Using a Generalized Additive Model to Examine the Relationship Between Body Mass Index and Health-Related Quality of Life in the Elderly Population – Results from the Population-Based German KORA-Age study

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Background and methodology

Background
Body mass index (BMI) is the most widely used measure of healthy weight. The World Health Organization (WHO) classifies a BMI of 18.5 [kg/m²] or less as underweight, 18.5-25 as normal weight, 25-30 as overweight, and over 30 as obese.

Methods and Data
We analyzed data from 5462 individuals aged 65 years or older, living in the region of Augsburg, Southern Germany. The data come from the KORA-Age study, which is based on a postal follow-up of individuals who participated in the population-based MONICA/KORA surveys S1-S4. HRQL was measured using the European EQ-5D index (Greener, 2003).

We estimated the functional form of the relationship between BMI and HRQL by using multivariate generalized additive models (GAMs). All estimates were adjusted for sociodemographic factors (age, gender, education) and the presence of 7 chronic diseases (diabetes mellitus, cardiovascular events, stroke, cancer, fractures, respiratory problems, and hypertension). Smoothing parameters were estimated through generalized cross-validation (GCV).

Results from the GAM were compared with approaches where BMI was modeled as a linear, quadratic or cubic term, or classified into the WHO categories. Subgroup analyses were performed contrasting younger (65-74) and older (75+) adults, as well as stratified by gender. Calculations were carried out using the statistical software R with the add-on package mgcv.

Results

1. Overall sample (65-93 years)

In the overall sample, the relationship between BMI and HRQL is inverse U-shaped with the maximum HRQL located around a BMI of about 24.7 kg/m² (Figure 1).

The estimated curve indicates that going from a BMI of 24.7 to 35 is associated with a EQ-5D utility loss of about 5.2 points (corresponding to 0.28 of standard deviation). This means that obese patients with a BMI of 35 have on average 5.2 points lower EQ-5D Index scores than individuals with healthiest BMI. On the other hand, underweight individuals with a BMI of 18 had an average impairment of 6.8 units compared to a BMI of 24.7 kg/m².

Comparison with alternative approaches

Figure 2 compares alternative approaches used to model the BMI-HRQL relationship: Assuming a linear or quadratic association does not capture the HRQL loss for low BMI subjects and thus leads to a severe bias in the prediction of HRQL for underweight individuals. A cubic polynomial reproduces the inverse U-shape but may be inappropriate if relationships are more curvilinear. Estimates based on the WHO categories reflect reduced HRQL in the low BMI category, but grouping different BMI values into one and the same category may obscure meaningful differences.

Discussion

Concerns have been raised whether the BMI reference range of 18.5-25 kg/m² is appropriate in the elderly population (Cook et al., 2005). Modeling the association between BMI and HRQL by means of generalized additive models avoids this problem.

Our results suggest that health in older adults is optimal around a BMI of 25 kg/m². Although there are no comparable studies on BMI and mortality reporting minimal risks for BMI ranges 25-29, other studies modeled the effect of BMI as a linear term but ignored that not only overweight but also underweight may be associated with reduced HRQL. Both approaches can bias findings since they may conceal the true functional form of the relationship.

Objectives
- To flexibly model the relationship between BMI and HRQL in the elderly population by neither using fixed BMI categories nor imposing a priori constraints on its shape such as linear or polynomial forms.
- To examine the degree to which not only high but also low BMI is associated with reduced HRQL and to identify the level of BMI associated with highest HRQL.

Methods

- To design a cubic polynomial to fit the inverse U-shape of the BMI-HRQL relationship.
- To categorize BMI into WHO categories, and compare these with linear models.

Results

- Significant inverse U-shape relationship between BMI and HRQL.
- Optimal health around BMI 25 kg/m².
- Importance of nonlinear relationship.

Discussion

- The BMI reference range may not be appropriate for older adults.
- Nonlinear relationship should be modeled.

References