ORIGINAL ARTICLE

Body mass index and health-related quality of life

R. Apple[1], L. R. Samuels[8], C. Fonnesbeck[8], D. Schlundt[2], S. Mulvaney[3,6,7], M. Hargreaves[4], D. Crenshaw[5], K. A. Wallston[5,6] and W. J. Heerman[3]

[1]Department of Internal Medicine and Pediatrics, Vanderbilt University Medical Center, Nashville, TN, USA; [2]Department of Psychology, Vanderbilt University, Nashville, TN, USA; [3]Department of Pediatrics, Vanderbilt University Medical Center, Nashville, TN, USA; [4]Department of Internal Medicine, Meharry Medical College, Nashville, TN, USA; [5]Center for Health Services Research, Institute for Medicine and Public Health, Vanderbilt University, Nashville, TN, USA; [6]School of Nursing, Vanderbilt University, Nashville, TN, USA; [7]Department of Biomedical Informatics, Vanderbilt University Medical Center, Nashville, TN, USA; [8]Department of Biostatistics, Vanderbilt University Medical Center, Nashville, TN, USA.

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Correspondence:
R. Apple, MD, Department of Internal Medicine and Pediatrics, Vanderbilt University Medical Center, 2511 Medical Center Drive, MCE 7th floor, Suite II, Nashville, TN 37232, USA. E-mail: rachel.apple@vanderbilt.edu

Summary

Objective

There are conflicting data regarding the association between body mass index (BMI) and health-related quality of life (HRQoL), especially among certain population subgroups and for mental and physical health domains.

Methods

This study analysed the relationship between BMI and HRQoL (Patient-Reported Outcomes Measurement Information System mental and physical health scales) using ordinary least squares regression. Each model allowed for the possibility of a non-linear relationship between BMI and the outcome, adjusting for age, gender, comorbidities, diet and physical activity.

Results

A total of 10,133 respondents were predominantly female (71.7%), White (84.1%), median age of 52.1 years (interquartile range 37.2–63.3) and median BMI of 27.9 (interquartile range 24.0–33.2). In adjusted models, BMI was significantly associated with physical and mental HRQoL ($p < 0.001$). For physical HRQoL, there was a significant interaction with age ($p = 0.02$). For mental HRQoL, there was a significant interaction with sex ($p = 0.0004$) but not age ($p = 0.7$).

Conclusions

This study demonstrates a non-linear association of variable clinical relevance between BMI and HRQoL after adjusting for demographic factors and comorbidities. The relationship between BMI and HRQoL is nuanced and impacted by gender and age. These findings challenge the idea of obesity as a main driver of reduced HRQoL, particularly among women and with respect to mental HRQoL.

Keywords: Body mass index (BMI), epidemiology, public health, quality of life.

Introduction

Health-related quality of life (HRQoL) is a multidimensional concept used to describe physical, mental, emotional and social functioning and generally focuses on an individual's perception of his or her own health status (1,2). With overweight and obesity now affecting nearly 70% of adults in the USA, understanding the multifaceted consequences of obesity, including its impact on HRQoL, will serve to inform decisions for policymakers, physicians and patients (1,2).

The current body of literature suggests a complex relationship between body mass index (BMI) and HRQoL. In many previous studies, obesity has been associated with reduced quality of life, even when controlling for comorbid illness. However, overweight has been associated with improved quality of life (2–11). HRQoL is made up of both physical and mental components, and the relationship between BMI and HRQoL may differ with respect to these two domains. Most studies demonstrate a greater deleterious impact of obesity on the physical domains of HRQoL as compared with mental domains, including studies examining individuals with obesity undergoing bariatric surgery or weight loss therapy (5,12–15). The relationship between BMI and mental HRQoL appears to be more complex, and results in the current literature are inconsistent. Some studies have found a negative association between obesity and mental HRQoL, while others have demonstrated no association (8,9,16,17). Furthermore, the effects of obesity on quality of life are not uniform for population subgroups. For example, obesity appears to have a differential impact on HRQoL on the basis of gender and age. Previous studies have indicated that women with obesity have greater impairment in physical domains of HRQoL than their male counterparts, and the association between BMI and HRQoL has a variable association with age (9,18–23).

While a mounting evidence base points to the adverse influence of obesity on HRQoL, many areas of uncertainty about their association still exist (9,12). For example, several studies have lacked comprehensive assessments of comorbidities that could potentially confound the relationship between obesity and quality of life (11,24,25). Many studies have focused on highly specific and sometimes homogenous geographic or demographic populations, limiting the generalizability of their findings (5,22,26,28). Additionally, most studies to date have examined the relationship between BMI and HRQoL without investigating potentially non-linear associations (3,6,8,11,24,25,29,30).

The purpose of this study was to test for associations between BMI and both physical and mental quality of life, controlling for comorbid illnesses, among a geographically diverse adult population in the USA. Because of the large sample size, this study is able to evaluate for potential non-linear effects while specifically investigating for interactions by age and gender. The authors hypothesized that higher BMI would be associated with lower values of both physical and mental HRQoL, with physical domains, females, and middle-aged individuals more significantly impacted than their respective counterparts.

Methods

Study design and data sources

A cross-sectional analysis of data obtained from an online survey was conducted. Study participants were recruited from the Mid-South Clinical Data Research Network, which integrates a clinical data infrastructure across the USA, consisting of (i) Vanderbilt University Medical Center partnering with Meharry Medical College, (ii) the Vanderbilt Healthcare Affiliated Network, (iii) Greenway Health and (iv) the Carolinas Collaborative, a consortium of four academic health systems and multiple community health systems across North Carolina and South Carolina (31).

Study population

A sample of potentially eligible patients from Vanderbilt University Medical Center, Vanderbilt Healthcare Affiliated Network and Greenway Health was contacted to complete a survey consisting of 72 items that queried participants about demographics and health behaviors (Figure 1). Survey participants were recruited using one of four approaches: face-to-face recruitment in medical clinics, an email sent directly from a patient's medical provider, an email sent from the research team or an email sent from a clinic's medical director (32). Survey data collection occurred between August 2014 and November 2015. The primary mode of survey administration was via an electronic survey delivered using REDCap (administered using a tablet computer in person or through an emailed survey link) (33). Participants recruited in person had the option to complete a paper survey. All participants signed informed consent prior to participating and received a $10 gift card for completing the survey. This study received approval from the Vanderbilt University Institutional Review Board.

Eligibility criteria were determined from structured data available in the electronic medical record and were as follows: survey participants had to (i) be $\geq$18 years old; (ii) have $\geq$1 clinic note in the electronic health record (EHR) since 30 April 2009; (iii) have $\geq$2 weight measures in the EHR since 30 April 2009; and (iv) have $\geq$1 height measurement in the EHR after age 18. Participants were excluded from survey participation if they had visual acuity or a mental condition that precluded their ability to participate. The survey was offered only in English, so English reading proficiency was also required of participants. Inclusion in this analysis also required that individuals have data for both the predictor and outcome variables of interest, have BMI $\geq$15 and $<$60 and be $\leq$90 years old. In addition, individuals who reported their gender as 'Other' were excluded due to the extremely small number of respondents in this category. An in-depth analysis of sociodemographic characteristics of survey responders and non-responders has previously been conducted, using inverse probability weighting. These analyses suggest that there is not a sampling bias in the survey responses (32).

The primary independent variable was BMI. For the purposes of this analysis, BMI was calculated using weight in kilograms divided by height in metres squared using self-reported height and weight data from the survey. The World Health Organization's obesity

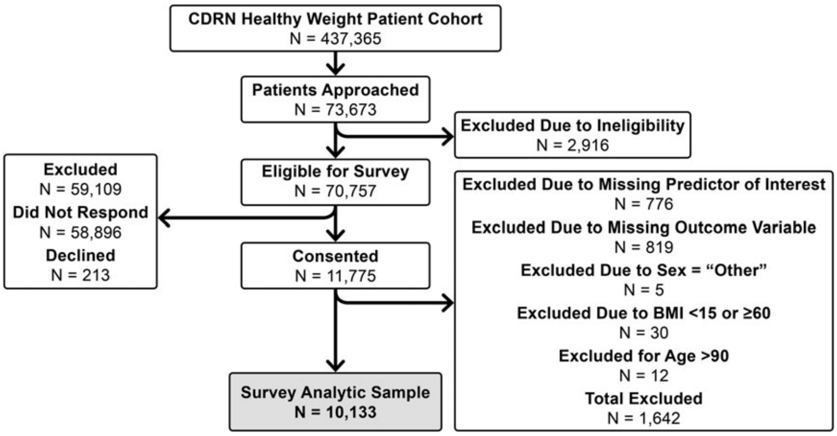

Figure 1 Flow diagram of survey participants. BMI, body mass index; CDRN, Clinical Data Research Network.

classification parameters were used to classify participants as underweight, normal weight, overweight, obese or extremely obese (34).

The primary dependent variable was HRQoL, as measured by the Patient-Reported Outcomes Measurement Information System (PROMIS) Global Health metric, a validated, non-obesity-specific tool for assessment of HRQoL (35). PROMIS was developed through an initiative of the National Institutes of Health in an effort to enhance clinical outcomes research by providing a means of measurement for patient-reported outcomes across a broad range of demographic characteristics and disease processes. The PROMIS Global Health instrument is a 10-item questionnaire that assesses self-reported overall health. The PROMIS Global Health instrument yields two scores: a global physical health score and a global mental health score, each of which is based on four items and is standardized using population norms (36). Physical HRQoL is captured using survey items to assess physical health and functioning, pain intensity and fatigue with a potential range of 16.2 to 67.7. Mental HRQoL encompasses overall quality of life, mental health, satisfaction with social interactions and relationships and emotional problems and has a potential range of 21.2 to 67.6 (36). Raw scores in each category were converted to standardized T-scores with the potential ranges as shown previously. As a point of reference, the mean T-score for both physical and mental domains among American adults is 50 with a standard deviation of 10 points (36). On both physical and mental scales, higher scores indicate better quality of life. Two of the included PROMIS Global items are not used to produce the physical or mental health scores (general health and social roles). In order to comment upon the relationship between the independent variables and overall HRQoL, a validated equation was used to convert the respondents' PROMIS raw scores into a EuroHRQL-5D (EQ 5D) score, which is a measure of general quality of life commonly utilized in obesity research (37).

Demographic characteristics, which were included as covariates, included age, gender, race/ethnicity, employment status, household income, education, marital status, current smoking status and number of children living in the household. Demographic characteristics were summarized using median and interquartile range (IQR) for continuous variables and using proportions for categorical variables. Self-reported physical activity and diet quality were also included as covariates with single items that ranged from 1 = 'I am very inactive' to 5 = 'I am active most days' and 1 = 'Poor quality diet' to 5 = 'Excellent quality diet', respectively. Spirituality, assessed with a single item ranging from 1 = 'Not spiritual' to 5 = 'Highly spiritual', was also included as a covariate.

Statistical analysis

This study analysed the relationship between BMI and each outcome (PROMIS mental health score and PROMIS physical health score) using ordinary least squares regression. Each model allowed for the possibility of a non-linear relationship between BMI and the outcome by modeling BMI using a restricted cubic spline with four knots. Both models were adjusted for age (flexibly modeled using a four-knot restricted cubic spline), gender, race/ethnicity (4 levels), income (7 levels), educational history (5 levels), employment status (4 levels), marital status (4 levels), number of people under age 19 living in the home (6 levels), current smoking status (yes/no), physical activity (5 levels), diet (5 levels), self-reported history of high blood pressure (yes/no), self-reported history of high cholesterol (yes/no), self-reported history of diabetes (3 levels) and spirituality (4 levels). To allow for the possibility that the relationship between BMI and the PROMIS scores differed by age and/or gender, interactions between gender and BMI and between age and BMI were also included. To evaluate the effect of important potential confounders, three models for each outcome were performed, including unadjusted analyses, partially adjusted analysis controlling for sociodemographics and fully adjusted models including all covariates in the previous models plus diet and physical activity behaviours.

Multiple imputation was used to address missing data. Of the 10,133 respondents who had data on the primary exposure and outcome variables, 1,921 (19%) were missing one or more covariates. The most common missing covariate was income (920 missing, 9%). The authors first imputed 10 sets of missing covariate values using predictive mean matching and then conducted the statistical analyses in each of the 10 partially imputed datasets. Final results arise from the average of the 10 sets of coefficient estimates and from an imputation-corrected variance–covariance matrix. A sensitivity analysis with complete cases was also conducted.

Because the utilized models allowed the relationship between BMI and the PROMIS scores to be non-linear, single regression-coefficient estimates are not helpful in model interpretation, and single-coefficient significance tests are not helpful in interpreting results. Instead, for each model, *F*-tests were conducted for the joint significance of all of the BMI-related coefficients taken together, as well as for the joint significance of the interaction terms. Model-based estimates from the resulting predictive models with 95% confidence intervals are also reported. All analyses were conducted using R version 3.4.3 (41).

Results

Population characteristics

The response rate as defined by the Council of American Survey Research Organizations at each of the sites varied substantially by recruitment method used (32). While in-person recruitment achieved up to 94% response rate, recruitment approaches using traditional paper mail resulted in a response rate between 3% and 6%. The overall response rate was 16.4%.

The analytic sample (*N* = 10,133) was predominantly female (71.7%), White (84.1%) and had a median age of 52.1 years (IQR 37.2–63.3). The median BMI of the analytic sample was 27.9 (IQR 24.0–33.2). Underweight individuals represented 1.2% of the sample, normal weight 30%, overweight 30%, obese 19% and extremely obese 20%. The median score on the PROMIS physical health scale was 50.8 (IQR 42.3–54.1), and the median score on the PROMIS mental health scale was 50.8 (IQR 45.8–56.0).

Demographic and clinical characteristics of patients included in the primary analysis are presented in Table 1, stratified by BMI category. All baseline sociodemographic characteristics were associated with obesity status, where being overweight, obese or extremely obese was associated with higher age, lower socioeconomic status, worse diet quality and lower levels of physical activity. Similarly, overweight and obesity were associated with higher levels of comorbid conditions including hypertension, diabetes and hyperlipidaemia.

Unadjusted estimates

Unadjusted linear regression using a restricted cubic spline showed a non-linear relationship between BMI and physical HRQoL, with little relationship between BMI and physical HRQoL for respondents with healthy weights, but a pronounced negative association between BMI and physical HRQoL for overweight and obese respondents. There was a similar pattern observed in unadjusted models comparing BMI and mental HRQoL. The addition of covariates to the models substantially changed both the shape and magnitude of the associations (Figure 2).

Adjusted estimates

After controlling for potential confounders, multivariable linear regression still suggested non-linear relationships between BMI and both physical and mental HRQoL scores (Figure 2). The *F*-tests of the overall association between BMI and quality of life were statistically significant for both physical health quality of life ($p < 0.0001$) and mental health quality of life ($p < 0.0001$). To evaluate the association between BMI and overall HRQoL, similar models using the EQ 5D scores were conducted and are presented as model-based estimates in Table 2. A complete-case sensitivity analysis was also conducted, and results did not substantively differ from the multiply-imputed dataset (results not shown).

For physical HRQoL, this study found a significant interaction between BMI and age ($p = 0.02$) and a trend toward significance for the interaction between BMI and gender ($p = 0.0579$). For mental HRQoL, there was a significant interaction between gender and BMI ($p = 0.0004$) but not between age and BMI ($p = 0.7$). For both physical and mental health quality of life, the relationship between BMI and HRQoL was more pronounced in men. Among women, BMI was not associated with mental HRQoL, but a steady, nearly linear association between higher BMI and lower physical HRQoL was observed. Figure 3

Table 1 Demographic and clinical characteristics of the study population

	Underweight *N* = 124	Healthy weight *N* = 3,073	Overweight *N* = 3,039	Obese *N* = 1,923	Morbidly obese *N* = 1,974
Age* (*N* = 10,118)	39.1 (30.1–61.3)	44.9 (31.5–61.3)	55.5 (40.9–66.1)	54.7 (42.9–64.5)	51.3 (40.1–60.5)
Gender* (*N* = 10,099)					
Male	12.2% (15)	19.0% (584)	38.3% (1,160)	33.1% (634)	23.4% (460)
Female	87.8% (108)	81.0% (2,483)	61.7% (1,868)	66.9% (1,281)	76.6% (1,506)
Race/ethnicity* (*N* = 9,959)					
White, non-Hispanic	82.1% (101)	88.0% (2,657)	86.3% (2,580)	80.9% (1,521)	77.9% (1,516)
Black, non-Hispanic	4.9% (6)	5.1% (153)	8.4% (250)	13.8% (259)	18.8% (365)
Hispanic	3.3% (4)	2.1% (63)	2.0% (60)	1.9% (36)	1.4% (27)
Other, non-Hispanic	9.8% (12)	4.9% (148)	3.3% (98)	3.5% (65)	2.0% (38)
Annual income* (*N* = 9,213)					
less than $10,000	2.0% (2)	3.4% (94)	2.2% (62)	4.2% (73)	4.7% (86)
$10,000 to $19,999	1.0% (1)	4.6% (126)	5.1% (142)	6.5% (114)	8.6% (158)
$20,000 to $34,999	15.8% (16)	11.4% (314)	12.5% (347)	12.8% (224)	17.8% (326)
$35,000 to $49,999	11.9% (12)	12.3% (338)	14.2% (394)	15.2% (266)	18.0% (330)
$50,000 to $74,999	17.8% (18)	20.6% (567)	21.5% (598)	22.5% (393)	22.0% (403)
$75,000 to $99,999	20.8% (21)	16.0% (440)	18.1% (502)	16.1% (282)	13.9% (255)
$100,000 or more	30.7% (31)	31.7% (873)	26.4% (732)	22.7% (398)	15.0% (275)
Highest level of education* (*N* = 10,073)					
Less than HS degree	2.5% (3)	1.2% (38)	1.7% (50)	1.8% (34)	2.3% (44)
HS graduate or GED	13.1% (16)	8.4% (257)	12.8% (386)	14.2% (271)	17.3% (338)
Some college or 2-year degree	20.5% (25)	22.2% (678)	29.6% (894)	33.4% (639)	36.5% (714)
College degree	25.4% (31)	31.0% (948)	25.7% (776)	23.8% (455)	23.2% (453)
More than college degree	38.5% (47)	37.2% (1,138)	30.4% (918)	26.9% (514)	20.8% (406)
Employment status* (*N* = 10,120)					
Unemployed/homemaker/stay at home Caregiver/full-time student	25.2% (31)	17.5% (536)	9.1% (277)	7.4% (143)	8.9% (176)
Unable to work (disabled)	13.0% (16)	5.1% (155)	7.0% (212)	9.0% (173)	14.1% (278)
Retired	15.4% (19)	16.6% (509)	24.6% (748)	22.5% (433)	13.7% (270)
Employed (full-time, part-time or self-employed)	46.3% (57)	60.9% (1,869)	59.2% (1,798)	61.0% (1,173)	63.3% (1,247)
Marital status* (*N* = 10,074)					
Never married	26.4% (32)	18.4% (563)	10.2% (309)	9.2% (176)	15.0% (294)
Divorced/separated	8.3% (10)	8.9% (273)	11.1% (336)	14.2% (271)	15.9% (312)
Widowed	3.3% (4)	4.0% (123)	4.4% (134)	4.0% (76)	4.3% (84)
Married/living with partner	62.0% (75)	68.6% (2,098)	74.2% (2,245)	72.6% (1,388)	64.8% (1,271)
Number of children <19 years living in household** (*N* = 10,020)					
0	70.7% (87)	68.2% (2,076)	70.4% (2,115)	69.6% (1,323)	65.2% (1,271)
1	11.4% (14)	14.6% (443)	13.7% (411)	14.4% (273)	17.9% (350)
2	11.4% (14)	11.9% (363)	10.5% (315)	11.5% (218)	11.6% (226)
3	4.1% (5)	4.0% (123)	3.6% (108)	3.3% (63)	3.8% (74)
4	1.6% (2)	0.9% (28)	1.3% (40)	0.8% (16)	1.2% (24)
5 or more	0.8% (1)	0.3% (9)	0.5% (14)	0.5% (9)	0.3% (5)
Current smoking status** (*N* = 9,898)					
No	87.5% (105)	92.4% (2,773)	90.4% (2,674)	90.1% (1,694)	90.1% (1,748)
Yes	12.5% (15)	7.6% (228)	9.6% (283)	9.9% (186)	9.9% (192)
Physical activity* (*N* = 10,118)					
I am very inactive	8.9% (11)	7.8% (238)	10.2% (309)	13.0% (249)	22.7% (448)
I am active a couple times a month	10.5% (13)	10.1% (309)	13.3% (404)	17.9% (343)	24.4% (481)
I am active most weeks	18.5% (23)	16.9% (520)	18.5% (562)	22.0% (423)	20.0% (394)
I am active several days a week	24.2% (30)	26.2% (805)	26.0% (788)	23.4% (449)	18.6% (367)
I am active most days	37.9% (47)	39.0% (1,196)	32.0% (972)	23.8% (456)	14.3% (281)
Diet quality* (*N* = 10,115)					
Poor	2.4% (3)	0.9% (28)	1.9% (59)	3.9% (75)	9.1% (179)
Fair	14.5% (18)	8.2% (250)	14.6% (443)	24.2% (464)	33.9% (668)
Good	27.4% (34)	32.6% (1,000)	43.1% (1,309)	45.8% (880)	42.7% (842)

Continues

Table 1. *Continued*

	Underweight *N* = 124	Healthy weight *N* = 3,073	Overweight *N* = 3,039	Obese *N* = 1,923	Morbidly obese *N* = 1,974
Very good	37.9% (47)	42.8% (1,311)	32.6% (989)	21.7% (417)	12.8% (252)
Excellent	17.7% (22)	15.5% (476)	7.8% (236)	4.4% (84)	1.5% (29)
High blood pressure* (*N* = 10,010)					
No	84.2% (101)	78.5% (2,387)	57.7% (1,733)	45.9% (872)	38.7% (753)
Yes	15.8% (19)	21.5% (652)	42.3% (1,270)	54.1% (1,029)	61.3% (1,194)
High cholesterol* (*N* = 9,953)					
No	77.0% (94)	73.7% (2,227)	52.4% (1,564)	46.8% (885)	51.0% (986)
Yes	23.0% (28)	26.3% (795)	47.6% (1,421)	53.2% (1,005)	49.0% (948)
Diabetes mellitus type I or II* (*N* = 10,073)					
No	96.0% (119)	92.9% (2,839)	84.0% (2,542)	71.6% (1,367)	62.1% (1,217)
Yes	2.4% (3)	5.0% (154)	11.9% (361)	19.7% (377)	26.8% (525)
Pre-diabetes or borderline diabetes	1.6% (2)	2.0% (62)	4.0% (122)	8.7% (166)	11.1% (217)
Spirituality* (*N* = 9,835)					
Very	40.5% (49)	43.2% (1,281)	47.2% (1,402)	48.6% (908)	49.4% (941)
Fairly	26.4% (32)	29.4% (874)	31.8% (946)	33.3% (622)	33.1% (631)
Slightly	16.5% (20)	15.9% (472)	13.9% (413)	12.6% (235)	11.8% (224)
Not at all	16.5% (20)	11.5% (341)	7.1% (212)	5.5% (103)	5.7% (109)

Demographic characteristics, psychosocial variables and comorbid illness stratified by obesity status among the 10,133 survey respondents included in the analytic sample.
*$p < 0.001$.
**$p < 0.05$.
GED, general educational development; HS, high school.

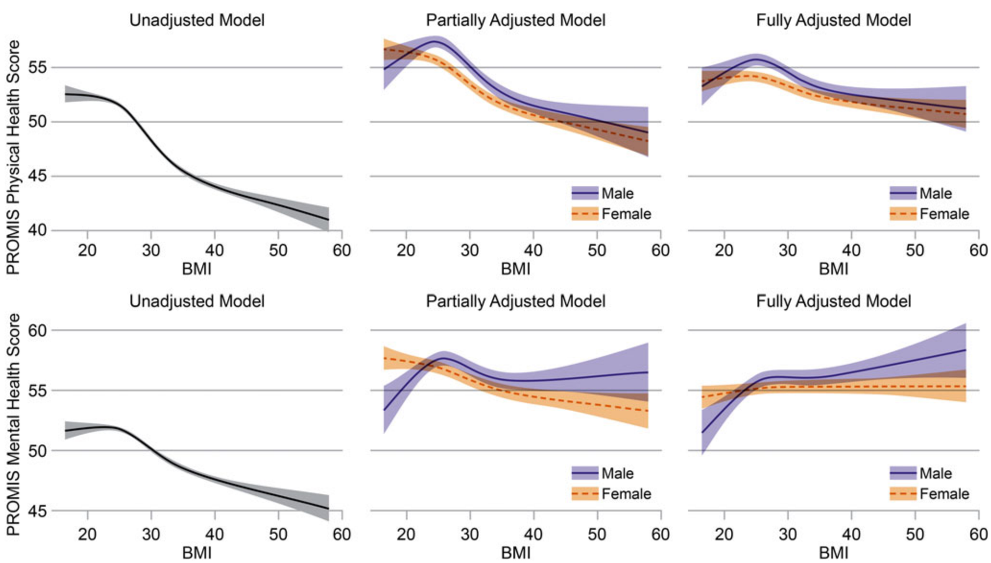

Figure 2 Model-based estimates showing the association between body mass index (BMI) and health-related quality of life in both physical and mental domains. We show model-based estimates and 95% confidence intervals for unadjusted models. Subsequent models are partially adjusted, controlling for age, gender, income, education, employment, marital status, race/ethnicity, smoking status, number of people age < 19 years living in the home, history of high blood pressure, history of diabetes, history of high cholesterol and spirituality. Fully adjusted models control for all of the previous covariates, with the addition of diet and physical activity. The *F*-tests of the overall association between BMI and quality of life were statistically significant for both physical health quality of life ($p < 0.0001$) and mental health quality of life ($p < 0.0001$). Estimates from the partially and fully adjusted models are shown for subjects with the sample median value for age (52) and with values of all other covariates equal to the sample mode. PROMIS, Patient-Reported Outcomes Measurement Information System.

shows model-based estimates for men and women across a range of ages, suggesting that older individuals have a stronger association between BMI and HRQoL.

Both diet and physical activity also showed significant associations with HRQoL ($p < 0.001$) in these analyses. Because the causal relationship between these two

Table 2 BMI and general health-related quality of life

BMI	Gender	Age 30	Age 50	Age 70
25	Female	0.80 (0.79, 0.81)	0.79 (0.79, 0.80)	0.80 (0.79, 0.80)
	Male	0.82 (0.81, 0.83)	0.81 (0.80, 0.82)	0.81 (0.80, 0.82)
28	Female	0.80 (0.80, 0.81)	0.79 (0.78, 0.80)	0.79 (0.78, 0.80)
	Male	0.82 (0.81, 0.83)	0.81 (0.80, 0.81)	0.81 (0.80, 0.82)
30	Female	0.80 (0.80, 0.81)	0.79 (0.78, 0.79)	0.78 (0.78, 0.79)
	Male	0.82 (0.81, 0.83)	0.80 (0.80, 0.81)	0.80 (0.79, 0.81)
35	Female	0.80 (0.80, 0.81)	0.78 (0.78, 0.79)	0.77 (0.76, 0.78)
	Male	0.82 (0.81, 0.83)	0.79 (0.79, 0.80)	0.78 (0.78, 0.79)
40	Female	0.80 (0.79, 0.81)	0.78 (0.77, 0.78)	0.76 (0.76, 0.77)
	Male	0.82 (0.81, 0.83)	0.79 (0.78, 0.80)	0.78 (0.77, 0.79)

Model-based estimates of a general health-related quality of life measure (EQ 5D), from adjusted ordinary least squares regression with non-linear BMI term as the primary predictor, controlling for age, gender, income, education, employment, marital status, race/ethnicity, smoking status, number of people age $<$ 19 years living in the home, physical activity, diet, history of high blood pressure, history of diabetes, history of high cholesterol and spirituality. Model-based estimates are given for a range of BMI values, stratified by age and gender. The model-based estimate for EQ 5D is given plus the 95% confidence interval.
BMI, body mass index.

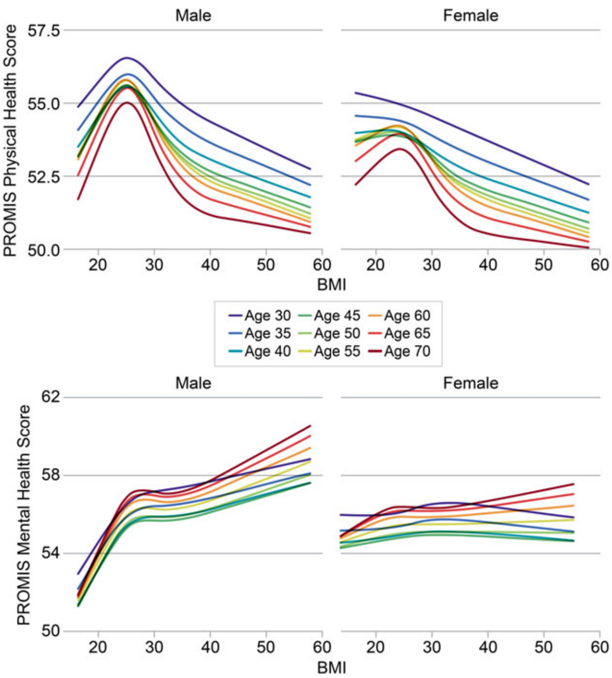

Figure 3 Associations between body mass index (BMI) and health-related quality of life (HRQoL), with interations by age and gender. Model-based estimates showing the association between BMI and HRQoL in both physical and mental domains are shown separately by gender, across a range of age values. Models are adjusted for age, gender, income, education, employment, marital status, race/ethnicity, smoking status, number of people age $<$ 19 years living in the home, physical activity, diet, history of high blood pressure, history of diabetes, history of high cholesterol and spirituality. For physical HRQoL, there was a significant interaction with age (p = 0.02) and a trend towards significance for the interaction with gender (p = 0.0579). For mental HRQoL, there was a significant interaction with gender (p = 0.0004) but not with age (p = 0.7).

covariates, HRQoL and obesity, is likely bidirectional, however, the data using partially adjusted models that controlled for all covariates except diet and physical activity were also analysed. Figure 2 shows that the exclusion of these covariates did not substantially alter the shape or magnitude of associations between BMI and HRQoL in either mental or physical health domains.

Discussion

This study of a large, geographically diverse sample demonstrated a statistically significant and nuanced association between BMI and both mental and physical domains of HRQoL. In some population subgroups, the effect of BMI on HRQoL is quite small: specifically, for women, the clinical relevance of associations between BMI and mental HRQoL is unclear. In contrast, older men had a clinically significant association between BMI and mental HRQoL. Because the associations are so complex, it is difficult to make sweeping generalizations about the nature and magnitude of the associations. However, this complexity fits within the paradigm of personalized medicine, which pushes the medical community to identify important individual differences that can shape both clinical recommendations and research agenda. Consequently, the main application of these results is to recognize that for some individuals, BMI will likely be a primary driver of HRQoL, while for others, the association may be minimal.

In general, these findings are in agreement with the current literature in that increased BMI is related to decreased overall HRQoL (6,14,21,39). However, it is important to note that the majority of previous studies have assumed that the relationship between BMI and HRQoL is linear (3,6,8,11,24,25,29,30). The non-linear nature of the associations revealed here, as well as the presence of multiple interactions by age and gender, points to a more complex relationship between BMI and HRQoL than has previously been described. When looking at overall measures of HRQoL (i.e. EQ 5D), other studies have consistently demonstrated small effect sizes (9). For example, a 2011 study by Bentley *et al*., reported a decrease of 0.06 points in the EQ 5D score between the normal weight category and the obese category (11). The present study found a decrease of 0.03 points on the model-based EQ 5D score between a 70-year-old male with a BMI of 25 and a 70-year-old male with a BMI of 40.

The current study found that the impact of BMI on physical HRQoL was greater among men than women, and that for women, there was very little association between BMI and mental HRQoL. These findings are consistent with those of Sarwer *et al*., who have examined the relationship between sexual dysfunction, quality of life and BMI in individuals with extreme obesity seeking bariatric surgery (40–42). These previous studies have demonstrated a positive association between weight loss and physical HRQoL among men and women, which was sustained up to 4 years following bariatric surgery. However, in these same cohorts, for women with extreme obesity undergoing bariatric surgery, measures of mental HRQoL initially improved but eventually returned to presurgery baseline by 4 years after surgery (42). These findings support the concept that the relationship between mental health and BMI is complex and multifactorial, particularly among women. Taken together, these data suggest several areas of future research, including evaluation of HRQoL among individuals with low BMI, while our models suggest a potential association, the sample size among underweight individuals was limited.

This study advances the current literature by using a novel measure in the PROMIS scale, which focuses predominantly on aspects of HRQoL that are important to patients. In addition, one area of significant strength of this study is the inclusion of multiple covariates in the modelling approach. As demonstrated by the change in the shape and directionality of the associations when comparing unadjusted to fully adjusted models, it is important to recognize the potentially complex relationships between HRQoL, BMI, comorbid illness and diet/physical activity behaviors. Another important contribution of these analyses is to suggest that while there is a statistically significant association between both diet and physical activity and HRQoL even after adjusting for other covariates and BMI, this study's overall conclusions about the associations between BMI and HRQoL do not depend on whether diet and physical activity are included in the model. While one cannot draw causal inference because of the cross-sectional nature of this study, this study points to the need for future research aimed at elucidating the causal pathway in obesity and quality of life.

To evaluate potential sources of bias that would explain these findings, one may consider the following limitations. In addition to the cross-sectional nature of the analysis and the potential for residual confounding, another limitation is the generalizability of the findings. This study's participants were all healthcare users, and as such, the results may lack generalizability to non-healthcare users. The study population was predominantly middle-aged, female, White, affluent, well-educated and fluent in English. In addition, it is possible that generic measures of HRQoL, such as PROMIS, may not be as sensitive to obesity-specific impairment in HRQoL, which may be better ascertained using an obesity-specific tool (43). The self-reports of height and weight, used to calculate BMI, may have introduced a differential misclassification bias; however, the association between BMI and other comorbid medical conditions (like diabetes and hypertension) limits that potential concern. While there were low survey response rates, prior in-depth analyses suggest no selection bias (32).

Conclusions

This study demonstrates a non-linear association between BMI and HRQoL after adjusting for demographic factors and comorbid illness, regardless of whether we controlled for diet and physical activity. The relationship between BMI and HRQoL is nuanced and significantly impacted by gender and age. These findings challenge the idea of obesity as a main driver of reduced HRQoL, particularly among women and with respect to mental HRQoL. Future studies using flexible modeling techniques with longitudinal follow-up are needed to further our understanding of the potentially bidirectional associations between BMI and HRQoL and to inform clinical and research practices in the fields of obesity and quality of life.

Conflict of Interest Statement

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