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Using Patient-Reported Outcome Measurement Information System Computer Adaptive Testing Domains to Investigate the Impact of Obesity on Physical Function, Pain Interference, and Mental Health in Sports Medicine Patients

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Background: While obesity has become an increasingly prevalent health concern in the United States, little emphasis has been placed on utilizing patient reported outcome measures (PROM) to investigate its impact on life from the patients' perspective. The purpose of the study was to determine the association between patients' body mass index (BMI) and three Patient-Reported Outcome Measurement Information System (PROMIS) computer adaptive test scores: upper extremity physical function (UE) or lower extremity physical function (PF), pain interference (PI), and depression (D).
Methods: Patients were recruited from two sports medicine orthopedic surgery clinics. PROMIS questionnaires were administered to patients arriving for their first visit. Patients were stratified into BMI groupings according to the National Institute of Health standards. Patients' BMI, sex, race, ethnicity, and injury were determined retroactively. Data were analyzed using a Pearson correlation and a least significant difference post hoc test.
Results: A total of 833 patients completed the set of PROMIS questionnaires that were retrospectively analyzed. BMI was found to have a correlation with PROMIS-UE ($R=-0.111$, $P<0.05$), PROMIS-PF ($R=-0.174$, $P<0.01$), PROMIS-PI ($R=0.224$, $P<0.01$), and PROMIS-D ($R=0.092$, $P<0.05$). Obese patients also portrayed the worst PROMIS-UE, PROMIS-PI, and PROMIS-PF.
Conclusion: We found BMI to correlate with each PROMIS domain: negatively with PROMIS-UE, PROMIS-PF, PROMIS-D, and positively with PROMIS-PI. Additionally, overweight and obese BMI patients portrayed worse physical function and pain interference scores than their healthy group counterparts.

Key words: Body mass index, Patient reported outcome measures, Overweight, Obesity, Quality of life, Pain

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INTRODUCTION

Obesity, defined as a body mass index (BMI) of 30 kg/m^2 or higher, is a pressing health care problem around the world. It has been significantly associated with chronic disease in both men and women.[1,2] Despite negative implications, obesity has become increasingly prevalent rising from 29.7% in 2009 to 32.4% in 2015.[2] Studies have reported that statistics may actually underestimate the impact of obesity on mortality and its associated costs.[1,3] Studies have addressed the impact of BMI on postoperative success in orthopedic surgery by utilizing objective measures, in addition to legacy patient reported outcome measures (PROM).[4,5] However, the

impact of BMI on physical function, pain interference, and depression in patients undergoing surgical or nonsurgical treatments has not been assessed from the patients' perspective utilizing the new Patient-Reported Outcome Measurement Information System's (PROMIS's) computer adaptive testing (CAT) domains.

As healthcare continues to evolve to a more value-based approach, PROM are becoming increasingly important, as they represent clinical outcomes from the patient perspective. Many insurance companies have already begun replacing fee-for-service models with recently-developed, pay-for-performance models.[6] These PROM also provide benefits to the patient, as patients are able to quantify progression throughout their treatment.[7] The National Institute of Health (NIH) created PROMIS in a concentrated effort to streamline PROM reporting via a single effective and efficient system.[8,9] PROMIS CAT forms are an electronic questionnaire that utilizes an item response theory to determine the most relevant subsequent question to ask—choosing from a large question bank specific to each subdomain. This has made PROMIS more responsive, had fewer ceiling and floor effects, and taken less time compared to legacy PROM.[10,11] Additionally, several studies have found CAT forms to be well received by patients from a diverse population—even denoting that it can promote elevated self-reflection.[12]

The purpose of this study is to investigate the association of BMI on numerous health domains, such as physical function, pain interference (the impact of pain on a patient's quality of life), and mental health (depression) as measured by PROMIS CAT domains to enable providers to further incorporate BMI into treatment choices. We hypothesize that BMI has a negative correlation with physical function scores and a positive correlation with pain interference and depression scores.

METHODS

This study was performed under Institutional Board Approval of Henry Ford Health System (No. 11361), which waived the requirement for informed consent. All patients presenting to one of two surgeons' ambulatory sports medicine clinics, as part of routine practice, were asked to complete an electronic questionnaire. The questionnaire consisted of an intake form that presented injury location options, followed by the corresponding PROMIS CAT forms: PROMIS-upper extremity physical function (PROMIS-UE) or PROMIS-lower extremity physical function (PROMIS-PF), PROMIS-pain interference (PROMIS-PI), and PROMIS-depression (PROMIS-D). If a patient presented for an upper extremity complaint, they were directed to PROMIS-UE, whereas if a lower extremity complaint was selected, they were directed to PROMIS-PF. All patients were then automatically directed to PROMIS-PI and PROMIS-D forms. These questionnaires were administered on iPad tablets (Apple, Cupertino, CA, USA) using a secure, web-based application designed to support data capture for research studies hosted at our institution (REDCap, Nashville, TN, USA).[13] The PROMIS CAT questionnaires were automatically scored on a standard system by REDCap; a score of 50 represents the average value of the general population with 10 points equal to one standard deviation change in that measure.[14,15]

Patients that presented for their first visit between June 30, 2017 and December 29, 2017, and completed the questionnaire, were retrospectively screened for inclusion. We screened a total of 858 patients and excluded a total of 25 patients for one of two reasons; 17 because they indicated both an upper extremity and lower extremity injury, and eight because they did not have a BMI indicated in their electronic medical record (EMR). In total, we included 833 of the 858 screened patients in our study. Several patient demographics were retrospectively collected from the EMR: BMI, age, sex, race, employment status, history of smoking and tobacco use, and an estimated median household income (MHI). Patients' BMI values were categorized as underweight, normal, overweight, and obese, according to accepted values provided by the NIH (Table 1).[16] Tobacco use was documented as current, former, never, or unknown. Employment status was documented as either employed or unknown, with the latter encompassing both unemployed and unknown in the EMR. To determine the estimated MHI, we utilized patients' zip codes and the United States Census Bureau 2010 data

Table 1. BMI categorization (n=833)

BMI (kg/m^2)	Group	PF value (n)	UE value (n)	Total (%)
<18.5	Underweight	6	2	1
18.5–24.9	Healthy	140	82	27
25.0–29.9	Overweight	157	121	33
≥30.0	Obese	189	136	39

BMI, body mass index; PF, physical function; UE, upper extremity.

through an online platform, American Fact Finder.[17]

Statistical analysis

Summary statistics were calculated for the demographic data. Pearson correlations were calculated between BMI, and PROMIS-UE, PROMIS-PF, PROMIS-PI, and PROMIS-D. Additionally, each NIH-dictated BMI category was compared to one another through their respective PROMIS domain mean scores utilizing a least significant difference post hoc test. For each test, a *P*-value of <0.05 denoted statistical significance. All statistical analyses were conducted by a trained psychometrician.

RESULTS

A total of 833 unique patients completed the PROMIS CAT forms and met inclusion criteria for the study. The demographics of the patient cohort are described in Table 2. The average age of patients surveyed was 46.6 years (range, 13–89 years; standard deviation [SD], 18.5 years) with a male predominance (54%). The average BMI was 29.4 kg/m^2 with a range of 17.7–58.9 kg/m^2 (SD, 7.0 kg/m^2). Seventy-two percent of patients, according to their indicated BMI, were classified as either overweight or obese (Table 1). Sixty-two percent (n = 519) of patients identified as White and twenty-one percent (n = 172) as Black. Forty-two percent (n = 346) of patients had documented employment in the EMR, and the preponderance of patients had no history of tobacco use (64%). There were 341 patients that presented with an upper extremity injury (the upper-extremity cohort) and 492 patients that presented with a lower extremity injury (the lower-extremity cohort) (Table 3). The most common upper and lower extremity diagnoses were rotator cuff tear and osteoarthritis, respectively.

We found BMI to correlate with each PROMIS domain: PROMIS-UE, PROMIS-PF, PROMIS-PI, and PROMIS-D. These established correlations indicate that for each point of increased BMI, the corresponding domain will change by the correlation coefficient. In upper extremity patients, BMI was found to have a correlation with PROMIS-UE ($R = -0.111$, $P < 0.05$). In lower extremity patients, BMI was found to have a correlation with PROMIS-PF ($R = -0.174$, $P < 0.01$), PROMIS-PI ($R = 0.224$, $P < 0.01$), and PROMIS-D ($R = 0.092$, $P < 0.05$). There were no statistically significant

Table 2. Patient demographic characteristics (n = 833)

Variable	Value
Age (yr)	46.6 ± 18.5 (13–89)
BMI	29.4 ± 7.0 (17.7–58.9)
MHI (USD)	62,576 ± 24,222 (21,415–157,536)
Sex	
Male	448 (54)
Female	385 (46)
Race	
White	519 (62)
Black	172 (21)
Asian	21 (3)
Other	43 (5)
Unknown	78 (9)
Employment status	
Employed	346 (42)
Unknown	487 (58)
Tobacco use	
Current	96 (12)
Former	185 (22)
Never	530 (64)
Unknown	22 (3)

Values are presented as mean ± standard deviation (range) or number (%).
BMI, body mass index; MHI, median household income; USD, United States dollar.

Table 3. Diagnoses (n = 833)

Variable	No. (%)
Upper extremity cohort (n = 341)	
Shoulder	
Rotator cuff	121 (15)
Instability/labrum	26 (3)
Nerve impingement	22 (3)
Osteoarthriti	21 (3)
Other	99 (12)
Elbow	
Lateral epicondylitis	37 (4)
Distal biceps	8 (1)
Other	7 (1)
Lower extremity cohort (n = 492)	
Knee	
Osteoarthritis	111 (13)
Anterior cruciate ligament	66 (8)
Meniscus	49 (6)
Osteoarthritis	34 (4)
Other	120 (14)
Hip	
Femoroacetabular impingement	37 (4)
Osteoarthritis	29 (3)
Other	46 (6)

Table 4. Correlations between BMI and PROMIS domains

Variable	PROMIS-UE	PROMIS-PF	PROMIS-PI	PROMIS-D
Upper extremity cohort BMI	–0.111*		0.063	0.012
Lower extremity cohort BMI		–0.174†	0.224†	0.092*

Pearson correlation (R-value).
Denotes a statistically significant finding, *$P< 0.05$; †$P< 0.01$.
BMI, body mass index; PROMIS, Patient-Reported Outcomes Measurement Information System; UE, upper extremity physical function; PF, lower extremity physical function; PI, pain interference; D, depression.

correlations found between BMI and PROMIS-PI or PROMIS-D in patients with an upper extremity injury (Table 4).

Both upper-extremity and lower-extremity patient cohorts exhibited statistically significant differences between BMI categorizations. For patients with upper extremity diagnoses, significant differences were found between overweight patients and obese patients when evaluating both PROMIS-UE and PROMIS-PI (33.7 vs. 31.1, 60.8 vs. 62.4; $P < 0.05$). No statistical significance was found between any BMI categories with regard to PROMIS-D in upper or lower extremity patients. In lower extremity patients, there were statistically significant differences between healthy patients and both overweight and obese patients when assessing PROMIS-PF (41.7 vs. 39.9, 41.7 vs. 38.6; $P < 0.05$). Lower extremity healthy patients also exhibited lower PI scores compared to obese patients (59.9 vs. 63.2; $P < 0.05$). Additionally, with regard to PI scores, overweight patients exhibited lower scores compared to their obese counterparts (61.3 vs. 63.2; $P < 0.05$) (Table 5).

Table 5. Impact of BMI categorization on PROMIS domain means

Variable	PROMIS-UE	PROMIS-PF	PROMIS-PI	PROMIS-D
Upper extremity cohort				
Underweight	27.5±8.3		68.4±2.1	54.8±5.7
Normal	33.2±8.5		61.4±6.6	49.5±9.0
Overweight	33.7±8.9*		60.8±6.0*	48.1±9.4
Obese	31.1±7.8*		62.4±6.9*	49.1±10.1
Lower extremity cohort				
Underweight		37.2±12.0	63.7±7.5	51.5±3.8
Normal		41.7±8.2*	59.9±7.5*	48.7±9.0
Overweight		39.9±7.4*	61.3±6.7*	49.0±10.4
Obese		38.6±5.6*	63.2±6.1*	50.0±8.8

Values are presented as mean±standard deviation. Least significant difference post hoc test.
*Denotes a statistically significant finding ($P< 0.05$).
BMI, body mass index; PROMIS, Patient-Reported Outcomes Measurement Information System; UE, upper extremity physical function; PF, lower extremity physical function; PI, pain interference; D, depression.

DISCUSSION

This study, conducted in the ambulatory shoulder and sports medicine clinic, set out to determine the association between BMI and several PROMIS CAT domains: PROMIS-UE, PROMIS-PF, PROMIS-PI, and PROMIS-D. In upper extremity patients, we found a negative correlation between BMI and physical function and significantly better scores in the overweight group when compared to the obese group in regard to physical function and pain interference. In lower extremity patients, we found correlations between BMI and physical function, pain interference, and depression. Additionally, we found the healthy group to have significantly better physical function and pain interference scores when compared to the obese group.

Elevated BMI was associated with a decrease in physical function for lower extremity patients. Our study found a statistically significant difference between healthy patients and both overweight and obese patients when assessing PROMIS-PF (41.7 vs. 39.9, 41.7 vs. 38.6; $P < 0.05$). These associations provide physicians with insight toward the impact of BMI on physical functioning. It is believed that an elevated BMI, particularly when reaching obese parameters, is accompanied with an increased amount of adipose tissue that compresses load-bearing joints. This compression results in inflammation and ultimately in the loss of muscle mass, and deterioration of the joint structures; collectively, over a period of time, these implications develop into a diminished level of physical functioning.[18] Our study demonstrates similar findings to previously conducted studies.[19,20] Although previous studies have attempted to quantify the association between BMI and physical function, there are contradictory findings in the literature.[21-24] Many of the previous studies used legacy PROM which have been shown to have limitations.[19,21,23,24] Our study utilized PROMIS CAT which has been shown to more precise than legacy PROM and have less floor and ceiling effects.[10,25,26] Additionally, previous studies focused solely on postoperative physical function. The incorporation of all ambulatory patients in this study, regardless of treatment modality, allows for greater generalizability of the study findings.

Elevated BMI demonstrated an association with pain interference in our patient population. Specifically, in lower extremity patients,

healthy patients exhibited lower pain interference scores compared to obese patients (59.9 vs. 63.2, $P < 0.05$) and overweight patients also exhibited lower scores compared to their obese counterparts (61.3 vs. 63.2, $P < 0.05$). These associations provide insight toward the impact of BMI on pain interference. It is believed that both increased mechanical stress and increased amounts of adipose tissue can lead to pain. The mechanical stress of overloading the knee, hip, and back, can cause both injury and degradation of these structures. In addition, both the increased size and number of adipocytes result in an enhanced inflammatory response; this is due to elevated levels of chemical mediators that interact with the nervous system to create the perception of pain: kinins, prostaglandins, and histamine.[27-29] The association our study found is comparable to that which has been previously documented in prior studies.[25,30] However, these studies used legacy PROM measures and questionnaires during different periods of postoperative treatment. Our study, as mentioned, utilized PROMIS CAT forms and was administered to all new patients presenting to the ambulatory sports medicine clinic.

With the appeal of NIH PROMIS and its potential to standardize PROM, the documentation of cohort scores and the factors that impact them are of vital importance. To date, in the ambulatory sports medicine clinic, there have not been any documented PROMIS domain scores reported for each respective BMI group. Our study provides valuable information to establish the association between BMI and the PROMIS CAT domains for upper and lower extremity patients. The scores established by our study for each BMI group give providers an enhanced ability to compare PROM scores beyond the generic reference population, to patients within the same BMI group. Moving forward with longitudinal studies of patients within their respective BMI groups, together with this information, could potentially enable physicians to better comprehend patients' PROMIS scores and better predict their expected improvement following specific treatment options–improving the viability of PROMIS and result in more effective and efficient personalized treatments. Additionally, further studies that address the responsiveness of the PROMIS CAT domains to longitudinal weight changes during specific treatment options could further benefit the medical community in determining the most effective individualized treatment.

Limitations

There are several limitations noted for our study. First, we did not control for some potentially confounding variables: age, sex, race, diagnosis. Secondly, there was a relatively small number of underweight patients included in this study, therefore making it challenging to statistically analyze the PROMIS CAT scores in this group. Existing literature has shown that underweight individuals exhibit similar statistics to overweight and obese individuals, each worse than those with a healthy BMI.[31,32] Additionally, we did not use any objective measures in our outcome reporting to address physical function, pain interference, or depression. As many studies have validated PROMIS CAT measures against traditional, diagnosis-specific PROM,[33-39] our practice is to measure PROMIS CAT domains only, as these measures are more efficient to administer than corresponding legacy scores.[10] Lastly, we only utilized the English language version of the PROMIS CAT forms. Thus, the study may not be completely generalizable to non-English populations. Despite this caveat, a broad range of socioeconomic diversity was encompassed within this study, as is evident by the demographic MHI and race distributions.

In conclusion, this study established that patients presenting to the ambulatory sports medicine clinic demonstrate several significant adverse associations between BMI, and PROMIS-PF, PROMIS-UE, PROMIS-PI, and PROMIS-D. Each of these findings verify that PROMIS CAT forms can be used as an efficient yet effective method to increase quality of care and to further research the impact between BMI and many aspects of life.

CONFLICTS OF INTEREST

One or more of the authors has declared the following potential conflict of interest or source of funding: SJM is a paid consultant for DePuy and Exactech; has received educational support from Arthrex; and has received hospitality payments from DePuy Synthes, Zimmer Biomet Holdings, Biomet Orthopedics, Exactech, Tornier, Conventus Orthopaedics, and Arthrex. ECM receives royalties from Springer, has received educational support from Pinnacle and Smith & Nephew, and has received hospitality payments from Smith & Nephew and Stryker. Other authors declare no potential conflicts of interest.

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AUTHOR CONTRIBUTIONS

Study concept and design: ECM, SJM, JWB; acquisition of data: JWB, PAB; analysis and interpretation of data: JWB, NAK, MSF; drafting of the manuscript: JWB, NAK, PAB; critical revision of the manuscript: ECM, MSF, SJM; and study supervision: ECM, SJM.

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