Index to Predict 5-Year Mortality of Community-Dwelling Adults Aged 65 and Older Using Data from the National Health Interview Survey

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BACKGROUND: Prognostic information is becoming increasingly important for clinical decision-making.

OBJECTIVE: To develop and validate an index to predict 5-year mortality among community-dwelling older adults.

DESIGN AND PARTICIPANTS: A total of 24,115 individuals aged >65 who responded to the 1997-2000 National Health Interview Survey (NHIS) with follow-up through 31 December 2002 from the National Death Index; 16,077 were randomly selected for the development cohort and 8,038 for the validation cohort.

MEASUREMENTS: 39 risk factors (functional measures, illnesses, behaviors, demographics) were included in a multivariable Cox proportional hazards model to determine factors independently associated with mortality. Risk scores were calculated for participants using points derived from the final model's beta coefficients. To evaluate external validity, we compared survival by quintile of risk between the development and validation cohorts.

RESULTS: Seventeen percent of participants had died by the end of the study. The final model included 11 variables: age (1 point for 70-74 up to 7 points for >85); male: 3 points; BMI <25: 2 points; perceived health (good: 1 point, fair/poor: 2 points); emphysema: 2 points; cancer: 2 points; diabetes: 2 points; dependent in instrumental activities of daily living: 2 points; difficulty walking: 3 points; smoker-former: 1 point, smoker-current: 3 points; past year hospitalizations-one: 1 point, >2: 3 points. We observed close agreement between 5-year mortality in the two cohorts; which ranged from 5% in the lowest risk quintile to 50% in the highest risk quintile in the validation cohort.

CONCLUSIONS: This validated mortality index can be used to account for participant life expectancy in analyses using NHIS data.

KEY WORDS: mortality prediction; life expectancy; prevention; older adults.

This abstract was presented in part at the 2009 meeting of the American Geriatrics Society, Chicago, IL.

Received January 26, 2009
Revised June 25, 2009
Accepted July 6, 2009
Published online August 1, 2009

J Gen Intern Med 24(10):1115–22
DOI: 10.1007/s11606-009-1073-y

INTRODUCTION

Age is an important predictor of mortality; however, there is substantial heterogeneity in the health and life expectancy of older adults. As the population ages, prognostic information is becoming increasingly important to clinicians, researchers, and policy makers in making medical decisions.[1] Mortality predictors can be used to target preventive services (e.g., mammography) or to decide whether to offer certain treatments to older adults (e.g., lipid-lowering agents or tight glycemic control), among other clinical decisions.[2]

In 2007, the National Center for Health Statistics (NCHS) publicly released the National Health Interview Survey (NHIS) linked mortality files, which linked 15 years of adult participants with death records from the National Death Index (the central computerized database containing all certified deaths in the US), providing an opportunity to develop a mortality index using the NHIS.[3] The NHIS is the principal source of information on the health of the civilian non-institutionalized population of the US.[3] It has been conducted annually since 1957. The survey collects information on general health status, distribution of acute and chronic illness, functional limitation, access to and use of medical services, and insurance coverage. Researchers and policy makers have frequently used these data to examine receipt of clinical services among US adults.[4–11] The survey includes questions on factors individually associated with mortality (e.g., age, function), but a validated prognostic index of mortality is not available for use with NHIS data.

Investigators have previously developed prognostic indices within segments of the population (e.g., hospitalized elders [12] and nursing home residents [13]). Others have examined the influence of specific comorbid diseases or functional status on mortality [14–16], and one study examined the influence of laboratory measures of subclinical and clinical disease (e.g., fasting glucose level) on 5-year mortality.[17] Only one study examined the influence of several self-reported characteristics (e.g., age, comorbid conditions) on 4-year mortality in a nationally representative sample of US adults aged 50 and older.[18] Using the Health and Retirement Study, Lee et al.

developed a prognostic index that can discriminate high and low risk of 4-year mortality.[18] Although Lee's index is very useful, it cannot be readily adapted for use with the NHIS because some questions are not available (e.g., "Has a doctor ever told you that you have congestive heart failure?"). Moreover, the Lee index predicts 4-year mortality rather than 5-year mortality, and 5 years is the cutoff generally recommended by experts when deciding whether or not to screen older adults for cancer and/or aggressively treat diabetics with insulin.[2, 19]

The purpose of our study was to develop a validated mortality index using NHIS data that could be used to predict 5-year mortality of community-dwelling older US adults. We used Cox proportional hazards models to develop our index rather than the logistic regression as used by Lee et al., since survival methods allow us to utilize the entire observed experience for each respondent regardless of the duration of follow-up. Another advantage is that survival methods allow for better calibration of the influence of risk factors on mortality over time. We hypothesized that our 5-year mortality index would be useful in evaluating the influence of life expectancy on receipt of clinical services (e.g., cancer screening tests). Such an index would be valuable for use with NHIS data as well as other datasets that include the questions asked in NHIS [e.g., the Medical Expenditure Panel Survey (MEPS)]. In addition, and possibly most importantly, with further validation, our index may be helpful to clinicians trying to target preventive services to older adults by life expectancy.

METHODS

The NHIS Linked Mortality files are available for each survey year from 1986 through 2000 with mortality follow-up from the NHIS adult participant's date of interview through 31 December 2002.[3] We restricted our study to survey years where consistent information on health conditions and reported causes of disability were available in the NHIS. The survey, redesigned in 1997, consists of several components, including a Family and Sample Adult Core that remain largely unchanged from year to year. The Sample Adult Core collects detailed health information from one randomly selected adult home at the time of the survey. For this study, we considered all sample adults aged 65 and older who responded to the 1997 through 2000 NHIS (n=25,488). The mean participation rate was 74.0% (range 80.4% in 1997 to 69.6% in 1999).

Mortality information was ascertained from a probabilistic match between NHIS and National Death Index (NDI) death certificate records. Methods of matching correctly identify an estimated 99% of all living NHIS respondents and 97% of those who died.[20] Because 1,154 respondents aged 65 and older had insufficient data to link with the NDI, our sample eligible for analyses included 24,334 respondents. Respondents were assigned a vital status code (0= assumed alive; 1= assumed deceased) based on their status as of 31 December 2002. NCHS provides sampling weights that take into account insufficient identifying data, which are used in mortality analyses to produce nationally representative estimates.

Study Sample

Proxy respondents were not permitted for all survey years included in our study, and the NHIS does not directly ask participants about a history of dementia. However, we further excluded 219 individuals who answered affirmatively to a question about having dementia. Our final sample included 24,115 respondents, representing an estimated 18.9 million community-dwelling US adults aged 65 and older. We randomly selected two-thirds of the respondents to be in the development cohort (n=16,077). We tested the reproducibility and calibration of our model with the remaining one-third or the validation cohort (n=8,038).

Outcome

Our primary outcome of interest was death by 31 December 2002. We measured 5-year mortality from the date of the respondents' interview until death or end of the follow-up period (31 December 2002), whichever came first. Respondents who were alive on 31 December 2002 were considered censored observations.

Factors of Interest

We considered four classes of variables available in NHIS as potential predictors of mortality: demographics, health behaviors, illness burden, and functional status. We considered two demographic variables: sex and age as a categorical variable (65-69, 70-74, 75-79, 80-84, and >85). We chose not to include race/ethnicity or socioeconomic variables in the development of our model since the association of these variables with mortality may be partly due to differences in quality, and we did not want to develop an index that could contribute to health-care disparities. We tested these variables in post-hoc analyses, but neither race/ethnicity nor educational level made it into our final model.

We considered three health behavior variables: smoking status [current, former, never (<100 cigarettes in lifetime)]; physical inactivity (<10 min per week of any activity that causes light sweating or a slight to moderate increase in breathing or heart rate); body mass index-BMI (<25 or 25+).[7] We chose this division for BMI since in separate exploratory analyses no upper BMI cutoff was found to be associated with a statistically significant increased risk of mortality. This is consistent with other studies that have shown that older adults at normal or below normal BMIs have lower survival than those who are overweight or even obese.[21]

We considered 12 measures of function: dependency in at least one activity of daily living (ADL: bathing, dressing, eating, getting in or out of bed or chairs, and using the toilet); dependency in at least one instrumental activity of daily living (IADL: handling household chores, doing necessary business, shopping or getting around for other purposes); any reported difficulty with (1) walking 1/4 mile, (2) walking up ten steps, (3) standing or (4) sitting for 2 h, (5) stooping, (6) reaching above the head, (7) grasping small objects, (8) lifting/carrying 10 pounds, (9) pushing/pulling large objects, or (10) going out to do things like shopping.

The category of illness burden considered 24 variables, including perceived health (excellent to poor), emotional health (6 variables), comorbidities (14 diseases), or hospitalizations

(0, 1, >2), clinic visits (0-1, 2-5, or >6), and/or emergency room visits (0, 1, >2) in the past year. Emotional health was defined by the questions, "During the past 30 days how much of the time did you feel:" (1) so sad that nothing could cheer you up, (2) nervous, (3) restless, (4) hopeless, (5) that everything was an effort, or (6) worthless. We included these variables since depression has been shown to be associated with mortality and the NHIS does not ask about depression specifically.[22] Respondents were asked whether a doctor told them they had: (1) hypertension, (2) coronary heart disease, (3) angina, (4) heart attack, (5) stroke, (6) other heart conditions, (7) emphysema/chronic bronchitis (we combined these variables into one for a diagnosis of chronic obstructive pulmonary disease or COPD), (8) asthma, (9) gastric/duodenal ulcer, (10) diabetes (including borderline), (11) cancer (excluding non-melanomatous skin cancer), (12) failing kidneys, (13) liver condition, or (14) joint pain/stiffness in the past 30 days.

Statistical Analysis

We used Cox proportional hazards models to develop our index. Initially, we examined the bivariable association between each of the 41 risk factors and mortality within the development cohort. In addition, we tested whether any of the risk factors were correlated at greater than 0.70. The ability to carry items greater than 10 pounds and the ability to push large objects were correlated at 0.72; we only included the former item in our multivariable analyses since it had a stronger bivariable association with mortality. Joint pain was not a significant predictor of mortality in bivariable analyses and therefore was not included in our multivariable model. The 39 remaining variables were considered in our initial multivariable model. We then used backward elimination to identify independent predictors of mortality. Because of our large sample size, and since we wanted to create a parsimonious and usable index, we set the p-value for retention in our model to $p<0.0001$.

The NHIS uses a complex sampling design involving stratification, clustering, and multistage sampling. Therefore, we used SAS-callable SUDAAN software (version 9.0) for all analyses. Results presented are weighted to reflect US population estimates and to adjust for non-response and mortality non-linkage; we present sample sizes (n) whenever possible.

To determine mortality risk, we developed a point-based risk scoring system. Points were assigned to each risk factor in the final model by dividing each beta coefficient by the lowest beta coefficient in the model and rounding to the nearest integer. A risk score was assigned to each participant by summing the points for each risk factor present. To test the external validity and calibration of the model, we applied the model to compute a risk score for each respondent in the validation cohort. For each cohort, we stratified the risk score into quintiles and calculated the 5-year mortality and the annual mortality rates. To further assess discrimination of the model, we also calculated these estimates for finer gradations of the raw point scores. Finally, we examined 5-year mortality by age group to examine whether our prognostic model outperformed age alone as a predictor of mortality.

Since age is an important predictor of mortality, we also wanted to examine the discrimination of the model excluding age. For this analysis, we dropped age as a predictor in our risk score, and we combined the samples of the development and validation cohorts to maximize power. We demonstrated performance of our model excluding age by graphing risk score by probability of 5-year mortality for three different age groups (65-69, 70-79, and >80).

Currently, SUDAAN software does not have the capability to compute a c-statistic from a Cox model to assess model discrimination. Therefore, we used a SAS macro designed by Harrell et al. to calculate a c-index for censored data.[23] This method does not account for the complex sampling design or weighting of our sample. We also assessed the model's calibration by examining the relationship between the expected and observed survival values using survival estimates from the development and validation cohorts for the most common covariate patterns (at least five or more individuals with the same covariate pattern).[24] We fit a least-squares regression with the validation set estimate as the dependent variable and the development set estimates as the independent variable. We report the beta coefficient (which represents the slope of the line of the plot between the expected and observed survival values) and the Pearson correlation. If a model is well-calibrated, the beta coefficient should approximate one, and the estimated survival probabilities in each cohort should be highly correlated.

RESULTS

Of the 16,077 participants in the development cohort, 27% were aged 80 or older; 62% were female, and 85% were non-Hispanic white. With respect to function, 18% were dependent in at least one IADL or ADL. Overall, 17% (n=4,061) had died by 31 December 2002. The characteristics of the development and validation cohorts were similar so we only present the development cohort's characteristics (Table 1). There were 47,468 person-years of observation in the development cohort and 24,733 person-years of observation in the validation cohort.

In bivariable analyses, advancing age was the risk factor most strongly associated with mortality. IADL and ADL dependency, fair/poor perceived health, and two or more hospitalizations were also strongly associated with mortality. Table 1 presents the characteristics of the respondents in the development cohort and the unadjusted hazard ratios of mortality.

The final multivariable model consisted of 11 variables with p-values significant at <0.0001, including: 2 demographic variables (sex and age), 2 behavior-related variables (smoking status and BMI), 5 clinical variables (COPD, diabetes, cancer, perceived health, and hospitalizations), and 2 functional measures (IADL dependency and difficulty walking 1/4 mile). Table 2 presents the adjusted hazard ratios from the model and the points assigned to each factor derived from its beta coefficients. The wording of NHIS questions used can be found in the Appendix.

Our model demonstrates excellent calibration with virtually identical mortality rates in the development and validation cohorts for each risk quintile (Table 3). Our model also demonstrates strong discrimination. Five-year mortality ranges from 6% in the lowest risk quintile to 52% in the highest risk quintile in the development cohort and from 5% in the lowest risk quintile to 50% in the highest risk quintile in the validation cohort. Table 3 also gives the rate of death per

Table 1. Demographic and Health Status Characteristics of the Development Cohort (n=16,077) and Unadjusted Mortality Hazard Ratios

		Weighted % with characteristic	Hazard ratio (95% confidence interval)
Age			
	85+	10.4	5.0 (4.4-5.7)
	80-84	14.6	3.3 (2.9-3.7)
	75-79	21.9	1.9 (1.7-2.2)
	70-74	26.6	1.4 (1.2-1.6)
	65-69	26.6	1.0
Men		37.9	1.4 (1.3-1.6)
Smoking status			
	Current	11.5	1.7 (1.5-1.9)
	Former	38.1	1.4 (1.3-1.5)
	Never (<100 cigarettes in lifetime)	50.4	1.0
Body mass index <25 kg/m^2		41.5	1.4 (1.3-1.6)
Physical inactivity	Less than 10 min per week of activity that causes slight to moderate increase in breathing or heart rate	12.9	2.6 (2.1-3.1)
Perceived health			
	Excellent/very good	40.2	1.0
	Good	34.4	1.6 (1.5-1.9)
	Fair/poor	25.4	3.3 (2.9-3.7)
Functional status			
	Dependent in at least 1 IADL*	13.0	3.4 (3.1-3.7)
	Dependent in at least 1 ADL*	4.9	4.0 (3.5-4.5)
	Any difficulty walking a 1/4 mile or 3 blocks	42.1	3.2 (2.9-3.4)
	Any difficulty walking up 10 steps	34.4	2.7 (2.5-3.0)
	Any difficulty standing on your feet for 2 h	17.6	2.5 (2.3-2.8)
	Any difficulty sitting for 2 h	17.6	1.5 (1.3-1.6)
	Any difficulty stooping/bending/kneeling	48.1	2.0 (1.9-2.2)
	Any difficulty reaching up over your head	19.8	2.0 (1.8-2.2)
	Any difficulty using fingers to grasp small objects	19.8	1.7 (1.6-1.9)
	Any difficulty lifting or carrying up to 10 pounds	28.9	2.5 (2.2-2.7)
	Any difficulty pushing/pulling large objects	37.9	2.4 (2.2-2.6)
	Any difficulty going out to things like shopping	24.9	3.0 (2.8-3.3)
Emotional health	During the past 30 days, how often did you feel at least a little of the time:		
	So sad that nothing could cheer you	26.6	1.5 (1.4-1.7)
	Nervous	30.5	1.2 (1.1-1.4)
	Restless or fidgety	28.5	1.4 (1.2-1.5)
	Hopeless	29.9	1.9 (1.7-2.1)
	That everything was an effort	21.0	1.8 (1.6-2.0)
	Worthless	8.9	1.8 (1.6-2.0)
Comorbid conditions			
	Hypertension	51.7	1.3 (1.2-1.4)
	Coronary heart disease	11.7	1.7 (1.5-1.9)
	Angina	9.1	1.5 (1.3-1.8)
	Heart attack	11.3	2.0 (1.8-2.2)
	Any other heart condition or heart disease	17.1	1.6 (1.4-1.8)
	Stroke	8.2	2.2 (1.9-2.5)
	Chronic obstructive pulmonary disease	5.3	2.8 (2.4-3.3)
	Asthma	8.0	1.4 (1.2-1.7)
	Stomach, duodenal, or peptic ulcer	13.9	1.3 (1.1-1.4)
	Cancer (excluding non-melanomatous skin cancer)	14.5	1.7 (1.6-2.0)
	Diabetes (including borderline diabetes)	15.0	1.7 (1.5-1.9)
	Weak or failing kidneys	3.1	2.9 (2.4-3.5)
	Liver condition	1.2	2.8 (2.1-3.7)
	Joint pain or stiffness in the past 30 days	51.0	1.1 (1.0-1.2)
Overnight hospitalizations in past year	None	81.9	1.0
	One	12.7	1.8 (1.6-2.0)
	Two or more	5.4	3.2 (2.8-3.7)
Emergency room visits			
	None	77.8	1.0
	One	14.8	1.5 (1.3-1.7)
	Two or more	7.4	2.4 (2.1-2.7)
Clinic visits			
	0-1	19.1	1.0
	2-5	55.4	1.4 (1.2-1.6)
	6+	25.4	2.6 (2.2-3.1)

**Abbreviations: ADL, Activity of daily living; IADL, instrumental activity of daily living; COPD, chronic obstructive pulmonary disease*

Table 2. Adjusted Cox Proportional Hazard Ratios (HR) for Mortality and Points Assigned to Each Risk Factor

Demographics		Adjusted HR (95% CI)*	Points
Age, years			
	65-69	1.0	0
	70-74	1.3 (1.1-1.5)	1
	75-79	1.7 (1.5-2.0)	3
	80-84	2.9 (2.5-3.3)	5
	85+	4.0 (3.4-4.6)	7
Male sex		1.7 (1.6-1.9)	3
Smoking status			
	Never	1.0	0
	Former	1.3 (1.2-1.5)	1
	Current	2.0 (1.7-2.3)	3
Body mass index <25 kg/m^2		1.4 (1.3-1.5)	2
Comorbid conditions			
	COPD†	1.5 (1.3-1.8)	2
	Diabetes mellitus	1.4 (1.3-1.6)	2
	Cancer	1.4 (1.2-1.5)	2
Overnight hospitalizations in past year			
	None	1.0	0
	One	1.3 (1.1-1.4)	1
	Two or more	1.7 (1.4-2.0)	3
Perceived health			
	Excellent/very good	1.0	0
	Good	1.2 (1.1-1.4)	1
	Fair/poor	1.6 (1.4-1.8)	2
Functional measures			
	Dependent in at least one IADL†	1.6 (1.5-1.8)	2
	Difficulty walking several blocks	1.8 (1.6-2.0)	3

**Each hazard ratio is adjusted for the other risk factors presented in the table*

† Abbreviations: COPD, chronic obstructive pulmonary disease; IADL, instrumental activity of daily living

person-year by risk quintile and by point score to further demonstrate the model's strong discrimination. Figure 1 demonstrates the cumulative mortality curves for each risk quintile in the validation cohort. To demonstrate our model's predictive abilities beyond age alone, Figure 2 excludes points assigned to age and demonstrates strong discrimination between 5-year survival estimates within the three age groups by point score excluding the points assigned to age.

In further calibration analyses, we found that the c-index of the model was 0.75. We also found that the beta coefficient from the linear regression of estimated survival probabilities was 0.93 and the correlation was 0.98, indicating excellent calibration of the model.

DISCUSSION

We developed and validated a prognostic index that can be used to predict 5-year mortality for community-dwelling US adults. Our index shows excellent calibration as demonstrated by similar mortality rates in the development and validation cohorts and strong discrimination as demonstrated by in-

Table 3. Validation of the Index: 5-Year Mortality in the Development and Validation Cohorts by Risk Group

	Development			Validation		
	n	Mortality 5-year % (95% confidence interval)	Person-year rate (%)	n	Mortality 5-year % (95% confidence interval)	Person-year rate (%)
Quintile of risk						
1	2,980	6 (5-8)	1	1,491	5 (4-7)	1
2	2,438	10 (8-12)	2	1,252	10 (8-13)	2
3	3,305	14 (12-16)	3	1,771	17 (15-20)	3
4	2,557	27 (25-29)	6	1,379	31 (28-35)	7
5	2,604	52 (49-54)	13	1,444	50 (47-54)	13
Point score						
0-1	579	2 (1-4)	0.6	301	3 (1-6)	0.7
2-3	1,368	7 (5-10)	1.2	698	5 (3-8)	0.9
4-5	2,258	8 (6-9)	1.5	1,078	8 (6-10)	1.4
6-7	2,348	11 (10-14)	2	1,306	12 (10-15)	2
8-9	2,170	15 (14-17)	3	1,131	19 (16-23)	4
10-11	1,805	25 (23-28)	6	944	29 (25-33)	6
12-13	1,388	35 (32-38)	8	758	37 (32-42)	8
14-15	944	47 (32-42)	12	553	49 (43-55)	11
16-17	586	58 (52-63)	16	322	55 (48-62)	16
18+	438	71 (65-77)	23	246	62 (54-70)	19

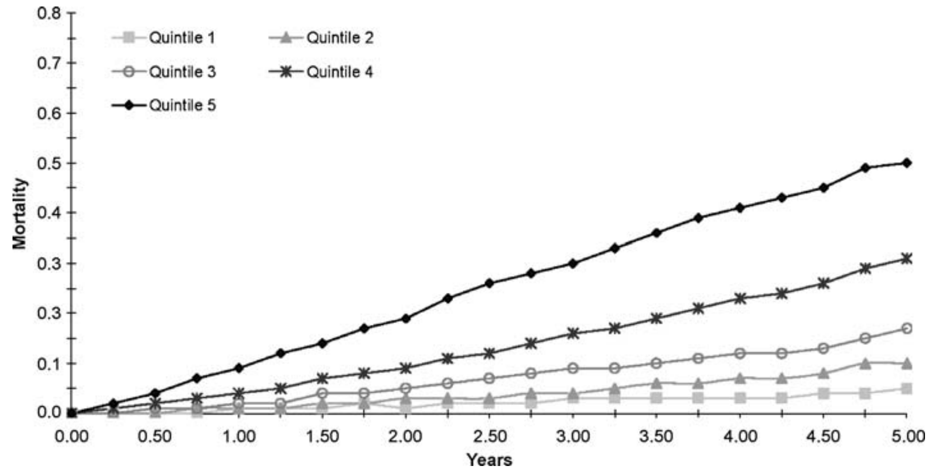

Figure 1. Mortality curves by score from validation cohort. This graph shows actual cumulative mortality based on quintile of risk using our predictive model and the validation cohort.

creasing risk of mortality by point score. Specifically, our index can be used to address questions related to life expectancy when using NHIS or related datasets such as MEPS. After validation in the clinical setting, the index may also be used by clinicians to estimate patient's 5-year mortality. This is important since increasingly clinicians are being asked to make decisions on disease prevention and treatment based on patient life expectancy.

We and others have previously performed studies using NHIS to examine receipt of preventive health measures (e.g., cancer screening, exercise counseling, immunizations) among older adults using health status as a proxy for life expectancy.[4–11] We did this because there was no validated index of mortality available for use with NHIS at that time. The index developed in this paper provides opportunity for health services researchers to examine receipt of screening and other health services by life expectancy among US adults using NHIS.

One of the potential clinical applications of our index may be in helping clinicians decide which women aged 80 and older to screen with mammography. There are no data from clinical trials to help guide this decision, and guidelines recommend that clinicians consider patient life expectancy.[19] Based on life expectancy tables, the average life expectancy of a woman aged 80 is 9.8 years [25]; however, there is significant variation among individual women. Several studies have shown that clinicians are poor predictors of patient life expectancy [26,27] and that prediction models can help improve these estimates.[28] According to our index, a woman aged 80 with no other risk factors would score 5 points and would have only an 8% probability of 5-year mortality; mammography screening would likely be appropriate for this woman. Meanwhile, an 80-year-old female who is a former smoker with COPD and diabetes, who needs help with shopping, has difficulty walking a quarter mile, and perceives herself to be in fair health, would score 17 points. This hypothetical woman would have a more than 50% probability of dying within 5 years, and it would likely be appropriate to counsel her about stopping screening. Other examples where our index might be useful may be in helping clinicians decide which of their older patients may benefit from tight glycemic control, from joint replacement surgery, or repair of an abdominal aortic aneurysm, and which are unlikely to benefit due to shortened life expectancy.[2]

As previously mentioned, Lee et al. developed a tool to be used by researchers and/or clinicians to estimate individuals' 4-year mortality.[18] Like our index, the Lee et al. index includes age, sex, BMI, history of diabetes and cancer, and difficulty with walking as risk factors. The Lee index also includes lung disease, smoking status, and difficulty managing money, similar to items included in our index, but worded differently. Three factors in the Lee index were not included in our index: difficulty with pulling and pushing, difficulty with bathing, and history of congestive heart failure. The former two were assessed in NHIS, but did not make it into our final model, whereas congestive heart failure is not assessed specifically in NHIS. Our index additionally includes perceived health and hospitalizations in the past year, which are important independent predic-

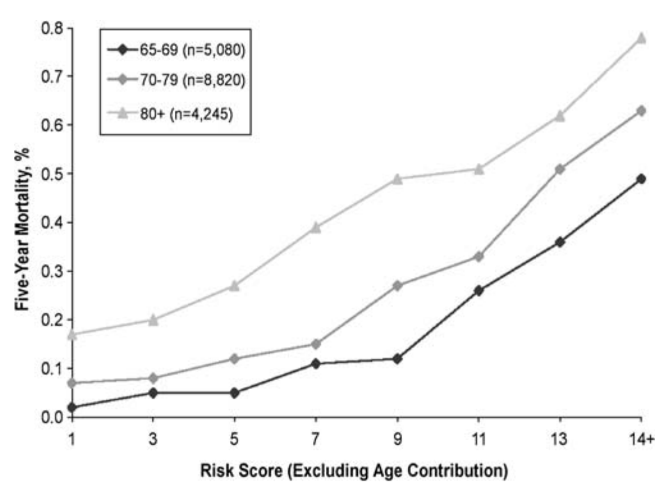

Figure 2. Five-year mortality by risk score in differing age groups. This graph shows mortality within age groups (65-69, 70-79, 80+) by risk score calculated using our predictive model but excluding the points contributed by age.

tors of mortality.[29,30] Besides its applicability to NHIS, a large nationally representative survey of US adults administered annually, our index predicts 5-year mortality, which may be more clinically useful, and was developed using survival methods rather than logistic regression.

Our index has notable limitations. First, it was developed for community-dwelling adults who can provide self-report, and therefore cannot be generalized to nursing home residents or those with dementia. However, another mortality index has been developed specifically for this group.[12] Second, follow-up is currently available only through 31 December 2002. Future studies can evaluate the index prospectively as additional years of NHIS mortality data become available. Finally, the index has yet to be validated in a clinical setting.

In summary, we have developed a mortality index to predict 5-year mortality among community-dwelling older adults. This index may be valuable to researchers using NHIS or MEPS to address important health service questions. Importantly, it may also be useful to clinicians who would like to target certain clinical services to older adults based on life expectancy.

Acknowledgements: *We would like to thank Long Ngo, PhD, from the Division of General Medicine and Primary Care, Department of Medicine, at Beth Israel Deaconess Medical Center and Harvard Medical School for his help in discussions of the analysis plan. Dr. Mara Schonberg was supported by a National Institute on Aging K23 award (K23AG028584).*

Conflict of Interest Statement: *None disclosed.*

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REFERENCES

1. US Census Bureau. Current Population Survey, July 2002. Washington, DC: US. Census Bureau; 2002. Accessed at www.census.gov in July 13, 2009.
2. **Huang ES, Zhang Q, Gandra N, Chin MH, Meltzer DO.** The effect of comorbid illness and functional status on the expected benefits of intensive glucose control in older patients with type 2 diabetes: a decision analysis. Ann Intern Med. 2008;141:11–9.
3. National Health Interview Survey. National Center for Health Statistics. [Public use data file and documentation]. Available at: http://www.cdc.gov/nchs/nhis. Accessed July 13, 2009.
4. **Mor V, Pacala JT, Rakowski W.** Mammography for older women: who uses, who benefits. J Gerontol. 1992;47 Spec No:43–9.
5. **Schonberg MA, McCarthy EP, Davis RB, Phillips RS, Hamel MB.** Breast cancer screening in women aged 80 and older: results from a national survey. J Am Geriatr Soc. 2004;52(10):1688–95.
6. **Sirovich BE, Welch HG.** Cervical cancer screening among women without a cervix. JAMA. 2004;291(24):2990–3.
7. **Schonberg MA, Marcantonio ER, Wee CC.** Receipt of exercise counseling among older women. J Am Geriatr Soc. 2006;54(4):619–26.
8. **Wee CC, McCarthy EP, Phillips RS.** Factors associated with colon cancer screening: the role of patient factors and physician counseling. Prev Med. 2005;41(1):23–9.
9. **Ross LE, Coates RJ, Breen N, Uhler RJ, Potosky AL, Blackman D.** Prostate-specific antigen test use reported in the 2000 National Health Interview Survey. Prev Med. 2004;38(6):732–44.
10. **Kapp JM, LeMaster JW, Zweig SC, Mehr DR.** Physician recommendations for mammography in women aged 70 and older. J Am Geriatr Soc. 2008;2100-2106.
11. **Meissner HI, Tiro JA, Haggstrom D, Lu-Yao G, Breen N.** Does patient health and hysterectomy status influence cervical cancer screening in older women? J Gen Intern Med. 2008;23(11):1822–8.
12. **Inouye SK, Peduzzi PN, Robison JT, Hughes JS, Horwitz RI, Concato J.** Importance of functional measures in predicting mortality among older hospitalized patients. JAMA. 1998;279(15):1187–93.
13. **Mitchell SL, Kiely DK, Hamel MB, Park PS, Morris JN, Fries BE.** Estimating prognosis for nursing home residents with advanced dementia. JAMA. 2004;291:2734–40.
14. **Carey EC, Walter LC, Lindquist K, Covinsky KE.** Development and validation of a functional morbidity index to predict mortality in community-dwelling elders. J Gen Intern Med. 2004;19(10):1027–33.
15. **Cappola AR, Fried LP, Arnold AM, et al.** Thyroid status, cardiovascular risk, and mortality in older adults. JAMA. 2006;295(9):1033–41.
16. **Saliba D, Elliott M, Rubenstein LZ, et al.** The Vulnerable Elders Survey: a tool for identifying vulnerable older people in the community. J Am Geriatr Soc. 2001;49(12):1691–9.
17. **Fried LP, Elliott M, Rubenstein LZ, et al.** Risk factors for 5-year mortality in older adults: the Cardiovascular Health Study. JAMA. 1998;279(8):585–92.
18. **Lee SJ, Lindquist K, Segal MR, Covinsky KE.** Development and validation of a prognostic index for 4-year mortality in older adults. JAMA. 2006;295(7):801–8.
19. **Walter LC, Covinsky KE.** Cancer screening in elderly patients: a framework for individualized decision making. JAMA. 2001;285(21):2750–6.
20. **Horm J.** Multiple causes of death for the national health interview survey. Record linkage techniques—Proceedings of an International Workshop and Exposition, 1997: National Research Council, Washington D.C., 1997.
21. **Janssen I, Mark AE.** Elevated body mass index and mortality risk in the elderly. Obesity Reviews. 2006;8:41–59.
22. **Schulz R, Beach SR, Ives DG, Martire LM, Ariyo AA, Krop WJ.** Association between depression and mortality in older adults: the Cardiovascular Health Study. Arch Intern Med. 2000;160(12):1761–8.
23. **Harrell FE Jr, Lee KL, Mark DB.** Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med. 1996;15(4):361–87.
24. **Hosmer DW Jr, Lemeshow S.** Applied Logistic Regression. 2nd ed. New York: John Wiley & Sons, Inc.; 2000:282.
25. **Arias E.** United States Life Tables, 2004. National Vital Statistics Reports. 2007;56:13.
26. **Walz J, Gallina A, Perrotte P, et al.** Clinicians are poor raters of life-expectancy before radical prostatectomy or definitive radiotherapy for localized prostate cancer. BJU Int. 2007;100(6):1254–8.
27. **Chow E, Davis L, Panzarella T, et al.** Accuracy of survival prediction by palliative radiation oncologists. Int J Radiat Oncol Biol Phys. 2005;61(3):870–3.
28. **Kong DF, Lee KL, Harrell FE, et al.** Clinical experience and predicting survival in coronary disease. Arch Intern Med. 1989;149(5):1177–81.
29. **Kawada T.** Self-rated health and life prognosis. Arch Med Res. 2003;34(4):343–7.
30. **Setoguchi S, Stevenson LW, Schneeweiss S.** Repeated hospitalizations predict mortality in the community population with heart failure. Am Heart J. 2007;154(2):260–6.

APPENDIX

Five-year Mortality Index for Adults Aged 65 and Older.

1. Age:
   - 65-69: 0 points
   - 70-74: 1 point
   - 75-79: 3 points
   - 80-84: 5 points
   - 85+: 7 points

2. Sex: Female: 0 points Male: 3 points

3. Weight: BMI: <25 2 points
   Height:
   703 x (weight in pounds/height in inches^2)
   Body Mass Index (BMI)=________

4. Would you say your health in general is:
   - Excellent/Very Good: 0 points
   - Good: 1 point
   - Fair/Poor: 2 points

5. Have you ever been told by a doctor or health professional that you had:
   a. Emphysema/Chronic Bronchitis? No: 0 points Yes: 2 points
   b. A cancer? (do not include skin cancer unless it was melanoma)
   No: 0 points Yes: 2 points
   c. Diabetes (include borderline diabetes)
   No: 0 points Yes: 2 points

6. Because of a physical, mental, or emotional problem, do you need the help of other persons in handling routine needs such as everyday household chores, doing necessary business, shopping, or getting around for other purposes?
   No: 0 points Yes: 2 points

7. By yourself, and without using any special equipment, how difficult is it for you to walk a quarter of a mile-about 3 city blocks?
   a. Not at all difficult: 0 points
   b. A little difficult to very difficult : 3 points
   c. Can’t do at all/do not do: 3 points

8. Which best describes your cigarette use?
   a. Never smoked (Less than 100 cigarettes in your entire life): 0 points
   b. Former smoker: 1 point
   c. Current smoker (smoke some days or every day): 3 points

9. During the past 12 months, how many times were you hospitalized overnight?
   - None: 0 points
   - Once: 1 point
   - Twice or more: 3 points