pain intensity among veterans with musculoskeletal disorder diagnoses (MSDs; nontraumatic joint disorder; osteoarthritis; low back, back, and neck pain). **Setting.** Administrative and electronic health record data from the Veterans Health Administration (VHA). **Subjects.** A national cohort of US military veterans with MSDs in VHA care during 2001–2012 ($N = 1,759,338$). **Methods.** These cross-sectional data were analyzed using hurdle negative binomial models of pain intensity as a function of BMI, adjusted for comorbidities and demographics. **Results.** The sample had a mean age of 59.4, 95% were male, 77% were white/Non-Hispanic, 79% were overweight or obese, and 42% reported no pain at index MSD diagnosis. Overall, there was a J-shaped relationship between BMI and pain (nadir $= 27$ kg/m^2), with the severely obese (BMI $\geq$ 40 kg/m^2) being most likely to report any pain (OR vs normal weight = 1.23, 95% confidence interval = 1.21–1.26). The association between BMI and pain varied by MSD, with a stronger relationship in the osteoarthritis group and a less pronounced relationship in the back and low back pain groups. **Conclusions.** There was a high prevalence of overweight/obesity among veterans with MSD. High levels of BMI ($>$27 kg/m^2) were associated with increased odds of pain, most markedly among veterans with osteoarthritis.

Key Words: Chronic Pain; Obesity; Musculoskeletal; Osteoarthritis

Introduction

Nearly one-quarter (i.e., 20.4%) of the US population experiences chronic pain, and more than two-thirds (i.e., 68% in 2007–2008) are classified as overweight or obese [1, 2]. Rates of comorbid pain and overweight/obesity are also high, with some estimates ranging from 20% to 45% of overweight/obese individuals reporting pain [3]. Studies have found body mass index (BMI) to be associated with increased risk of recent pain [4] and report of a painful condition within the previous year [3], including low back pain [5]. Further, obesity has been shown to predict the onset and progression of pain [6], and obese patients have reported poor eating habits and avoiding physical activity in response to pain [7].

A number of studies document a significant relationship between certain painful musculoskeletal conditions and weight. For example, weight is a predictor of presence of musculoskeletal conditions. A national study (N = 5,237,763) using electronic health record (EHR) data in the Veterans Health Administration (VHA) suggested that musculoskeletal disorders (MSDs) are as prevalent in veterans as in community samples and found that more than 78% of the cohort of veterans diagnosed with MSD in 2011 were classified as overweight or obese [8]. The relationship between BMI and MSDs is particularly evident for osteoarthritis (OA) [3, 9–11]. More specifically, there is a significant relationship between weight and OA of the knee and, to a lesser extent, of the hip and hand [12]. A recent study with a large sample of younger veterans receiving VHA care (N = 144,246, aged 34–55) demonstrated a relationship between OA and obesity as well [13]. Despite the considerable evidence documenting a relationship between BMI and OA, the relationship between OA and pain, and among BMI, OA, and pain, is less consistently described in the literature [14]. In addition, the association between overweight/obesity and pain across other common MSDs has not been well elucidated.

Given that pain and overweight/obesity are each more prevalent in veterans than the general population [15–17] and the potential negative outcomes, further examination of their co-occurrence is warranted. Information regarding correlates of comorbid pain and obesity is limited [6], particularly among veterans receiving VHA care. Survey data from a national sample of nearly 46,000 veterans interested in weight loss treatment demonstrated that a high proportion (72%) of overweight and obese veterans self-reported one or more painful conditions, with 10% reporting back pain, 26% reporting arthritis pain, and 35% reporting combined back and arthritis pain [18]. In that study, participants with higher BMIs were more likely to report painful conditions (i.e., arthritis or both back pain and arthritis). The current study sought to expand on these data in several ways. The results of the survey study do not focus explicitly on the correlates of painful conditions other than BMI. Rather than relying on self-report data for diagnoses of painful conditions, the current study sought to examine diagnostic codes entered into the EHR by clinicians during clinical encounters, which is likely a more valid indication of MSD diagnosis. Further, the current study was able to examine additional demographic variables (e.g., marital status) and more specific medical and mental health diagnoses (e.g., traumatic brain injury) than the survey study.

One limitation of the existing literature is that it is largely based on examination of the correlation between weight and pain intensity among patients with chronic pain (i.e., existing pain conditions). Although BMI consistent with overweight/obesity is a precursor to pain and some MSDs, it is unknown what percentage of patients develop MSDs in the absence of high BMI. There are clinical implications for knowing this information, as the common recommendation to lose weight to improve pain is not helpful for potentially large segments of the population who develop MSDs in the absence of high BMI (e.g., patients with normal weight BMI at index MSD diagnosis). The current study examines the relationship between BMI and pain intensity at incident diagnosis of MSD. Further, the relationship between BMI and pain intensity among patients with specific pain-related conditions (i.e., MSD) using EHR-derived data has received relatively little attention. To address these gaps, the aims of the current study were to examine whether, among veterans with musculoskeletal disorders in VHA care, 1) BMI and pain intensity are associated at initial MSD diagnosis and 2) whether this association varies by specific MSD.

Methods

Study Population

A detailed description of the MSD cohort has been published previously [8]. *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9CM) codes for musculoskeletal disorders were used to define the cohort [8]. We searched the VHA EHR data for all outpatient and inpatient records with an MSD diagnosis noted between January 1, 2000, and December 31, 2011. To be included in the MSD cohort, veterans had to have two or more outpatient visits with any MSD diagnosis occurring within 18 months of one another, or one or more inpatient admissions with an MSD diagnosis [8]. The index date for cohort entry was defined as the date of the first observed MSD diagnosis. The method of using two outpatient codes or one inpatient code to determine the presence of a diagnosis is frequently used in administrative data [8, 19]. Although there is systematic underuse of ICD codes in VHA compared with non-VHA settings, potentially due to reliance on ICD codes in non-VHA settings for the purpose of billing [20–22], our sample was restricted to those with a diagnosis on record. Validated data support the reliability of height and weight data as well as the reliability of data reflecting smoking, gout, and pain that are available through the VHA's EHR

[23–27]. The data used in the current study included only those veterans identified with an initial MSD diagnosis between 2001 and 2011 to allow for a second confirmatory MSD diagnosis. To more clearly examine the relationship between BMI and pain intensity within specific MSD groups, data were limited to veterans with only one MSD at entry into the cohort (N = 3,471,987 of nearly four million veterans in the MSD cohort, 2001–2011) (see the Supplementary Data for a detailed inclusion/exclusion flowchart). Veterans with diagnoses of nontraumatic joint pain, low back pain, back pain, neck pain, and OA were retained (N = 2,286,059). After removing veterans with missing pain intensity, BMI, and/or demographic data, 1,759,338 patients were available for the analyses.

The study was approved by the Institutional Review Board at VA Connecticut Healthcare System.

Defining MSD

For the current study, only codes associated with the diagnosis of a nontraumatic joint disorder (e.g., arthropathies, ankylosis), low back pain (LBP), other back pain (general), neck pain, and OA were examined, as these were the most prevalent diagnostic code groupings.

Variables

Demographics

Age, gender, race/ethnicity, and marital status (married vs not married) as of the MSD cohort index date were extracted from the EHR, used to describe the sample, and included in models as covariates.

MSD Group

MSD diagnoses were grouped into the following categories: OA, nontraumatic joint disorders, LBP, general back pain, and neck pain, as described above.

Body Mass Index

BMI was calculated from the height and weight data on or closest to the MSD index date within three months before or after entry into the cohort using the following formula: 703 × weight (lb)/[height (in)]^2. BMI classifications were based on standard cutoffs as follows: normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25 to 29.9 kg/m^2), obesity (BMI 30+ kg/m^2). Obesity was further subdivided into Class I (BMI 30–34.9 kg/m^2), Class II (BMI 35–39.9 kg/m^2), and Class III (BMI 40+ kg/m^2) [28].

Pain Intensity Ratings

The pain intensity numeric rating scale (NRS) is used in routine clinical care within the VHA to screen for the presence and intensity of pain typically when other vital signs are obtained [29]. Veterans are asked, "On a scale of 0 to 10, where 0 means no pain and 10 means the worst possible pain, what is your current pain level?" NRS pain intensity ratings were identified on the MSD index date. When multiple pain intensity ratings were recorded on the index date, we retained only the highest pain intensity rating [30].

Medical and Mental Health Conditions

High-prevalence, high-impact medical and mental health comorbid diagnoses commonly associated with chronic pain [19] and overweight/obesity [18] were identified using the same criteria as MSD diagnoses (i.e., two or more outpatient codes within 18 months, or at least one inpatient code). Coronary artery disease (CAD), hypertension (HTN), stroke, hepatitis C virus (HCV), type 2 diabetes mellitus (DMII), and chronic obstructive pulmonary disease (COPD) were included as medical comorbidities [13, 31]. Mental health conditions included depressive disorders (i.e., major depressive disorder, dysthymia, depression due to other causes, or not otherwise specified), anxiety disorders (i.e., panic disorder without agoraphobia, generalized anxiety disorder, anxiety state not otherwise classified, nervousness), post-traumatic stress disorder (PTSD), alcohol use disorders, and substance use disorders. Only comorbid conditions noted in the year before and up to six months after the MSD index date were retained for the analysis, as they were likely to be active at the time of the MSD diagnosis. These criteria have been used in prior published work using the MSD cohort [8].

Statistical Analysis

A large proportion of pain intensity NRS ratings were 0s (42%), representing "no pain"; therefore, we used a hurdle negative binomial model to examine BMI as a predictor of pain intensity [32]. This model, which can accommodate the overabundance of 0s in the outcome, has two parts: the first part (logistic part) models the probability of non-0 vs 0 pain using logistic regression, while the second part (count part) models the mean pain intensity rating conditional on the pain intensity rating being non-0 using a 0-truncated negative binomial regression model with a log link [33]. Both parts of the model were adjusted for demographic variables and presence of each medical and mental health diagnosis listed above. We present adjusted odds ratios (ORs) for the logistic part of the model and adjusted rate ratios (RRs; ratio of means) for the count part. BMI and age were modeled as continuous predictors using natural cubic splines with four degrees of freedom (three knots placed at the 25th, 50th, and 75th quantiles) to allow for nonlinear relationships. To assist with interpretation, we also present the results from supplemental analyses treating BMI as a categorical variable with five levels (normal, overweight, obesity classes I, II, and III).

To see whether the relationship between BMI and pain varied by MSD, we also considered a model that contained the interaction of MSD with all the other variables in the model.

Missing Data and Exclusion Criteria

Veterans with missing data for the variables of interest (pain intensity, BMI, demographics) were excluded from analyses (Supplementary Data). Veterans with more than one MSD diagnosis on the index date, with an MSD other than nontraumatic joint disorder, OA, LBP, back pain, or neck pain, those with an implausible BMI (e.g., BMI 2 or 7,000 kg/m^2), or who were underweight (BMI < 18.5 kg/m^2) were also excluded. The Supplementary Data demonstrate differences between those excluded compared with those included in the analysis. The groups were similar in most of their characteristics. Pain was slightly higher in those excluded (median 3 vs 2 on the 0–10 scale).

Results

Sample Characteristics

Table 1 summarizes the sample characteristics categorized by MSD group. Overall, veterans had a mean age of 59.4, 95% were male, 77% were white/non-Hispanic, and 43% were not married. The most common comorbidities were HTN (50%), diabetes (18%), depressive disorders (16%), and CAD (16%). Those with OA were 10 years older on average than those with other MSDs and were more likely to have diagnoses of HTN, CAD, and diabetes, but were less likely to have depressive disorders, anxiety disorders, PTSD, and alcohol and substance abuse disorders than those with other MSDs.

The mean BMI on MSD index date (SD) was 29.3 (5.5), with 40% of the sample classified as overweight, 25% classified as having mild obesity (class I), 9% as having moderate obesity (class II), and 4% as having severe obesity (class III). The median (interquartile range) pain intensity NRS score on the same day was 2.0 (0.0–6.0), with 42% of veterans reporting no pain. The median pain intensity among those with OA was 0, compared with 3 or 4 for the other MSDs. The proportion of veterans with any pain ranged from 56% in overweight to 65% in class III obesity. The mean of non-0 pain intensity ratings ranged from 5.3 in overweight to 5.5 in normal BMI and 5.6 in those with class III obesity. Within the MSD groups, report of any pain increased with BMI (e.g., among those with OA, 40% of overweight reported pain vs 55% of those with class III obesity).

The Relationship Between Continuous BMI and Pain Intensity

Figure 1 (left) presents the adjusted ORs for the relationship between BMI and non-0 pain intensity NRS scores, as estimated from the logistic part of the hurdle model, with BMI = 23 kg/m^2 (the median value in the normal BMI group) taken as the reference. The relationship is J-shaped and statistically significant ($P < 0.0001$), with the OR of any pain decreasing until a BMI of 27 kg/m^2, and then sharply increasing. For example, the odds of any pain at BMI = 45 kg/m^2 are estimated to be 26% (1.26 times) higher than at BMI = 23 kg/m^2. For interpretability, the right side of Figure 1 presents the association between BMI and any pain in terms of probabilities. Because the estimated probabilities depend on the value of the covariates, we are presenting them for a "typical" patient: a white male with nontraumatic joint disorder, who is married, with no comorbidities. Figure 2 presents the relationship between BMI and pain intensity when pain is present (non-0), as estimated from the count part of the hurdle model. This relationship is also J-shaped and statistically significant but is weaker in magnitude (the ratio of mean pain at a specific BMI vs BMI = 23 kg/m^2 varies from 0.97 to 1.10).

The Relationship Between Continuous BMI and Pain Intensity by Specific MSD

The model containing interactions (Figure 3) indicated that the relationship between BMI and pain intensity varied by MSD, with a higher BMI having a stronger relationship with pain intensity among those with OA and a less pronounced relationship in those with back pain and LBP.

The Relationship Between Categorical BMI and Pain Intensity

Table 2 describes the overall adjusted association between BMI categories and pain intensity. The logistic part of the model indicates that BMI category is significantly associated with having any pain (i.e., having non-0 pain). Those in obesity classes II and III had 9% and 23% higher odds of any pain, respectively, than those with normal weight. The overweight veterans had slightly (5%) lower odds of any pain than those with normal weight. The second (count) part of the model indicates that, among veterans with any pain, there is only a small association between BMI and pain intensity level (all RRs very close to 1; they are statistically significant because of the large sample).

The Relationship Between Categorical BMI and Pain Intensity, by Specific MSD

In specific MSDs, overweight and obesity class I were similar to normal weight veterans in terms of likelihood of reporting any pain (ORs between 0.94 and 1.05) (see the logistic part of the Supplementary Data). The relationship between likelihood of reporting any pain and obesity classes II and III vs normal weight was more pronounced in all groups, with the strongest relationship observed in the OA group (for obesity class III vs normal,

Table 1. Summary characteristics of the sample by MSD group and combined

	Nontraumatic Joint Disorder (N = 623,697)	Back Pain (N = 134,726)	Low Back Pain (N = 428,481)	Neck Pain (N = 84,497)	OA (N = 487,937)	Combined (N = 1,759,338)	*P* Value (Difference Among all MSD Groups)
Age, mean (SD), y	56.92 (16.08)	56.16 (16.48)	55.92 (15.86)	57.27 (14.58)	66.83 (12.74)	59.38 (15.83)	<0.0001
Male, %	93	93	94	93	97	95	<0.0001
Race/ethnicity, %							<0.0001
White	74	77	75	77	84	77	
Black	18	15	16	15	10	15	
Hispanic	6	6	6	5	3	5	
Other	3	3	3	3	2	2	
Not married, %	46	47	46	47	36	43	<0.0001
Hypertension, %	47	46	46	47	59	50	<0.0001
CAD, %	14	15	14	14	21	16	<0.0001
Stroke, %	1	0	0	1	0	1	<0.0001
Hepatitis C, %	3	4	3	3	2	3	<0.0001
Diabetes, %	18	17	17	16	22	19	<0.0001
COPD, %	7	9	8	9	10	8	<0.0001
Depressive disorders, %	16	21	20	20	12	16	<0.0001
Anxiety disorders, %	7	8	8	9	4	6	<0.0001
PTSD, %	9	10	10	10	5	8	<0.0001
Alcohol abuse, %	8	9	8	9	4	7	<0.0001
Substance abuse, %	4	5	4	4	2	4	<0.0001
BMI (on MSD diagnosis day), kg/m^2	29.41 (5.56)	28.91 (5.50)	29.18 (5.46)	28.28 (5.02)	29.71 (5.62)	29.34 (5.53)	<0.0001
BMI category, %							<0.0001
Normal	21	24	22	26	19	21	
Overweight	39	39	40	42	40	40	
Obese class I	26	24	25	22	26	25	
Obese class II	10	9	9	7	10	9	
Obese class III	4	4	4	2	5	4	
Pain (on MSD diagnosis day), median (IQR)	3.00 (0.00–6.00)	4.00 (0.00–7.00)	4.00 (0.00–7.00)	3.00 (0.00–6.00)	0.00 (0.00–4.00)	2.00 (0.00–6.00)	<0.0001
Pain intensity NRS category, %							<0.0001
0	39	33	33	36	57	42	
1–3	17	15	15	16	14	15	
4–6	24	25	26	25	17	23	
7–10	20	27	27	23	12	20	

BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; IQR = interquartile range; MSD = musculoskeletal disorder; NRS = numeric rating scale; OA = osteoarthritis; PTSD = post-traumatic stress disorder.

OR = 1.37 in OA; ORs in other groups ranged from 1.08 [back pain] to 1.23 [nontraumatic joint disorder]). As with continuous BMI, the count part of the model indicates that there is a weak association between categorical BMI and pain intensity level among veterans with any pain, with RR estimates near 1 in all MSD groups.

Discussion

The MSD cohort provided rich data with which to examine the relationship between BMI and pain intensity in veterans with musculoskeletal disorders in VHA care. In particular, the current study quantified overweight/obesity and pain (or absence of pain) among patients with the five most common categories of MSD and describes how the association between BMI and pain varies across MSDs. Overall, examination of patterns and relationships within the data indicate a J-shaped relationship between BMI and pain (nadir of 27 kg/m^2), with patients with increased BMI being more likely to report “any pain.” This finding is consistent with the existing literature, which demonstrates high comorbidity between overweight/obesity and chronic pain [3].

With respect to examining the interaction between BMI and MSD and their relationship with pain intensity, in the current study, higher BMI and pain intensity had a stronger relationship for patients with OA than those with other MSDs. More specifically, the more weight a patient with OA carried, the higher the likelihood of experiencing pain at the time of OA diagnosis. Data suggest that overweight/obesity may have a particularly significant effect on load-bearing joints such as hips, knees, and ankles, which is likely reflected by OA diagnosis in some of the patients in the MSD cohort [34]. Alternatively, these patients may have experienced military service and possibly combat exposure, during which they were likely carrying heavy loads of equipment,

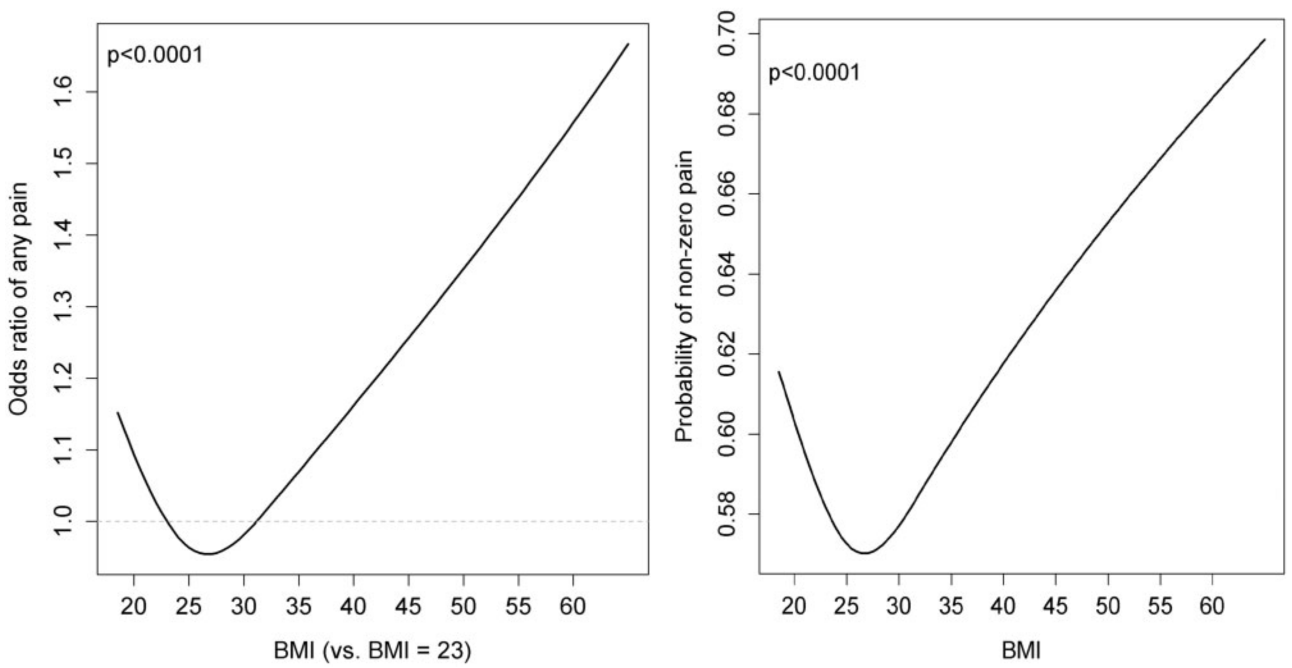

Figure 1. Relationship between body mass index (BMI) and any pain. The left plot presents adjusted odds ratios for the association between BMI (kg/m^2) and the presence of any pain (i.e., non-0 pain). The reference value is BMI = 23 kg/m^2. Estimates were obtained from the logistic part of the hurdle-negative binomial model. BMI was modeled using natural cubic splines with 4 degrees of freedom (three knots). The right plot presents the estimated probability of non-0 pain from the same model for a white male with nontraumatic joint disorder, married, with no comorbidities.

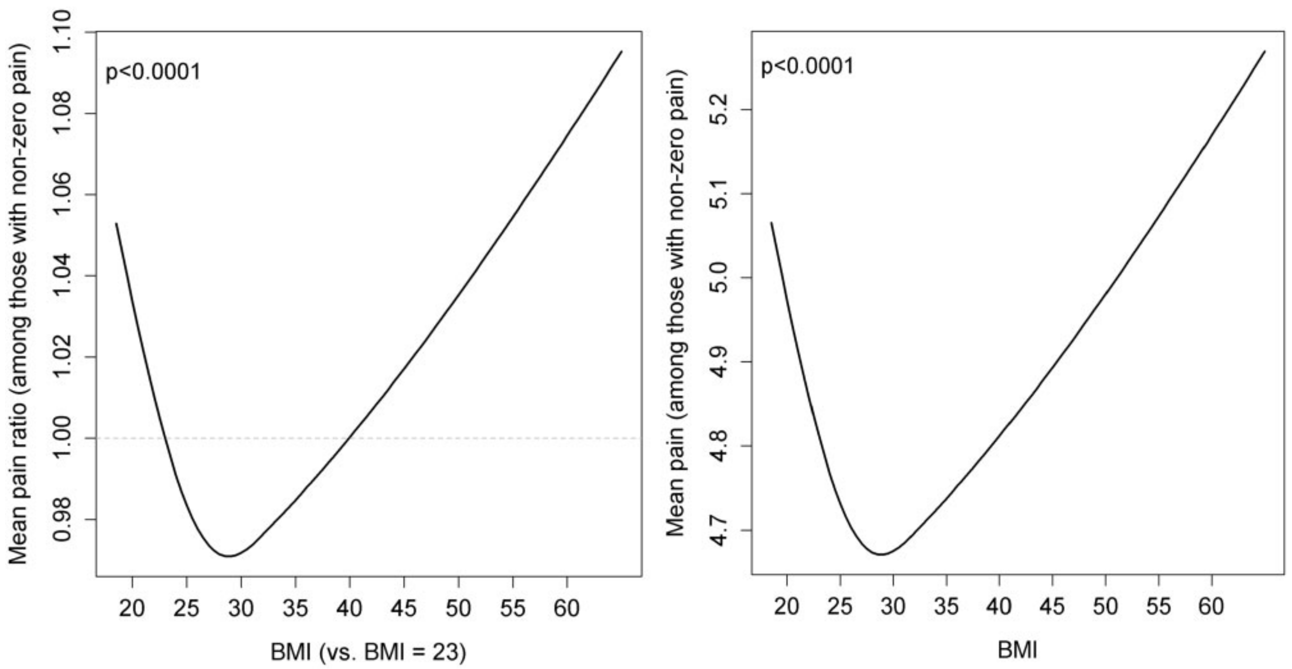

Figure 2. Relationship between body mass index (BMI) and pain intensity among subjects with any pain. The left plot presents the adjusted mean (rate) ratios for the association between BMI (kg/m^2) and pain among subjects with non-0 pain. The reference value is BMI = 23 kg/m^2. Estimates were obtained from the count part of the hurdle-negative binomial model. BMI was modeled using natural cubic splines with 4 degrees of freedom (three knots). The right plot presents the estimated mean pain of subjects with non-0 pain for a white male with nontraumatic joint disorder, married, with no comorbidities.

which may have contributed to development of OA in these load-bearing joints. OA with associated pain may cause patients to limit activity and may lead to increased BMI as a result. It is also possible that patients with higher BMI and OA in this sample are experiencing more disease burden over time, more inflammation, and more

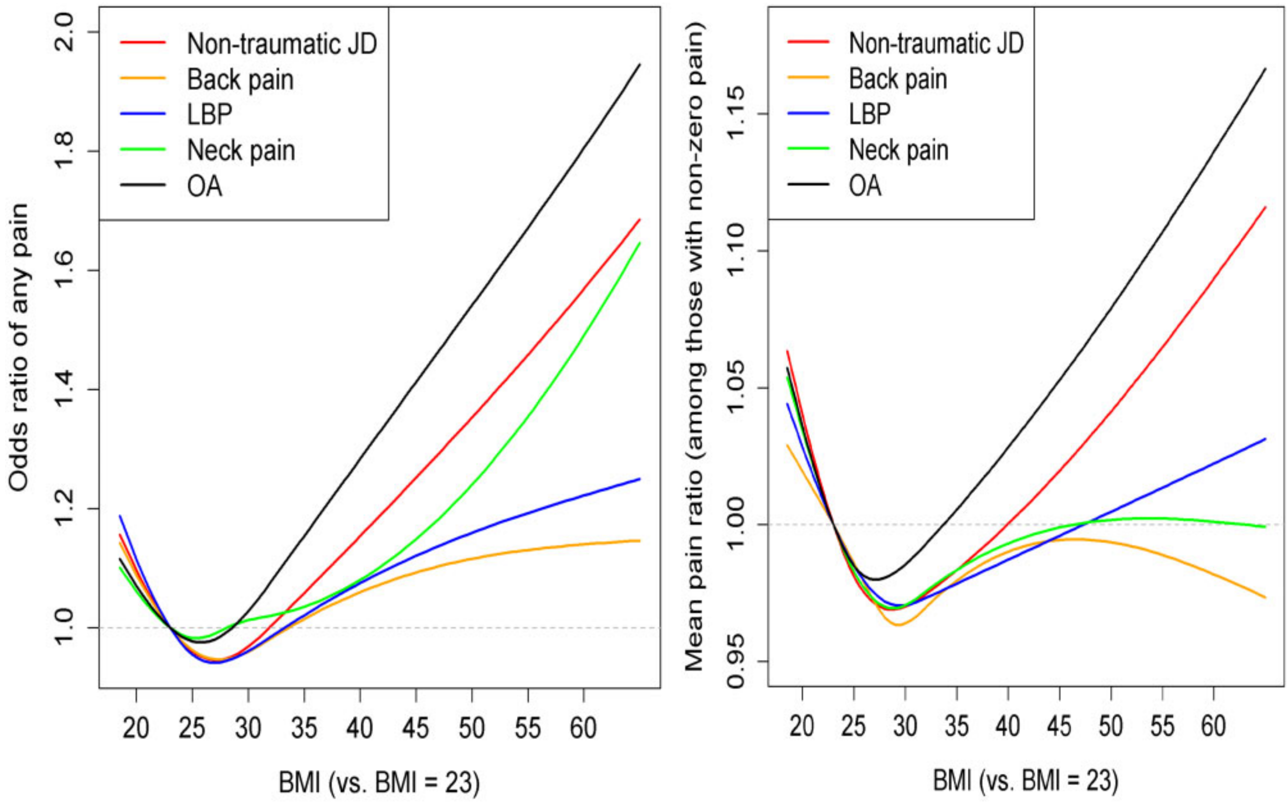

Figure 3. Odds ratios and mean ratios between body mass index (BMI) and any non-0 pain. The left plot presents adjusted odds ratios for the association between BMI (kg/m^2) and the presence of any pain (i.e., non-0 pain), by musculoskeletal disorder (MSD) group. The right plot presents the adjusted mean ratios for the association between BMI (kg/m^2) and pain among subjects with non-0 pain, by MSD group. Estimates were obtained from the hurdle-negative binomial model, which included interactions of the MSD group with all variables in the model. The reference value is BMI = 23 kg/m^2. BMI was modeled using natural cubic splines with 4 degrees of freedom (three knots).

Table 2. Overall association between BMI as a categorical predictor and pain intensity

	Logistic Part of the Hurdle Model				Count Part of the Hurdle Model			
	OR of any Pain	95% CI		*P* Value	RR (Mean Pain Ratio) Among Those with any Pain	95% CI		*P* Value
Normal (BMI 18.5–25 kg/m^2, reference)								
Overweight (BMI 25–30 kg/m^2)	0.95	0.94	0.96	<0.0001	0.97	0.97	0.97	<0.0001
Obese class I (BMI 30–35 kg/m^2)	1.00	1.00	1.01	0.32	0.97	0.97	0.98	<0.0001
Obese class II (BMI 35–40 kg/m^2)	1.09	1.08	1.11	<0.0001	0.99	0.98	0.99	<0.0001
Obese class III (BMI ≥40 kg/m^2)	1.23	1.21	1.26	<0.0001	1.01	1.01	1.02	<0.0001

Results are from a hurdle-negative binomial model adjusted for MSD group (nontraumatic joint disorder, low back pain, back pain, neck pain, and OA), age, gender, race/ethnicity, marital status (married vs not married), and presence of each of the following comorbidities (hypertension, CAD, stroke, hepatitis C, diabetes, COPD, depression, anxiety, PTSD, alcohol abuse, and drug abuse).

BMI = body mass index; CAD = coronary artery disease; COPD = chronic obstructive pulmonary disease; MSD = musculoskeletal disorder; NRS = numeric rating scale; OA = osteoarthritis; PTSD = post-traumatic stress disorder.

coping challenges, and thus are more likely to report pain. When considering BMI as a categorical, rather than continuous, variable (as depicted in Tables 2 and Supplemental Table 2), the same relationship was demonstrated: Those with class II and III obesity were overall more likely to report pain than patients with lower BMIs, and this association was stronger in those with OA than in other MSDs.

The findings in the current study highlight differences between veterans with OA and other MSDs. For example, veterans with OA were older, were more likely to report a pain intensity of 0, and were more likely to have medical diagnoses (likely reflecting their older age, as the medical diagnoses more common among patients with OA were HTN, CAD, and diabetes) than those with other MSDs. Consistent with our finding of some proportion of patients with OA reporting 0 pain, a meta-analysis of studies examining MRI evidence of OA in people with asymptomatic, uninjured knees found evidence of OA in 4–14% of adults aged <40 years and 19–43% of adults aged 40 years or older [35]. There are several potential explanations for the finding that veterans with OA were more likely to report 0 pain, including that pain intensity is often assessed while the veteran is sitting to have other vital signs taken, which reduces load-bearing on joints that may be affected by OA, thereby significantly lessening or eliminating pain. In addition, pain associated with OA can vary considerably within and across days [14]. Consistent with other recent studies [13], veterans with OA were less likely to have mental health diagnoses than those with other MSDs, perhaps due to a more minimal impact of pain/MSD on functioning and quality of life than, for instance, those with low back pain might experience.

The demographic make-up of the sample in the current study differs from those of other studies examining overweight/obesity and MSDs or pain. In contrast to other large samples of patients with chronic pain conditions and/or overweight/obesity, our sample was predominantly male, allowing for examination of these patterns among a large sample of men. Patients with OA [36] and low back pain [37] tend to be predominantly female. Further, studies suggest that the association between overweight/obesity and low back pain is stronger in women than men [5]. Given the inconsistent sample characteristics and results among studies of overweight/obesity and pain or MSDs with respect to gender and race/ethnicity, future studies examining overweight/obesity and pain should consider analyzing data by gender.

The patients in the current study had an average BMI in the overweight (bordering on mild obesity) range, yet the mean pain intensity on the index date reflected only mild pain intensity, with 42% reporting no pain. The overall low levels of pain observed in this cohort may reflect any number of other circumstances, including fluctuations in pain intensity (particularly with and without physical activity), well-controlled pain, reduced pain while patients are sitting for vital sign acquisition, underreporting of pain intensity due to social desirability or data entry error [38], or the presence of an MSD without constant accompanying pain, such as OA [8]. The current study also includes a sample of recently diagnosed MSDs, for which pain may be less severe or inconsistently present earlier in the disease process. It possible that detecting MSDs before pain manifests will allow clinicians to advise patients about lifestyle changes (e.g., implementing a brisk walking program for low back pain) that may help prevent or manage new-onset pain earlier. Researchers may also identify predictors of pain onset among those with recently diagnosed MSDs who did not report pain. Although the current study examined cross-sectional associations among pain, BMI, and MSDs, longitudinal analyses examining change in pain intensity ratings may yield richer data and allow for causal inferences in these associations. Specifically, future studies may want to consider examining changes in weight and pain in the time since MSD onset. Such analyses may help address the issue in the current study of the time dependence of pain on MSD onset and may explain the 0 or low level of pain reported by many of the patients at MSD onset.

This study has several limitations. The sample was limited by missing data and relatively stringent inclusion criteria. For example, veterans with more than one MSD were excluded; 16% of the original sample of veterans in VHA care had more than one MSD at index date. These patients may have had higher disease burden and potentially higher pain intensity, given their multiple pain conditions. The data presented here may not reflect their unique circumstances with respect to overweight/obesity and multiple painful MSDs. The sample was further restricted to exclude patients with missing data on variables of interest. These exclusions may limit generalizability to other veterans with MSD. Additional variables of interest in pain research, such as medication use (e.g., opioids), were not included in the current study but should be considered in future studies. Although we are examining initial MSD diagnosis in this study, it is possible that some proportion of these veterans in VHA care had MSD diagnoses made previously in non-VHA clinical settings (i.e., these are not truly "new diagnoses"). The cross-sectional nature of this study and its reliance on administrative data do not allow for causal inferences to be made (i.e., overweight/obesity can increase pain in MSD, which may promote reduced physical activity and, consequently, increased prevalence of overweight/obesity and pain intensity). Because the data examined in the current study do not allow for inferences about the effect of change in weight on pain to be drawn, future studies should consider longitudinal designs to investigate how changes in BMI are associated with changes in pain outcomes. Finally, although there are a number of published studies describing the relationship between BMI and knee OA, the currently included diagnoses of OA were based solely on ICD codes, rather than on radiographic evidence indicating the grade of OA, which was not available for the current study. As a result, the relationship found in this study cannot be directly compared with the existing literature that focuses on grade of OA.

In this large sample of veterans diagnosed with OA, nontraumatic joint disorders, back pain, or neck pain, 78% were overweight or obese at the time of diagnosis. This reflects a higher prevalence of overweight/obesity among veterans than the general US population [1]. Moreover, BMI was associated with greater likelihood of reporting pain, especially among those with OA. Given the high prevalence of comorbid MSDs and overweight/obesity, addressing these conditions with combined efforts is paramount [39, 40]. Both overweight/obesity and MSD (particularly OA) are notable public health problems, and when they co-occur, the likelihood of successful management of both conditions may be greater than the management of either alone. Effective management of these conditions should consider a treatment model that addresses both conditions rather than a singular condition. Perhaps physical activity, often reduced because of pain associated with MSDs but certainly prescribed for conditions such as low back pain, should be strongly considered in these treatment models. This would provide the added benefit of assisting with weight loss, weight loss maintenance, and comorbidity management, in addition to reducing pain and pain-related interference. On the other hand, patients with MSDs and pain should be encouraged to engage in appropriate pain management options (e.g., medication, interventional procedures, acupuncture), irrespective of weight. It may be equally helpful for "normal weight" patients to engage in physical activity for chronic pain management, either through self-directed exercise, physical therapy, or aquatic therapy, for example, as it would for those with overweight/obesity to engage in physical activity for both pain and weight management.

The VHA has made considerable efforts to address chronic pain and overweight/obesity separately, but there is no clear clinical guidance or program implementation to address their co-occurrence, despite the demonstrated high rate of co-occurrences in veterans [8] and potential for individuals who experience comorbid pain and overweight/obesity to have worse treatment outcomes from "single-focus" treatment approaches. As the nation's largest integrated health care system, the VHA is in a unique position to develop clinical programs and policy to address these conditions and reduce associated problems.

Supplementary Data

Supplementary data are available at *Pain Medicine* online.

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