Practice of Epidemiology

Development of a Modified BODE Index as a Mortality Risk Measure Among Older Adults With and Without Chronic Obstructive Pulmonary Disease

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The BODE index was developed as a prognostic mortality risk tool for persons with chronic obstructive pulmonary disease (COPD). It incorporates 4 measures: **b**ody mass index, lung **o**bstruction, **d**yspnea, and **e**xercise capacity. The intent of this study was to examine how well a BODE-like index constructed using a simpler lung function measure, peak expiratory flow, in combination with physical functioning and symptom information more readily found in survey data (a quasi-BODE index), performs in identifying persons at higher risk of mortality and whether it may be extended as an assessment of mortality risk to persons without diagnosed COPD. Using US national survey data from the Health Retirement Study for 2006–2010, each unit increase in the quasi-BODE index score was associated with a multiplicative 50% increase in mortality risk (odds ratio = 1.50, 95% confidence interval: 1.41, 1.59). The quasi-BODE index is a multidimensional health status instrument based on the BODE index, which is a good predictor of mortality. The quasi-BODE index was compiled using simple measures of physical and respiratory function. It is a potentially useful prognostic instrument for older adult populations with or without COPD, including those with severe physical limitations, particularly when combined with demographic factors and comorbid conditions.

chronic disease; dyspnea; frail elderly; health status indicators; lung diseases, obstructive; mortality; respiratory function tests; survival

Heart disease, stroke, cancer, chronic obstructive pulmonary disease (COPD), and diabetes were leading causes of death in the United States for persons aged 45 years or older in 2006 (1). These chronic illnesses are known to pose increased risks for mortality, but health status is multidimensional and is influenced through diverse processes. There is broad interest in measurable factors beyond chronic disease that provide information about mortality risk, recognizing that measures of risk are population-based and may not be applicable on an individual basis. Limitations in physical functioning, which tend to precede disability, could provide additional information about future health status (2–4).

Disease assessments and screening instruments that consider multiple factors may be particularly useful for identifying persons at risk of adverse outcomes (5–10). For example, systemic consequences of comorbid conditions associated with COPD have been recognized as affecting health status, morbidity, and mortality (11–15). Another recognized dynamic in older adults is frailty, which has been found to be independently predictive of adverse outcomes (9). Frail individuals, who are defined as having 3 or more frailty criteria—unintentional weight loss (>10 pounds (>4.5 kg) in the past year), self-reported exhaustion, weakness (low grip strength), slow walking speed, and low physical activity—are at increased risk of falls, worsening morbidity, Activities of Daily Living disability, hospitalization, and death (9).

One aspect of physical health not often considered in populations without respiratory disease is lung function. Limitations

in lung function are among those physiological measures that have been associated with decreased physical capacity, poorer health status, and reduced survival (16–22). Poor lung function has been shown to be both an indicator of impaired health and a predictor of mortality in the elderly, not only for those with respiratory disease but also for those with cardiovascular disease and diabetes (23–26). Dyspnea (difficulty breathing or shortness of breath) is associated not only with asthma and COPD but also with cardiovascular diseases such as coronary artery disease and congestive heart failure. Intuitively, dyspnea results in reduced ability to exercise, and persons with poor lung function may adopt sedentary lifestyles (27). Physical inactivity, in turn, is known to be associated with increased risk of mortality and morbidity (28, 29). Finally, cachexia, which results in loss of muscle mass and diminished imunological response, is frequently associated with increased risk of mortality (30, 31). The BODE index incorporates these 4 characteristics into 1 scored value to assess mortality risk using the following measures: **b**ody mass index (BMI), lung **o**bstruction, **d**yspnea, and **e**xercise capacity (7).

The BODE index was originally developed as a prognostic tool for persons with COPD; its usefulness for persons without COPD has not been examined to date. The BODE index requires BMI (weight (kg)/height (m)^2), degree of airflow obstruction measured by means of spirometry (percentage of predicted forced expiratory volume in 1 second (FEV_1)), dyspnea as assessed by the modified Medical Research Council dyspnea scale, and exercise capacity as determined by a 6-minute walk test (7). However, only BMI and dyspnea measures are easily obtained. Formal spirometry requires subjects to exhale with maximum effort for at least 6 seconds, which can be very difficult for many elderly or debilitated persons. In community surveys of older adults, the proportion of individuals unable to perform spirometry has ranged from 12% to 17% (32, 33). The 6-minute walk test requires a 100-foot (30.5-m) hallway and measures the distance a person can walk quickly in 6 minutes on a hard, flat surface (34). The BODE index is useful as an assessment of health status and risk for poor outcomes but is impractical for debilitated persons. In one prospective study of survival, 26% of the original cohort of 327 COPD participants either could not complete the 6-minute walk test (64 participants) or could not perform adequate spirometry (20 participants) (35).

Our objective was to construct a quasi-BODE index using a simpler lung function measure, peak expiratory flow (PEF), as well as information more readily found in survey data such as standardized assessments of physical functioning and symptoms. PEF, although not as commonly used as FEV_1 as a health status measure, can be a more practical physiological measure to obtain from elderly persons (36–38). Percentage of predicted PEF has been shown to be a predictor of survival among older adults in the general population (10, 18, 24) and in adults with diabetes (25). Others have found significant correlations between percentage of predicted PEF and measures of physical and cognitive function in the elderly (39).

The intent of this study was to examine how well the quasi-BODE index, constructed using proxy measures, performs in identifying persons at higher risk of mortality and in measuring mortality risk not only among persons with COPD but also among those without COPD. We also examined the value

Table 1. Elements of the BODE Index[a] as Originally Constructed

Measure	Scale Points
Body mass index[b]	
>21	0
≤21	1
FEV_1, %[c]	
≥65	0
50–64	1
36–49	2
≤35	3
mMRC dyspnea scale	
0–1	0
2	1
3	2
4	3
6-minute walking distance, m	
≥350	0
250–349	1
150–249	2
≤149	3

Abbreviations: FEV_1, forced expiratory volume in 1 second; mMRC, modified Medical Research Council.

[a] The BODE index incorporates 4 characteristics into 1 scored value to assess mortality risk using the following measures: **b**ody mass index, lung **o**bstruction, **d**yspnea, and **e**xercise capacity (7).

[b] Weight (kg)/height (m)^2.

[c] Percentage of predicted FEV_1 value.

of adding other prognostic measures to the quasi-BODE index, including mental health, demographic factors, and parental longevity.

MATERIALS AND METHODS

Cohort and data collection

Source data came from the Health Retirement Study (HRS), in which a biennial survey is administered to stratified samples of US residents over the age of 50 years. The HRS, initiated in 1992, is an ongoing study sponsored by the National Institute on Aging and conducted by investigators at the University of Michigan. Surveys are conducted on a 2-year cycle. Significant survey changes were made in 2002. Physical measurements (e.g., lung function) were added in 2004. Data for this project consist of the publicly available deidentified HRS data.

The HRS data collected for each participant include mortality information, measurements of BMI, physical functioning (e.g., ability to exercise), mobility, strength, and fine motor skills, and questionnaire items about coughing or wheezing and shortness of breath (details are provided in the Web Appendix, available at http://aje.oxfordjournals.org/). A PEF test was added in 2004 to measure lung function for a small sample of participants and was expanded in 2006 and

Table 2.   Characteristics of Health Retirement Study National Survey Respondents Over Age 50 Years by Occurrence of Death Within 2 Years Postsurvey, United States, 2006 and 2008

	% of Total (n = 12,501)	% Who Died in Next 2 Years (n = 673)	% Who Remained Alive in Next 2 Years (n = 11,828)	P Value
Age category, years				
51–64	33.6	9.5	35.0	<0.0001
65–74	37.3	29.3	37.8	<0.0001
75–84	22.0	34.0	21.3	<0.0001
≥85	7.1	27.2	6.0	<0.0001
Male sex	42.1	49.6	41.7	<0.0001
Parental longevity[a]				
Mother lived to age ≥70 years	69.5	64.6	69.7	0.008
Father lived to age ≥70 years	56.5	55.6	56.5	0.15
Mother lived to age ≥75 years	60.6	55.3	60.9	<0.0001
Father lived to age ≥75 years	44.3	42.1	44.5	<0.0001
Race/ethnicity				
Non-Hispanic white	76.8	78.0	76.8	0.45
Hispanic	8.5	7.1	8.5	0.20
Black	13.3	14.1	13.2	0.50
Other	1.5	0.7	1.5	0.11
Body mass index[b] <21	5.3	12.8	4.8	<0.0001
Comorbid conditions				
Diabetes	21.5	35.4	20.7	<0.0001
Cancer	15.6	27.8	14.9	<0.0001
COPD	10.6	22.4	10.0	<0.0001
Heart disease	26.5	50.1	25.1	<0.0001
Stroke	6.8	15.3	6.3	<0.0001
No diabetes/cancer/COPD/ heart disease/stroke	46.1	18.9	47.6	<0.0001
High blood pressure	59.5	68.4	59.0	<0.0001
Arthritis	63.2	69.4	62.8	0.0006
Respiratory function				
Persistent cough/wheeze	18.0	26.4	17.5	<0.0001
Shortness of breath	19.8	34.2	19.0	<0.0001
Persistent cough or shortness of breath	28.8	44.1	27.9	<0.0001
Oxygen use	1.9	8.8	1.5	<0.0001

Table continues

2008. No HRS physical measures are exactly the same as the 6-minute walk test used to calculate the BODE index, but available measures can reasonably be expected to serve as self-reported equivalents to a physical function domain for a quasi-BODE mortality risk measure. The HRS includes a battery of questionnaires for participants about diagnosed chronic diseases and associated symptoms; family history; self-assessment of general health status and expectations about longevity; physical, cognitive, and affective functioning measures; demographic characteristics; living arrangements; and economic resources. HRS information on mortality comes from the National Death Index, plus interviews with family members.

Development of quasi-BODE index

In constructing the quasi-BODE index, we strove to approximate the original BODE index as closely as possible (Table 1). HRS data included BMI information. The original BODE index utilized FEV_1 categories similar to American Thoracic Society definitions (7). We substituted percentage of predicted PEF using a regression equation for predicted

Table 2. Continued

	% of Total (n = 12,501)	% Who Died in Next 2 Years (n = 673)	% Who Remained Alive in Next 2 Years (n = 11,828)	P Value
% of predicted PEF				
≥65	85.9	67.3	87.0	<0.0001
50–64	7.9	13.5	7.6	<0.0001
36–49	4.4	12.3	4.0	<0.0001
0–35	1.8	6.8	1.5	<0.0001
Limitations with physical functions				
Walking 1 block	14.6	40.3	13.1	<0.0001
Lifting or carrying weights >10 pounds (>4.5 kg)	24.1	49.2	22.6	<0.0001
Reaching/extending arms above shoulder level	16.0	26.2	15.5	<0.0001
Use of health-care services				
Overnight stay in hospital in last 2 years	27.3	51.3	25.9	<0.0001
Visit to a physician in last 2 years	90.9	88.0	91.0	0.06
Third quartile of number of physician visits in last 2 years	24.3	37.6	23.5	<0.0001
Evidence of depression[c]	13.8	22.6	13.3	<0.0001
Smoking status				
Previous smoker	56.7	66.3	56.2	<0.0001
Current smoker	12.6	16.0	12.4	0.007
Pack-years of smoking				
Persons with information	56.5	66.3	56.0	<0.0001
<11	14.7	11.6	14.9	0.02
11–<26	13.5	13.1	13.6	0.70
26–≤40	14.6	19.0	14.4	0.001
>40	13.7	22.6	13.2	<0.0001

Abbreviations: COPD, chronic obstructive pulmonary disease; PEF, peak expiratory flow.

[a] Age if alive at the time of the survey or age at death.

[b] Weight (kg)/height (m)^2.

[c] Score >3 on the 8-item Center for Epidemiologic Studies Depression Scale.

PEF developed from a population of persons with "normal" lung function (i.e., no COPD, no history of smoking, and no coughing/wheezing/shortness-of-breath symptoms reported) within HRS respondents in the 2006 and 2008 surveys (40, 41). Full details of that analysis are provided elsewhere (42). Predicted PEF values were calculated for men and women separately and factored in age (years; continuous variable), height, and race/ethnicity (42, 43).

The dyspnea scale used in the BODE index captured a dyspnea range from "not troubled with breathlessness except with strenuous exercise" to "too breathless to leave the house or breathless when dressing or undressing" (44). We evaluated shortness of breath and wheezing/cough as proxy measures. While the BODE index included 6-minute walk test distance, we substituted difficulties in mobility and strength with walking 1 block and lifting more than 10 pounds (>4.5 kg).

Elements included in the original BODE index had first been chosen because each was independently associated with poorer health status, adverse outcomes, and increased risk of death. The elements included had demonstrated the strongest association with mortality using logistic regression. Each of the potential quasi-BODE index elements from the HRS (BMI ≤21, categories of percentage of predicted PEF, shortness of breath, wheezing/cough, and mobility and strength difficulties) was similarly evaluated independently as a predictor of mortality using logistic regression models and receiver operating characteristic curves. Points were associated with the quasi-BODE elements based on the magnitude of the odds ratio for mortality (1 point: odds ratio (OR) = 1.0–2.4; 2 points: OR = 2.5–5.0; 3 points: OR >5.0).

After constructing the quasi-BODE index, its use as a prognostic factor was tested in logistic regression models for

Table 3. Odds Ratio Associated With Risk of Mortality in the Subsequent 2 Years According to Elements of the Quasi-BODE Index Among Health Retirement Study National Survey Respondents Over Age 50 Years, United States, 2006 and 2008

Health Retirement Study Measure	Scale Points	Risk of Mortality in Next 2 Years	
		Odds Ratio	95% Confidence Interval
Body mass index[a]			
>21	0	1	Reference
≤21	2	2.9	2.3, 3.7
% of predicted PEF			
≥65	0	1	Reference
50–64	1	2.2	1.8, 2.6
36–49	2	4.5	3.5, 5.6
≤35	3	6.7	4.8, 9.5
Shortness of breath			
No shortness of breath	0	1	Reference
Shortness of breath	1	2.2	1.9, 2.6
Difficulty with mobility and strength[b]			
No difficulty	0	1	Reference
Lifting or carrying >10 pounds (>4.5 kg)	1	2.1	1.7, 2.5
Walking 1 block	2	3.1	2.6, 3.7

Abbreviation: PEF, peak expiratory flow.

[a] Weight (kg)/height (m)^2.

[b] Points are associated with either difficulty with walking 1 block or difficulty with lifting/carrying >10 pounds (>4.5 kg), whichever has the higher number of points for the individual.

Figure 1. Percentages of respondents over age 50 years (n = 12,501) and aged 65 years or older (n = 8,301) by quasi-BODE index score, Health Retirement Study national surveys, United States, 2006 and 2008.

mortality in the 2-year postsurvey period, adjusting for patient demographic and morbidity characteristics. Additional models, in which various comorbid conditions were added to the quasi-BODE index, were constructed to determine whether they contributed additional value to the area under the receiver operating characteristic curve (C statistic). The study population consisted of persons aged 50 years or older with sensitivity analyses conducted for the subpopulation aged 65 years or older. Stratified analyses were conducted for populations with and without COPD because the BODE index was originally constructed using a COPD population. Odds ratios and associated 95% confidence intervals were estimated for risk factors, and the C statistic was used to gauge the predictive power of the models.

SAS statistical software (SAS Institute, Inc., Cary, North Carolina) was used to perform the analyses. All P values are 2-sided with a significance level of 0.05.

RESULTS

Complete information on demographic factors, comorbid conditions, BMI, respiratory symptoms, percentage of predicted PEF, physical function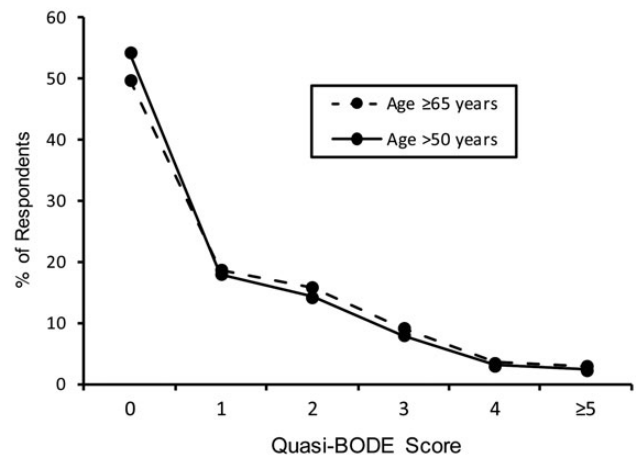ing limitations, and depression symptoms was available for 12,501 participants (Table 2). Of these, 673 (5.4%) died during the 2 years following the HRS survey. Smoking history was incomplete for persons who were current smokers or who had smoked in the past, and missing values were imputed using mean study population values for age at starting smoking, age at stopping smoking, and packs per day (details given in Web Appendix).

As expected, persons who died during the next 2 years were older than those who did not die (61.2% vs. 27.3% were aged ≥75 years; P < 0.0001) and were more likely to have chronic diseases (80% of those who died had at least 1 of the chronic conditions as compared with slightly more than 50% of survivors). Specifically, they were more likely to have heart disease (50.1% vs. 25.1%; P < 0.0001), diabetes (35.4% vs. 20.7%; P < 0.0001), cancer (27.8% vs. 14.9%; P < 0.0001),
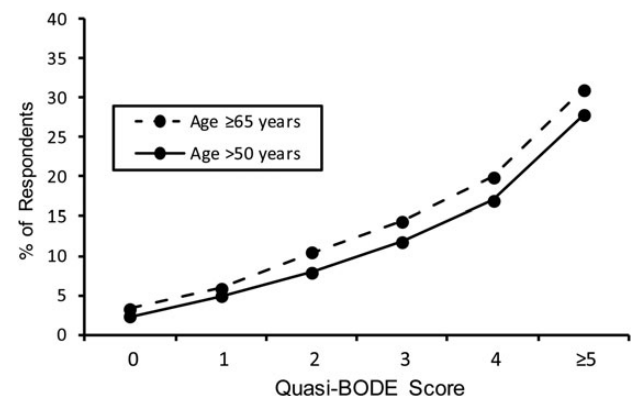

Figure 2. Percentages of respondents over age 50 years (n = 12,501) and aged 65 years or older (n = 8,301) within each quasi-BODE index score who died within 2 years postsurvey, Health Retirement Study national surveys, United States, 2006 and 2008.
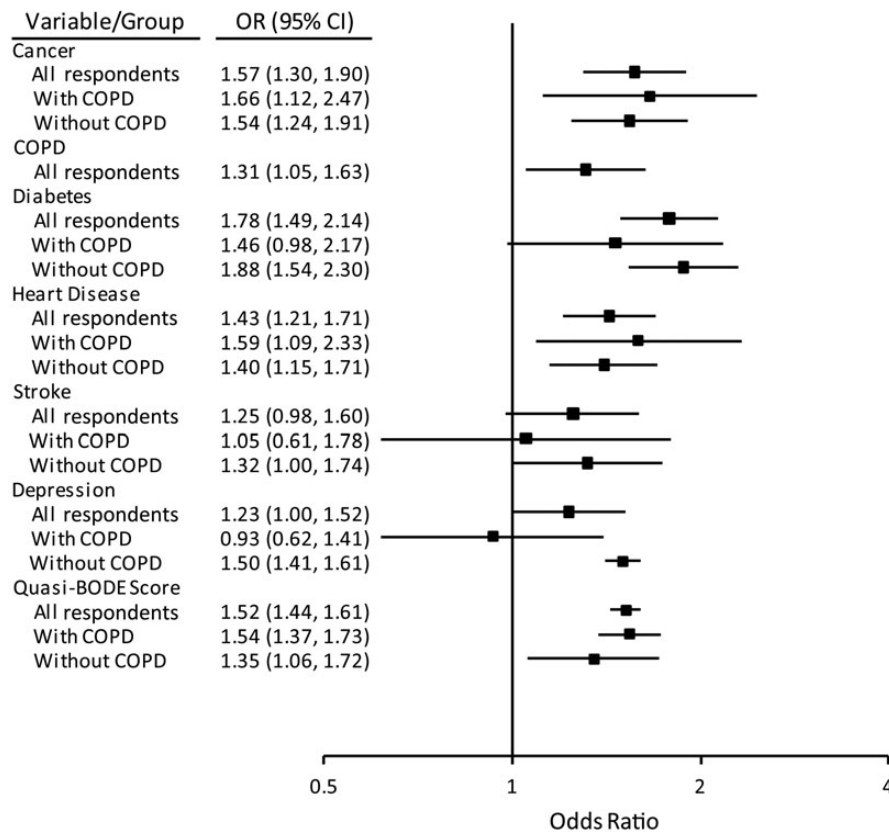
Variable/Group	OR (95% CI)
Cancer	
All respondents	1.57 (1.30, 1.90)
With COPD	1.66 (1.12, 2.47)
Without COPD	1.54 (1.24, 1.91)
COPD	
All respondents	1.31 (1.05, 1.63)
Diabetes	
All respondents	1.78 (1.49, 2.14)
With COPD	1.46 (0.98, 2.17)
Without COPD	1.88 (1.54, 2.30)
Heart Disease	
All respondents	1.43 (1.21, 1.71)
With COPD	1.59 (1.09, 2.33)
Without COPD	1.40 (1.15, 1.71)
Stroke	
All respondents	1.25 (0.98, 1.60)
With COPD	1.05 (0.61, 1.78)
Without COPD	1.32 (1.00, 1.74)
Depression	
All respondents	1.23 (1.00, 1.52)
With COPD	0.93 (0.62, 1.41)
Without COPD	1.50 (1.41, 1.61)
Quasi-BODE Score	
All respondents	1.52 (1.44, 1.61)
With COPD	1.54 (1.37, 1.73)
Without COPD	1.35 (1.06, 1.72)

Figure 3. Adjusted odds ratio (OR) for risk of mortality within 2 years postsurvey among all respondents over age 50 years ($n = 12{,}501$), respondents with chronic obstructive pulmonary disease (COPD) ($n = 1{,}328$), and respondents without COPD ($n = 11{,}173$), Health Retirement Study national surveys, United States, 2006 and 2008. Odds ratios for a 1-unit increase in quasi-BODE score were estimated separately by group (all respondents, respondents with COPD, and respondents without COPD); odds ratios were also adjusted for sex and age (not shown). Bars, 95% confidence interval (CI).

or COPD (22.4% vs. 10.0%; $P < 0.0001$) or to have had a stroke (15.3% vs. 6.3%; $P < 0.0001$). Among those aged ≥65 years, there was a reduced percentage difference for persons with cancer (27.4% vs. 18.4%; $P < 0.0001$), but percentage differences were similar for the remaining chronic conditions (data not shown). Persons who died in the next 2 years were also much more likely to have a BMI less than 21 (12.8% vs. 4.8%; $P < 0.0001$), a percentage of predicted PEF of 49% or less (19.2% vs. 5.5%; $P < 0.0001$), shortness of breath (34.2% vs. 19.0%; $P < 0.0001$), and difficulty with walking 1 block (40.3% vs. 13.1%; $P < 0.0001$) or lifting/carrying more than 10 pounds (>4.5 kg) (49.2% vs. 22.6%; $P < 0.0001$). Persons who died were more likely to have been hospitalized in the 2 years prior to the survey (51.3% vs. 25.9%; $P < 0.0001$) or to have had evidence of depression (22.6% vs. 13.3%; $P < 0.0001$). Race/ethnicity characteristics were not associated with mortality in this cohort, but maternal longevity was significantly associated. Persons whose mothers lived to be aged 75 years or older also had better survival (60.9% vs. 55.3%; $P < 0.01$).

Table 3 shows specific quasi-BODE index elements and how they compare with the original BODE index. Unadjusted odds ratios for mortality risk are also shown in Table 3. The maximum possible value for the original BODE index is 10, and that for the quasi-BODE index is 8. Quasi-BODE index scores greater than 5 applied to only 1% of the population; these were truncated to 5 in our analyses. Figure 1 shows the quasi-BODE index scores for the study population and the subpopulation aged 65 years or older. Figure 2 provides a summary of the percentage within each quasi-BODE index score who died during the 2 years postsurvey. Each 1-unit increase in the quasi-BODE index was associated with a multiplicative 50% increase in mortality risk (OR = 1.50, 95% CI: 1.41, 1.59).

Figure 3 shows the sex- and age-adjusted odds ratio estimates for the quasi-BODE index compared with other morbidity factors considered in the adjusted regression equation. To demonstrate the influence of these factors in populations with COPD (wCOPD) and populations without COPD (woCOPD), stratified estimates for these populations are shown in addition to estimates for the entire study population. Odds ratio estimates for persons aged 65 years or older were similar (data not shown). Regression models were constructed with and without the quasi-BODE index. Inclusion of the quasi-BODE index served to attenuate odds ratios associated with heart disease and stroke in both the wCOPD and woCOPD populations;

Table 4. Characteristics of Health Retirement Study National Survey Respondents Over Age 50 Years by Quasi-BODE Score, United States, 2006 and 2008

Factor	% With Quasi-BODE Score 0–1 (n = 9,040)	% With Quasi-BODE Score 2–3 (n = 2,776)	P Value (2–3 vs. 0–1)[a]	% With Quasi-BODE Score ≥4 (n = 685)	P Value (≥4 vs. 0–1)[b]	P Value (≥4 vs. 2–3)[c]
Age category, years						
51–64	37.1	25.4	<0.0001	21.0	<0.0001	0.01
65–74	38.5	33.8	<0.0001	35.3	0.10	0.02
75–84	19.6	28.1	<0.0001	29.3	<0.0001	0.45
≥85	4.8	12.8	<0.0001	14.3	<0.0001	0.51
Male sex	45.3	32.7	<0.0001	38.4	0.0004	0.005
Parental longevity[d]						
Mother lived to age ≥70 years	70.6	67.5	<0.0001	62.6	<0.0001	0.04
Father lived to age ≥70 years	56.9	55.3	0.005	56.5	0.53	0.03
Mother lived to age ≥75 years	61.8	58.4	<0.0001	53.0	<0.0001	0.03
Father lived to age ≥75 years	45	42.4	0.001	43.1	0.47	0.34
Race/ethnicity						
Non-Hispanic white	78.3	72.1	<0.0001	76.4	0.23	0.03
Hispanic	8.5	8.9	0.54	5.7	0.01	0.006
Black	11.8	17.2	<0.0001	16.8	0.0001	0.79
Other	1.4	1.8	0.16	1.2	0.62	0.27
Body mass index[e] ≤21	0.0	15.6	0.01	32.7		<0.0001
Comorbid conditions						
Diabetes	19.0	28.0	<0.0001	27.3	<0.0001	0.70
Cancer	14.5	18.0	<0.0001	20.6	<0.0001	0.12
COPD	5.9	18.3	<0.0001	41.8	<0.0001	<0.0001
Heart disease	21.4	38.5	<0.0001	45.4	<0.0001	0.001
Stroke	4.6	11.4	<0.0001	16.9	<0.0001	<0.0001
No diabetes/cancer/COPD/ heart disease/stroke	52.4	32.2	<0.0001	19.1	<0.0001	<0.0001
High blood pressure	56.6	67.1	<0.0001	66.7	<0.0001	0.88
Arthritis	58.6	75.4	<0.0001	73.6	<0.0001	0.31
Respiratory function						
Persistent cough/wheeze	12.6	27.6	<0.0001	49.5	<0.0001	<0.0001
Shortness of breath	9.4	41.9	<0.0001	67.9	<0.0001	<0.0001
Persistent cough or shortness of breath	18.6	50.9	<0.0001	74.3	<0.0001	<0.0001
Oxygen use	0.3	3.5	<0.0001	16.6	<0.0001	<0.0001
% of predicted PEF						
≥65	95.4	73.3	<0.0001	11.1	<0.0001	<0.0001
50–64	4.6	14.2	<0.0001	26.4	<0.0001	<0.0001
36–49	0.0	10.7	<0.0001	37.7	<0.0001	<0.0001
0–35	0.0	1.8	<0.0001	24.8	<0.0001	<0.0001

Table continues

odds ratios for diabetes were slightly reduced (see Web Tables 1–3).

Possible *C* statistic values range from 0.0 to 1.0; values of 0.70 or higher are generally considered acceptable, with values of 0.80 or higher considered strong (45). The *C* statistic values for final models ranged from 0.76 (wCOPD) to 0.82 (woCOPD and all respondents). In a model including only the quasi-BODE index as a factor, the *C* statistic was 0.72 for all respondents and 0.70 for the wCOPD and woCOPD populations. Adding age and sex to these models increased

Table 4. Continued

Factor	% With Quasi-BODE Score 0–1 (n = 9,040)	% With Quasi-BODE Score 2–3 (n = 2,776)	P Value (2–3 vs. 0–1)[a]	% With Quasi-BODE Score ≥4 (n = 685)	P Value (≥4 vs. 0–1)[b]	P Value (≥4 vs. 2–3)[c]
Limitations with physical functions						
Walking 1 block	0.0	48.9	<0.0001	68.2	<0.0001	<0.0001
Lifting or carrying weights >10 pounds (>4.5 kg)	10.9	55.2	<0.0001	71.4	<0.0001	<0.0001
Reaching/extending arms above shoulder level	10.0	30.0	<0.0001	38.5	<0.0001	<0.0001
Use of health-care services						
Overnight stay in hospital in last 2 years	22.0	38.2	<0.0001	48.6	<0.0001	<0.0001
Visit to a physician in last 2 years	91.7	87.0	0.04	84.7	0.11	0.61
Third quartile of number of physician visits in last 2 years	20.5	31.8	<0.0001	38.7	<0.0001	<0.0001
Evidence of depression[f]	8.8	25.6	<0.0001	32.6	<0.0001	0.0003
Smoking status						
Previous smoker	54.7	59.8	<0.0001	71.8	<0.0001	<0.0001
Current smoker	10.4	15.6	<0.0001	28.8	<0.0001	<0.0001
Pack-years of smoking						
Persons with information	54.5	59.5	<0.0001	71.5	<0.0001	<0.0001
<11	15.6	12.9	0.0005	9.9	<0.0001	<0.0001
11–<26	13.8	13.3	0.48	11.2	<0.0001	<0.0001
26–≤40	13.7	16.1	0.0009	21.2	<0.0001	0.002
>40	11.4	17.2	<0.0001	29.2	<0.0001	<0.0001

Abbreviations: COPD, chronic obstructive pulmonary disease; PEF, peak expiratory flow.

[a] Quasi-BODE score 2–3 compared with quasi-BODE score 0–1.
[b] Quasi-BODE score ≥4 compared with quasi-BODE score 0–1.
[c] Quasi-BODE score ≥4 compared with quasi-BODE score 2–3.
[d] Age if alive at the time of the survey or age at death.
[e] Weight (kg)/height (m)^2.
[f] Score >3 on the 8-item Center for Epidemiologic Studies Depression Scale.

the C statistic to 0.80 for all respondents and to 0.74 for the wCOPD populations and 0.79 for the woCOPD populations. Further adding morbidity information increased the C statistic by only 0.02 (Web Tables 1–3).

Models of chronic morbidity without the quasi-BODE index, but with age and sex, had C statistics ranging from 0.70 (wCOPD) to 0.80 (woCOPD). Adding the quasi-BODE index increased the value to 0.76 for the wCOPD population model and to 0.82 for the woCOPD and all-respondents models.

Table 4 summarizes characteristics of persons grouped by quasi-BODE index scores. For the total study population, the majority had scores of 0–1 (72.3%), with 22.2% having scores of 2–3 and 5.5% having scores of 4 or higher. The distribution was similar among persons aged 65 years or older (0–1: 68.5%; 2–3: 24.9%; ≥4: 6.5%). Very few persons with COPD (5.9%) or stroke (4.6%) had quasi-BODE index scores of 0 or 1. Persons without any chronic conditions of interest (diabetes, cancer, COPD, heart disease, or stroke) comprised approximately one-half of the 0–1 group,

one-third of the 2–3 group, and one-fifth of the ≥4 group. A greater percentage of persons with mothers who lived to age 75 years or over was found in the 0–1 score group (61.8% vs. 53.0% in the ≥4 score group; $P < 0.0001$).

Depression was strongly associated with quasi-BODE index scores. Persons who were highly depressed per the 8-item Center for Epidemiologic Studies Depression Scale questionnaire (rating ≥4) comprised 8.8% of those with a quasi-BODE index score of 0–1, 25.6% of those with a score of 2–3, and 32.6% of those with a score of 4 or higher. Findings were similar when the analysis was limited to those aged 65 years or older (0–1: 7.7%; 2–3: 23.1%; ≥4: 31.4%).

Since we had to impute aspects of smoking history, we limited its use to sensitivity analyses. In models that included smoking history as an additional factor, 26–40 pack-years and 40 or more pack-years were significantly associated with an increased risk of mortality, and the estimated odds ratio for the quasi-BODE index was unchanged in these models.

DISCUSSION

We developed a quasi-BODE index that was strongly predictive of mortality using survey items about chronic respiratory symptoms and physical limitations, BMI, and a simple measure of respiratory function. The index was predictive when used alone and also when used in conjunction with sex, age, and other morbidity information. This health status instrument was predictive not only among persons with COPD but also among older persons without COPD. Percentage of predicted PEF was substituted for percentage of predicted FEV_1 in this quasi-BODE score, allowing a test that can be more practically administered to older adults, especially those with severe physical limitations.

There is strong appeal for a simple multidimensional assessment tool that correlates well with future prognosis. Since its development in 2004, the BODE index has been demonstrated in many studies to be a more accurate predictor of mortality among patients with COPD than lung function alone and also a predictor of severe exacerbations of COPD resulting in hospitalization (46–50). The BODE index is a stronger predictor of survival among COPD patients than are respiratory health status questionnaires such as the Clinical COPD Questionnaire (51) and the St. George Respiratory Questionnaire (52), which do not include objective physical measurements in their assessments. Other investigators have also examined modified BODE instruments with various proxy measures substituted for the 6-minute walk test, including peak oxygen uptake (53), a shuttle walk test (54), and history of COPD exacerbations (50). The advantages of the quasi-BODE index as compared with the original BODE index and these adapted BODE indices are that 1) it can be administered without any form of exercise challenge, 2) the equipment needed to administer a PEF test is much less expensive and easier to use than spirometry to obtain FEV_1 or exercise cycle ergometry to obtain peak oxygen uptake, and 3) it does not require that the patient have a history of COPD. The *C* statistic for the quasi-BODE index among COPD patients without additional factors for demographic characteristics or comorbid conditions (0.70) was within the range of those reported in prospective COPD cohort studies with mortality as an endpoint (0.67–0.75) (7, 50, 53, 55).

A recent study demonstrated that combining the BODE index with certain prognostically significant comorbid conditions improved the index's predictive accuracy for mortality in persons with COPD (56). Our study also demonstrated that several chronic illnesses and symptoms were associated with increased mortality in this broader population, with depression being notable among them. While prior studies have shown simple correlations between the BODE index and depression scores in COPD (57–60), we have demonstrated that depression is an important prognostic determinant of survival in a broader population even after adjustment for the quasi-BODE index and other comorbidity.

Although we cannot find other studies that have applied the modified or original BODE index to a non-COPD population, it is not surprising that this multidimensional health-status assessment tool works as well in the general adult population as it does in persons who report having been diagnosed with COPD. As in the original BODE index, each element in our quasi-BODE index is independently associated with a higher risk of mortality. Very low BMI has long been recognized as a poor prognostic factor in the general population (61), and the physical status measures in the BODE index are similar to characteristics associated with frailty, which is associated with an increased risk of death (9). Percentage of predicted PEF has been shown to be a predictor of survival in adults with diabetes (25) and in older adults in the general population without COPD (10, 18, 24).

Our study was not without limitations. Chronic condition status was based on self-report, which may have resulted in misclassification errors due to recall bias and underreporting or overreporting, with well-defined diseases (e.g., diabetes) having less error. Physical function and mental health assessments were only recorded at 1 time point and were also subject to self-report bias. Subjective assessment of health, however, cannot be easily separated from objective assessments and is an important factor when assessing future survival (62). Multicenter studies of longer duration have demonstrated wide variability in BODE performance among different populations and with different follow-up times (55). Another multicenter study found that the BODE index calibration (the absolute risk predicted by the score as compared with the observed risk in another population) was poor but could be improved by refitting the BODE scores (63). Validation of the quasi-BODE score requires replication of this work in other older adult populations, and its utility needs to be established in direct comparisons with other prognostic tools that have been used in populations with a high prevalence of chronic disease (7, 55, 56).

The HRS is a valuable research resource for studying the experience of the elderly in the United States A recent study that highlighted characteristics of the "oldest old" HRS participants compared those who lived to age 97 years with those who did not in the cohort born between 1900 and 1911. The study demonstrated that exceptionally long-lived participants tended to have fewer chronic conditions (0.85 morbid conditions as compared with 1.30; $P < 0.001$), greater mobility, lower scores on the depression scale (1.55 vs. 2.03; $P = 0.002$), and no history of smoking (72% vs. 56%; $P < 0.001$), although there was a large portion who were old and in poor health.

Among the exceptional survivors, women were found to have a greater number of functional limitations compared with men (2.6 vs. 1.6; $P = 0.005$), and a larger percentage were found to have a BMI less than 18.5 (19% compared with 4.6%; $P = 0.007$). Of interest is that hereditary factors were found to potentially play a role in improved survival: 31.7% of those who were exceptional survivors had a mother who lived to be aged 85 years or older as compared with 23.9% of those who were not ($P = 0.01$), and 21.9% compared with 16.7% had a father who lived to be aged 85 years or older ($P = 0.06$). In our analysis, greater maternal longevity was also associated with reduced risk of mortality.

In conclusion, we have developed a multidimensional health-status instrument based on the BODE index that is a good predictor of mortality but is more practical than the original BODE index because it uses much simpler measures of physical and respiratory function. This tool could potentially be useful in older adult populations with or without COPD, including persons with severe physical limitations. We have also identified

several demographic factors and comorbid conditions that, when assessed along with the BODE index, can serve as a very strong yet efficient prognostic instrument.

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