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Association of continuous body mass index with health-related quality of life in the United States by age and sex

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Abstract

Objective: To estimate health-related quality of life (HRQoL) utilities by continuous BMI by age, sex, and demographic group in the US.

Methods: We estimated HRQoL (overall and by domain) by continuous BMI using SF-6D data from 182,778 respondents ages 18 and older from the repeated cross-sectional Medical Expenditure Panel Survey (MEPS) 2008-2016. We adjusted for BMI self-report bias for potential confounding between BMI and HRQoL.

Results: We found an inverse J-shaped curve of HRQoL by BMI, with lower values for females and the highest utilities occurring at a BMI of 20.4 (95% CI 20.32-20.48) for females and 26.5 (95% CI 26.45-26.55) for males. By BMI category, excess weight contributed to HRQoL utility loss of 0.0349 for obesity overall, rising to 0.0724 for Class III obesity. By domain, Pain was the largest cause of HRQoL loss for obesity (26%), followed by Role Limitations (22%).

Conclusions: Health-related quality of life is lower for people with excess body weight across a broad range of ages and BMI levels, especially at high levels of BMI, with Pain the largest driver of HRQoL loss. These findings highlight the importance of promoting a healthy weight for the entire population while also targeting efforts to prevent extreme weight gain over the life course.

Keywords

BMI; health-related quality of life

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Introduction

Over 40% of US adults have obesity,[1] and excess weight gain continues to rise, with half of US adults projected to have obesity by 2030,[2] and nearly 60% of children predicted to have obesity by age 35.[3] Excess body weight is associated with a range of adverse outcomes, including increased health care costs,[4] risks of comorbidities including cardiovascular disease, diabetes, and several cancers,[5–7] and premature mortality.[8,9]

In addition to these outcomes, excess weight has impacts on quality of life,[10] estimates of which are important to more fully characterize the population health effects of the obesity epidemic and the cost-effectiveness of policies and programs to promote healthy weight across the lifecourse.[11,12] However, estimates of excess weight-related quality of life are generally based on discrete body mass index (BMI) categories,[10] which are not sensitive to changes in weight within categories, and may not capture quality of life impacts at extreme values of BMI. Estimating continuous BMI-related health-related quality of life (HRQoL, also known as 'utilities') provides a more accurate and flexible approach that supports unbiased estimation of the current burden of disease across the entire BMI distribution and evaluation of the improvements in population HRQoL from small, individual-level weight changes due to public health interventions.

In this study we estimate BMI-specific HRQoL by age and sex and provide estimates of excess weight-related HRQoL loss by continuous BMI and BMI category. We also assess how these relationships vary by race/ethnicity and federal poverty level to examine the interplay between social determinants of health and excess weight-related HRQoL.

Methods

Data

We used repeated cross-sectional data from the Medical Expenditure Panel Survey (MEPS) 2008-2016 and harmonized variable definitions across years. MEPS did not include consistent measures of health status after 2017. After excluding pregnant women and respondents with missing variables of interest, our pooled dataset contained 182,778 adults (aged 18 and older). See Appendix 1 for details on dataset harmonization, exclusion criteria, and respondent characteristics.

Adjustment for BMI Self-Report Bias

We corrected BMI values in MEPS for self-report bias using a semi-parametric method, previously described,[2,4,13] which adjusts the entire distribution of self-reported BMI to match nationally-representative, measured data from the National Health and Nutrition Examination Survey (NHANES). This method uses cubic splines to apply quantile-specific adjustments to self-reported BMI, such that the age- and sex-specific distributions of adjusted BMI are statistically similar to NHANES (Appendix 2). Because the degree of self-report bias increases (i.e., underreporting is larger in magnitude) at higher levels of the BMI distribution, this correction is needed for accurate estimates of the burden of disease in population subgroups with higher BMI.

Health-related Quality of Life

The SF-12 is a commonly used 12-item survey for measuring patient-reported health status across multiple domains.[14] The SF-12v2 items were included until 2017 in the MEPS Adult Self-Administered Questionnaire, which collects a variety of health status measures from adults ages 18 and older. The SF-6D can be calculated from SF-12 responses, and yields a HRQoL utility metric anchored by 0 (death) and 1 (perfect health) based on 7 items from the SF-12 across 6 dimensions: physical functioning, role limitations, social functioning, pain, mental health, and vitality (see Appendix 3 for details).[15] In addition to the original SF-12 responses, the SF-6D utility estimation includes a binary dummy variable to account for the effects on utilities when one or more dimensions of health is at the 'most severe' level.[15]

We used the SF-6D to estimate HRQoL utilities for each respondent in MEPS, and also estimated the contribution of each dimension to the final utility value (i.e., disutility associated with the level of reported limitations in each dimension as estimated in Brazier 2004).[15] We re-allocated the dummy variable for disutility associated with "most severe" proportionally across the number of dimensions at the most severe level for each respondent when estimating the disutility attributable to each of the 6 dimensions.

We also grouped the dimensions to estimate disutility associated with physical health compared with mental health. We grouped "physical limitations" and "pain" under physical health, and "social functioning", "mental health", and "vitality" under mental health. "Role limitations" were included in physical health if the individual responded that they were limited as a result of physical problems, mental health if the individual responded that they accomplished less than they would like as a result of emotional problems, or both if the individual responded having limitations as a result of both physical and emotional problems.

Health-Related Quality of Life Standardization

To adjust for potential confounding of the relationship between BMI and HRQoL, we standardized respondents' estimated utilities to be representative of a synthetic, 'average' population, thus controlling for the effects of other salient factors (e.g., smoking, marital status, etc.), using an approach similar to a previous study to estimate BMI-specific healthcare costs.[4]

We controlled for the following variables: BMI (continuous), year (continuous), geographical region (Northeast, Midwest, South, West), age (continuous), sex (male/female), race/ethnicity (White, Black, Hispanic, American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander, multiple races), marital status (married, widowed, divorced, separated, never married), education (less than high school, some high school, GED or high school diploma, some college, college graduate, graduate school, unknown), smoking status (yes/no), and poverty level (continuous). Continuous variables were modeled as cubic polynomials for greater flexibility.

Using the fitted model, we adjusted each respondent's HRQoL utility and SF-6D domain scores to be representative of a standardized individual. We adjusted for all variables except BMI (and age when fitting bivariate models – see below), thus controlling HRQoL outcomes for other salient factors. Post-standardization all other covariates are therefore set to the mean value for each subgroup under consideration. See Appendix 4 for details.

Predicted HRQoL by BMI

Following a similar approach that we previously used to estimate healthcare costs by continuous BMI,[4] we used generalized additive models (GAMs)[16] to estimate the relationship between log BMI and HRQoL outcomes. We fit two different types of models: a univariate model (cubic smoothing splines) with log BMI as a continuous predictor, and a bivariate model[17] with both age and log BMI as continuous predictors to capture the interaction between age and BMI (see Appendix 5). We predicted HRQoL outcomes for BMI values between 10 and 80. We also estimated the BMI value at which the predicted mean HRQoL was maximized by sex and race/ethnicity subgroup. Based on this ‘optimal’ BMI, we estimated the HRQoL loss associated with higher (or lower) values of BMI for each subgroup.

With the BMI-specific HRQoL predictions we also estimated utilities by binary obesity status: non-obesity (BMI<30) vs obesity (BMI≥30), and by BMI category: underweight (<18.5), normal weight (18.5 to <25), overweight (25 to <30), Class I obesity (30 to <35), Class II obesity (35 to <40), and Class III obesity (40+). We also estimated how these categorical HRQoL utilities change with age by fitting smooth splines to the predicted utilities within each BMI category by age. We predicted outcomes from ages 18 to 85 because age is top-coded at 85 years old in MEPS.

Model Uncertainty

The provided sample weights were used to appropriately weight all respondents. To estimate confidence intervals for all results we bootstrapped the MEPS and NHANES datasets 1,000 times, taking into account the complex survey structure, and re-estimated all models described above, including adjustments for self-report bias. We fit separate models for each subgroup (i.e., HRQoL standardization and predicted HRQoL by BMI for each subgroup in the bootstrapped dataset) to allow all model parameters to vary. We calculated 95% confidence intervals (CIs) as the 2.5 and 97.5 percentiles of the bootstrapped results. All analyses were performed in R (version 3.6.1).

Sensitivity Analyses

To assess the sensitivity of our results to the SF-6D (scored using a UK valuation set),[15] we re-ran the analysis using EQ-5D-3L responses (an alternative HRQoL utility measure) from MEPS 2000-2003 (n=75,617), scored using a US valuation set.[18] We also re-ran our analyses using self-reported BMI to assess how sensitive our results are to BMI bias correction.

Results

We found an inverse J-shaped curve of HRQoL by BMI, which was generally similar by sex but with higher HRQoL levels for males (see Figure 1A). The highest HRQoL occurred at a BMI of 26.5 (95% CI 26.45-26.55) for males versus 20.4 (95% CI 20.32-20.48) for females, but was fairly flat around this region (see Figure 1B). Although HRQoL curves by BMI had different absolute levels by race/ethnicity and poverty level, with much larger differences by poverty level than by race/ethnicity, HRQoL loss curves by BMI (compared to 'optimal' BMI) were similar by subgroup (see Appendix 6.1).

Our bivariate model estimates found that HRQoL decreases by age, with increasingly large disutility at high BMIs and older ages (see Appendix 6.2). We find that both underweight and excess weight are associated with lower quality of life, especially at older ages, with the highest HRQoL values at BMIs in the mid-20s at all ages. BMI-specific utility values by age and sex are available in a public data repository https://doi.org/10.7910/DVN/PC0YPC. Disutilities associated with underweight are likely due to a combination of reverse causation (i.e., illness causes weight loss as well as reductions in health status not mediated by weight change) and direct health effects of underweight such as liver disease, often caused by food insecurity or eating disorders such as anorexia nervosa.

We find a gradient in HRQoL by BMI category across all ages, with decreasing HRQoL in all categories by age (see Figure 2). We also find that underweight (BMI less than 18.5) is associated with higher HRQoL loss than overweight (BMI between 25 and 30), especially at older ages, but is still lower than HRQoL loss associated with obesity (BMI of 30 and above). The highest HRQoL loss associated with BMI categories occurs around ages 65-70, after which the HRQoL loss compared to normal weight begins to decline due to HRQoL decreasing more quickly in the reference category (see Figure 2 and Appendix 6.3 for estimates by sex).

Comparing HRQoL loss by physical vs mental health groupings, we find that BMI-related physical HRQoL loss increases with age, especially for high levels of BMI, with comparatively little physical HRQoL loss at young ages (see Figure 3). In contrast, BMI-related mental HRQoL loss is fairly stable by age, with comparatively large decrements even at younger ages. At younger ages, most of the BMI-related HRQoL loss is therefore due to mental health disutility, while physical health disutility starts to contribute the majority of the loss starting in the late 40s (see Figure 3).

Controlling for demographic factors, obesity was associated with a decrease in HRQoL of 0.0349 (95% CI 0.0326-0.0373), with increasing loss of HRQoL by BMI category of excess weight, from 0.0117 (95% CI 0.0095-0.0141) for overweight to 0.0724 (95% CI 0.0678-0.0770) for Class III obesity (BMI 40+) (see Table 1).

Among the 6 dimensions of HRQoL assessed by the SF-6D, higher levels of reported Pain accounted for the largest amount (26%) of HRQoL loss among adults with obesity compared to adults without obesity, followed by Role Limitations (22%), Social Functioning (17%), Vitality (15%), Mental Health (12%), and Physical Functioning (8%) (see Table 1). The ordering of these dimensions generally remained the same by class of obesity, with larger HRQoL decrements at higher BMI levels, especially for Pain (see Figure 3). The physical and mental health groupings and dimension-specific HRQoL losses by BMI were similar by subgroup (race/ethnicity and poverty level), except for sex, where domain-specific 'optimal' BMI values are generally between 19-25 for females, compared to 23-28 for males (see

Appendix 6.4–5.5). These differences by sex were similar by race/ethnicity and poverty level.

Sensitivity Analyses

We found that the EQ-5D-3L estimates higher levels of utility for the population, as it is well-known that it is not as sensitive as the SF-6D to smaller decrements in HRQoL.[19,20] However, the relative disutility from excess weight (compared to 'optimal' BMI) is similar for both instruments, with larger BMI-related disutility from the EQ-5D-3L, suggesting that our estimates of excess weight-related HRQoL loss based on the SF-6D may be conservative (see Appendix 6.6). Our sensitivity analysis comparing self-reported vs adjusted BMI also yielded similar HRQoL estimates, with slightly higher HRQoL loss estimated using self-reported BMI (see Appendix 6.7).

Discussion

Using a flexible modelling approach, we estimated continuous BMI-related HRQoL by age, sex, and demographic group in the US. We find a strong gradient of quality of life by both age and BMI. HRQoL decreases by age, with excess weight associated with increasingly poor quality of life as people age, highlighting the importance of maintaining a healthy weight across the lifecourse.

Our categorical estimates find that on average, obesity is associated with a decrease in quality of life utilities of about 0.035 compared to non-obesity, with estimates ranging from 0.029 for Class I obesity to 0.072 for Class III obesity compared to normal weight, a nearly 10% decrease in HRQoL. These categorical estimates are similar to previous estimates of obesity-related quality of life, both in the US and globally.

Although broadly similar to previous categorical estimates,[21–27] our age and BMI-specific continuous estimates provide flexible, specific utility values that are more precise and can enable more accurate estimates of the impact of obesity prevention interventions as they are sensitive to small changes in BMI across the entire distribution. Our continuous approach also provides estimates that are more robust to changes in the BMI distribution and demographic composition (e.g., age structure) over time, which will impact category averages.

We find that HRQoL losses associated with excess weight are similar by race/ethnicity and poverty level, but are different by sex. Males tend to have higher 'optimal' BMI values for self-reported HRQoL domains. These values are higher than male 'optimal' BMI values previously estimated for healthcare costs and all-cause mortality,[4,9] highlighting the need to use BMI-specific empirical data to account for multiple outcomes (e.g., costs, risks of morbidity and mortality, quality of life) to provide a more comprehensive assessment of the impact of changes in BMI. However, even for males, excess weight above commonly used thresholds for obesity (e.g., BMI of 30) is associated with lower quality of life. These differences in 'optimal' BMI for HRQoL by sex also highlight the importance of considering continuous outcomes by subgroup, as obesity prevention interventions that have similar effects on weight may have differential impacts on BMI-related outcomes by subgroup.

In addition to estimating HRQoL utility values, we estimated the contribution of individual SF-6D domains to utilities, providing insight into what specific aspects are associated with decreases in quality of life. We find that the largest causes of disutility change by age, with BMI-related HRQoL loss at younger ages mainly due to mental health disutility, with physical health disutility associated with excess weight rising with age. This is consistent with previous estimates that risks of physical heath morbidity and mortality associated with excess weight often take time to accumulate, generally beginning to affect adults who are 35 years of age and older.[8,28] In contrast, the BMI-related disutility related to mental health that is already present at younger ages could be indicative of weight stigma or other psychological impacts of excess weight.

Even at younger ages however, high levels of BMI are associated with disutility related to physical health, especially related to self-reported pain. It is well known that excess weight is associated with pain, especially back pain,[29,30] but the extent to which pain is the primary driver of reduced quality of life at high levels of BMI is a striking finding of our study. Discussions around reduced quality of life due to excess weight can be abstract, and empirical findings on utility values can be difficult to interpret, especially for the general population. However, our finding that Pain resulting from excess weight is the primary driver of reduced quality of life provides an emotionally salient, relatable outcome that highlights in clear terms adverse impacts of excess weight, and can help to galvanize efforts around obesity prevention policies and programs. In addition to the salience of this outcome, obesity-related pain has been linked with the high prevalence of prescription opioid use in the United States, compounding the chronic disease impacts of the obesity epidemic with the tragic consequences of the opioid epidemic.[31]

Although MEPS provides important insights into the relationship between BMI and HRQoL (including potential confounding demographic and behavioral factors), the cross-sectional nature of the data presents some limitations regarding the interpretation of these findings. For example, because BMI is linked with multiple chronic health conditions that may in themselves impact HRQoL, it is not clear that reducing an individual's BMI would yield the same improvements in HRQoL as estimated by these cross-sectional differences if the chronic health conditions persist following weight loss. Individual-level longitudinal data are needed to better characterize such changes in BMI with changes in HRQoL. Instead, our findings provide estimates of the association of HRQoL with BMI, and could be used to estimate the population-level counterfactual HRQoL impact of obesity prevention interventions in which (some amount of) excess weight is not acquired in the first place.

Although substantial, our estimates of quality of life loss due to excess weight may be conservative, with estimates from the EQ-5D resulting in even larger HRQoL losses than our primary estimates based on the SF-6D. Nevertheless, our estimates provide robust evidence that health-related quality of life is lower for people with excess body weight across a broad range of ages and BMI levels, especially at high levels of BMI, with Pain the largest driver of HRQoL loss. These findings highlight the importance of promoting a healthy weight for the entire population while also targeting efforts to prevent extreme weight gain over the life course.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key Points

What is already known?

Excess body weight is associated with a range of adverse outcomes, including increased health care costs, risks of comorbidities, premature mortality, and reduced health-related quality of life (HRQoL).

What are the new findings?

Assessing HRQoL by continuous BMI, we find the highest HRQoL values occur at a BMI of 20.4 for females and 26.5 for males. Obesity is associated with an average utility loss of 0.0349 for obesity overall, with Pain the largest cause of HRQoL loss (26%), followed by Role Limitations (22%). HRQoL loss rises with increasing BMI, with an average utility loss of 0.0724 for Class III obesity.

How might these results change the direction of research?

Our finding that Pain resulting from excess weight is the primary driver of reduced quality of life provides an emotionally salient, relatable outcome that highlights in clear terms adverse impacts of excess weight, and can help to galvanize efforts around obesity prevention policies and programs.

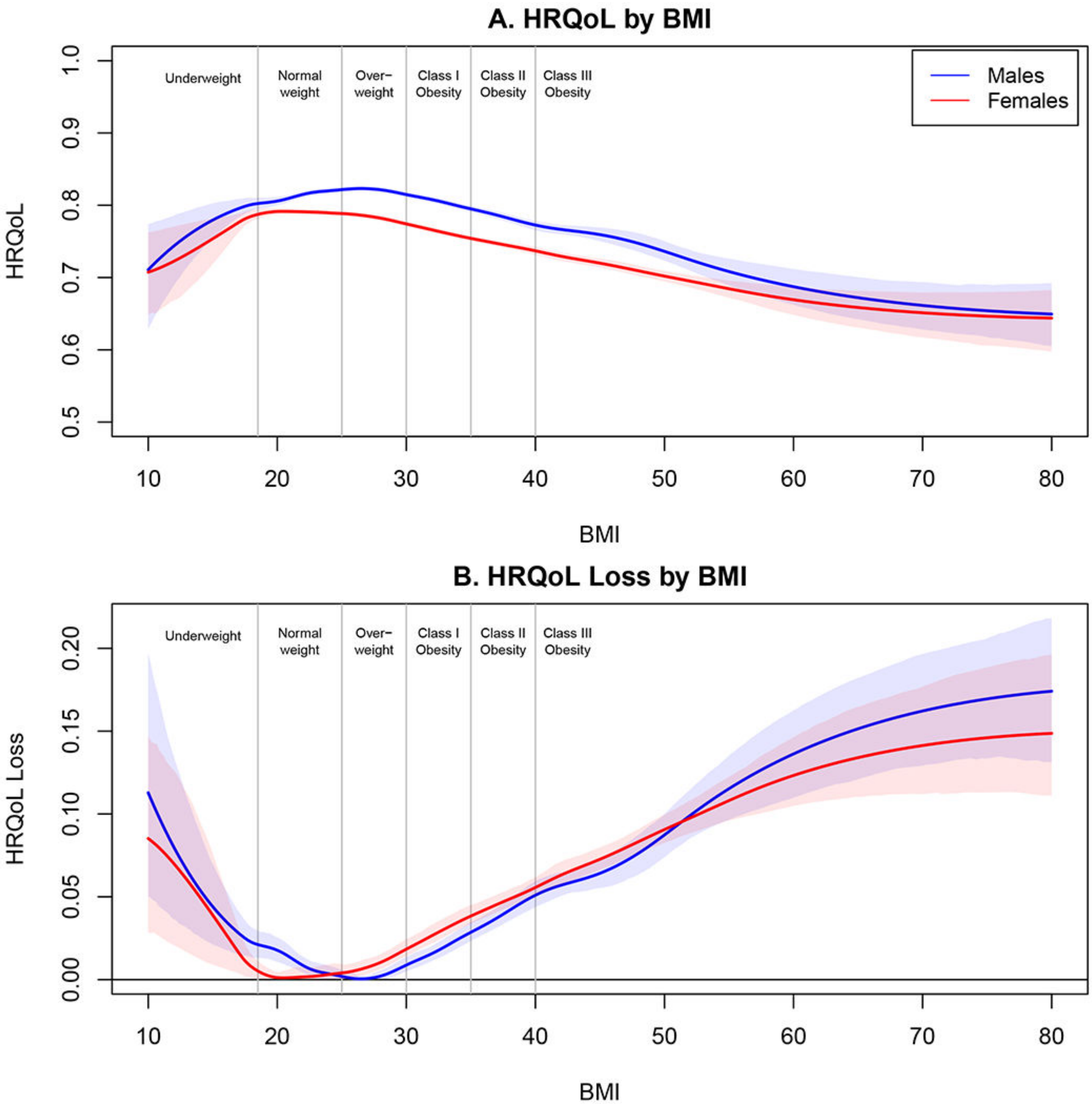

Figure 1:

Estimated BMI-Related Health-Related Quality of Life by Sex (Adults 18+)

Footnote: Estimated health-related quality of life utilities are controlled for potential confounding variables. HRQoL loss is estimated compared to the 'optimal' BMI. Shaded areas represent 95% confidence intervals.

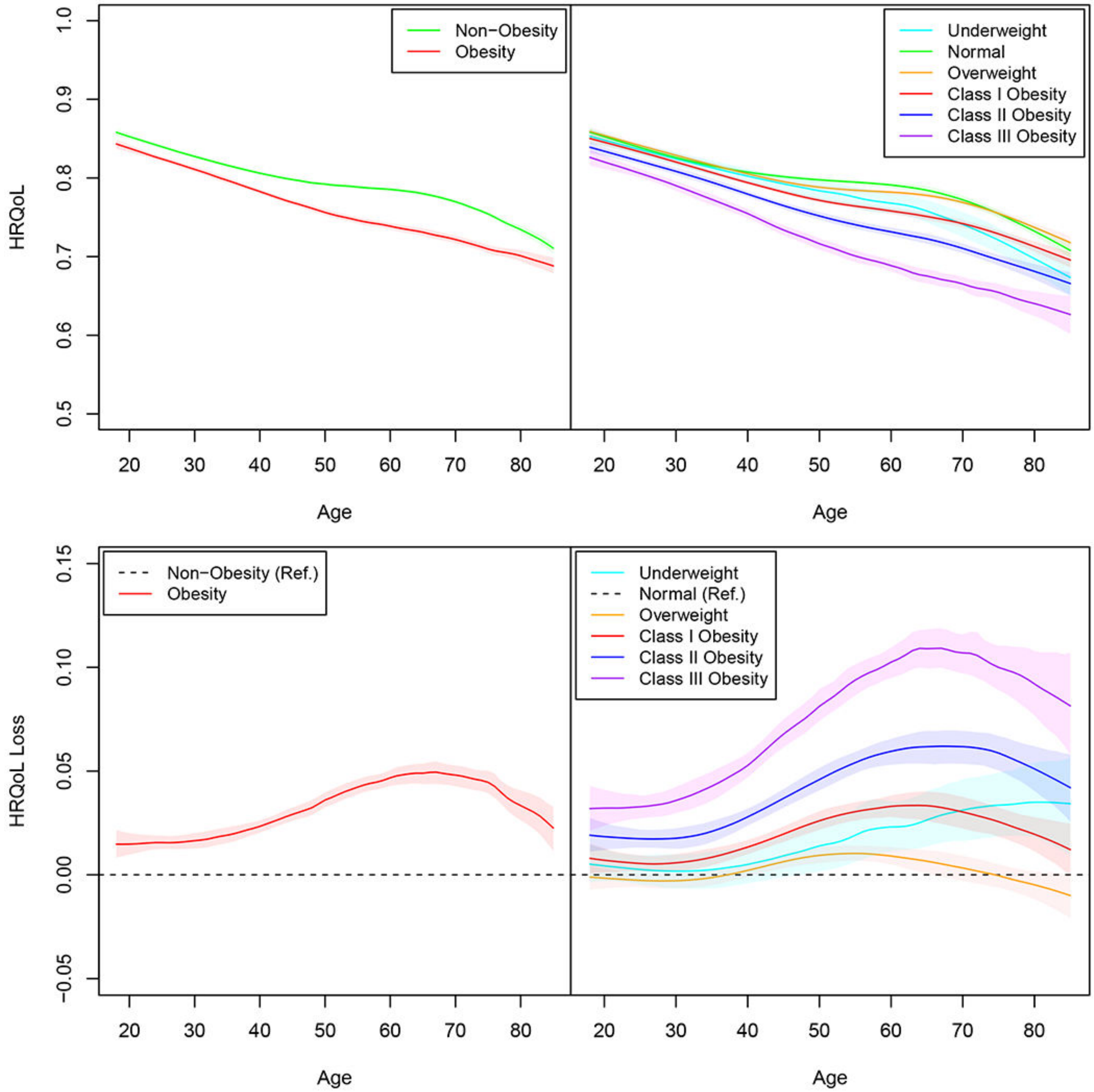

Figure 2:
Estimated HRQoL and HRQoL Loss by Age and BMI Category
Footnote: Estimated health-related quality of life utilities are controlled for potential confounding variables. HRQoL loss is estimated compared to the reference BMI category.

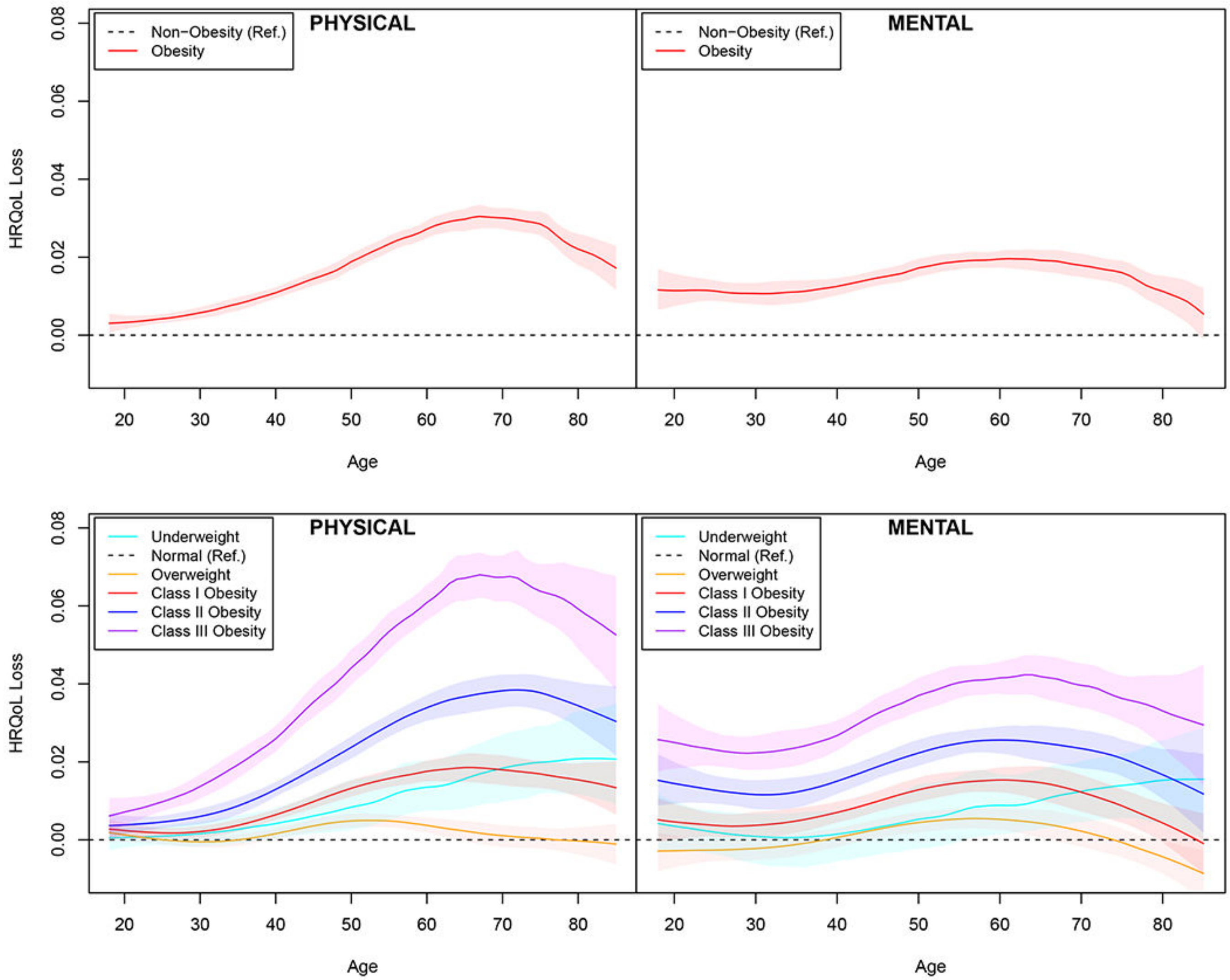

Figure 3:

Physical vs Mental HRQoL Loss by Age and BMI Category

Footnote: Estimated health-related quality of life utilities are controlled for potential confounding variables. Physical includes the SF-6D domains “physical limitations” and “pain”. Mental includes the SF-6D domains “social functioning”, “mental health”, and “vitality”. “Role limitations” was included in either Physical, Mental, or both, depending on the individual-level response. Shaded areas represent 95% confidence intervals.

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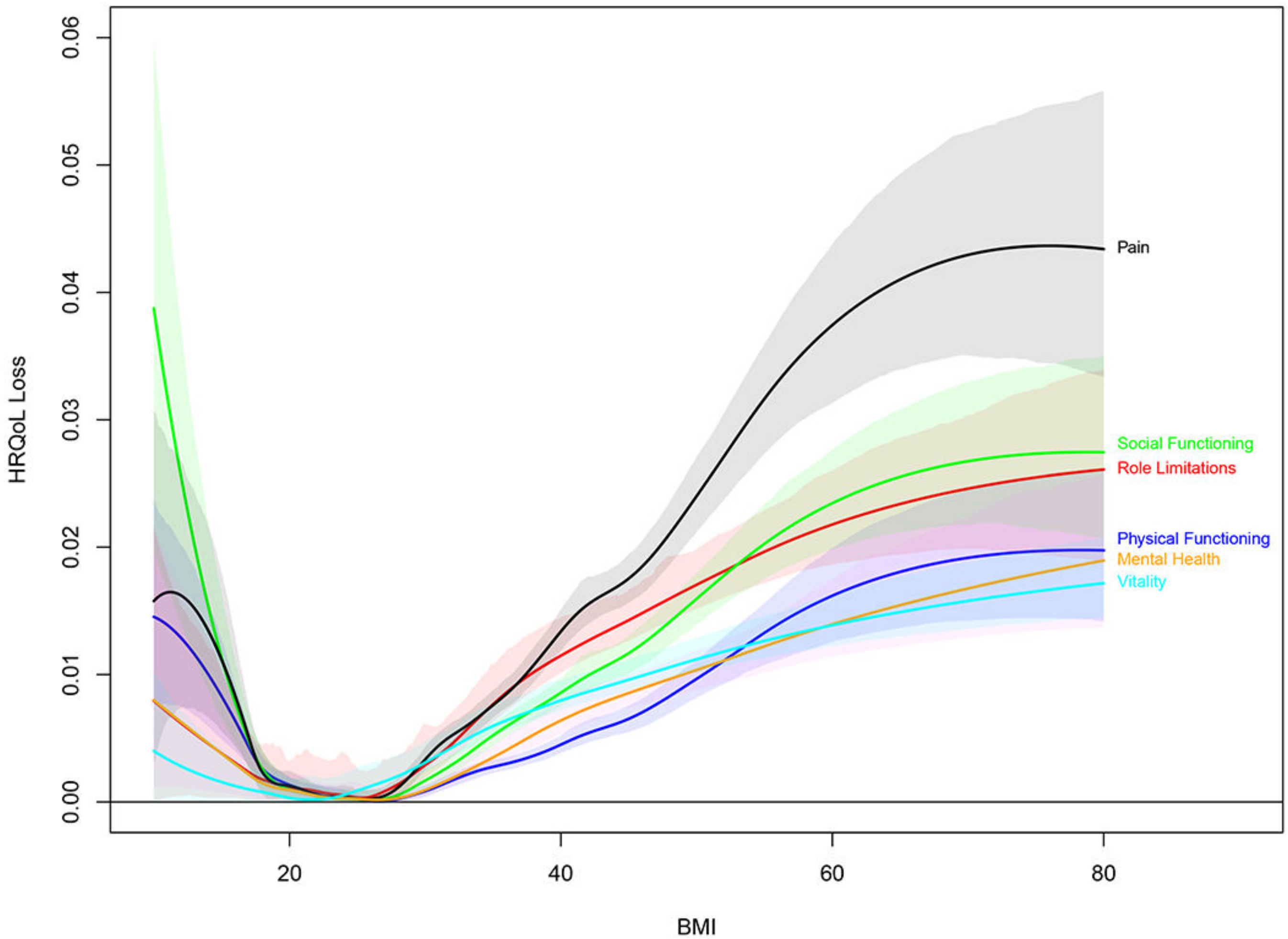

Figure 4:

Estimated BMI-Related HRQoL Loss by SF-6D Domain (Adults 18+)

Footnote: Predicted HRQoL values are controlled for potential confounding variables. Excess HRQoL loss is estimated compared to the lowest predicted BMI-specific HRQoL decrement for each domain. Shaded areas represent 95% confidence intervals.

Table 1:

SF-6D(SF-12v2) HRQoL Outcomes by BMI Category, Mean (95% CI)[a]

Obesity Status (BMI range)	HRQoL	Loss in Quality of Life[b]								
		Total	Group[c]		Domain					
			Physical	Mental	Physical Functioning	Role Limitations	Social Functioning	Pain	Mental Health	Vitality
Non-Obesity (BMI < 30)	80.10 (79.95-80.26)	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Obesity (BMI ≥ 30)	76.61 (76.36-76.85)	3.49 (3.26-3.73)	1.84 (1.70-1.97)	1.66 (1.53-1.80)	0.27 (0.23-0.30)	0.77 (0.69-0.85)	0.59 (0.54-0.64)	0.90 (0.83-0.97)	0.43 (0.38-0.48)	0.53 (0.49-0.57
BMI Category										
Underweight (BMI < 18.5)	80.28 (79.55-80.99)	0.44 (−0.27-1.15)	0.27 (−0.12-0.67)	0.17 (−0.26-0.60)	0.20 (0.07-0.32)	−0.05 (−0.25-0.16)	0.23 (0.05-0.40)	0.10 (−0.07-0.29)	0.02 (−0.12-0.16)	−0.07 (−0.18-0.0
Normal weight (18.5 ≤ BMI < 25)	80.72 (80.53-80.90)	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Overweight (25 ≤ BMI < 30)	79.54 (79.34-79.74)	1.17 (0.95-1.41)	0.73 (0.62-0.85)	0.44 (0.29-0.59)	0.07 (0.04-0.10)	0.31 (0.22-0.39)	0.18 (0.13-0.23)	0.30 (0.25-0.35)	0.08 (0.02-0.13)	0.26 (0.21-0.30
Class I Obesity (30 ≤ BMI < 35)	77.87 (77.62-78.11)	2.85 (2.55-3.15)	1.58 (1.42-1.74)	1.27 (1.09-1.44)	0.18 (0.14-0.23)	0.69 (0.60-0.80)	0.45 (0.39-0.52)	0.72 (0.64-0.80)	0.29 (0.23-0.35)	0.51 (0.46-0.57
Class II Obesity (35 ≤ BMI < 40)	76.05 (75.71-76.37)	4.67 (4.33-5.01)	2.49 (2.28-2.69)	2.18 (1.98-2.39)	0.34 (0.28-0.39)	1.07 (0.96-1.19)	0.77 (0.70-0.85)	1.19 (1.09-1.29)	0.55 (0.47-0.62)	0.74 (0.68-0.80
Class III Obesity (BMI ≥ 40)	73.48 (73.07-73.93)	7.24 (6.78-7.70)	3.82 (3.54-4.10)	3.41 (3.15-3.68)	0.64 (0.56-0.72)	1.45 (1.31-1.59)	1.28 (1.17-1.39)	1.94 (1.79-2.08)	0.92 (0.82-1.02)	1.00 (0.94-1.07

[a]Mean of predicted outcomes for respondents in each BMI category, controlling for age, sex, and other covariates. Utilities are rescaled to 0-100 for display purposes.

[b]HRQoL losses were estimated by assuming that all respondents would instead follow the BMI distribution observed in the reference category, then calculating the difference between the current predicted outcomes and the predicted outcomes for the reference weight population. Dimension-specific losses may not sum to total loss due to rounding.

[c]SF-6D domain-specific disutilities were aggregated into "physical" and "mental" health groupings. Physical Functioning and Pain were grouped under "physical", Social Functioning, Mental Health, and Vitality were grouped under "mental", and Role Limitations was grouped under either/both "physical" and/or "mental" depending on the response.