Mortality Predictive Indexes for the Community-Dwelling Elderly US Population

Zi Zhang, MD[1], Dawei Xie, PhD[1], Jibby E. Kurichi, MPH[1], Joel Streim, MD[2], Guangyu Zhang, PhD[3], and Margaret G. Stineman, MD[1,4]

[1]Department of Biostatistics and Epidemiology, Center for Clinical Epidemiology and Biostatistics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA; [2]Geriatric Psychiatry Section, Department of Psychiatry, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania and VISN 4 Mental Illness Research Education and Clinical Center, Philadelphia Veterans Affairs Medical Center, Philadelphia, Pennsylvania, USA; [3]Department of Epidemiology and Biostatistics, University of Maryland, College Park, Maryland, USA; [4]Department of Physical Medicine and Rehabilitation, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.

BACKGROUND: Few predictive indexes for long-term mortality have been developed for community-dwelling elderly populations. Parsimonious predictive indexes are important decision-making tools for clinicians, policy makers, and epidemiologists.

OBJECTIVE: To develop 1-, 5-, and 10-year mortality predictive indexes for nationally representative community-dwelling elderly people.

DESIGN: Cohort study.

SETTING: The Second Longitudinal Study of Aging (LSOA II).

PARTICIPANTS: Nationally representative civilian community-dwelling persons at least 70 years old. We randomly selected 60% of the sample for prediction development and used the remaining 40% for validation.

MAIN MEASURES: Sociodemographics, impairments, and medical diagnoses were collected from the LSOA II baseline interviews. Instrumental activities of daily living (IADLs) stages were derived to measure functional status. All-cause mortality was obtained from the LSOA II Linked Mortality Public-use File.

RESULTS: The analyses included 7,373 sample persons with complete data, among which mortality rates were 3.7%, 23.3%, and 49.8% for 1, 5, and 10 years, respectively. Four, eight, and ten predictors were identified for 1-, 5-, and 10-year mortality, respectively, in multiple logistic regression models to create three predictive indexes. Age, sex, coronary artery disease, and IADL stages were the most essential predictors for all three indexes. *C*-statistics of the three indexes were 0.72, 0.74, and 0.75 in the development cohort and 0.72, 0.72, and 0.74 in the validation cohort for 1-, 5-, and 10-year mortality, respectively. Five risk groups were defined based on the scores.

CONCLUSIONS: The 1-, 5-, and 10-year mortality indexes include parsimonious predictor sets maximizing ease of mortality prediction in community settings. Thus, they may provide valuable information for prognosis of elderly patients and guide the comparison of alternative interventions. Including IADL stage as a predictor yields simplified mortality prediction when detailed disease information is not available.

KEY WORDS: mortality; prediction; score system; community; instrumental activities of daily living.
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Clinical prediction rules with better precision and parsimonious predictor sets making them easily and practically implemented in community settings can help us better serve the health needs of elderly people. Such prediction rules are research-based tools that quantify the contributions of relevant patient characteristics to provide numeric indexes in ways that assist with clinical decision-making.[1–3] The process of developing clinical prediction rules includes identifying a parsimonious set of the most essential predictors from patients' characteristics to estimate the probability of specific outcomes.[1–3]

Mortality prediction is particularly important in individualizing care in elderly populations which have great diversity of chronic conditions, functional limitations, and social challenges that can impact health, quality of life, and the benefits and risks of medical interventions. However, most published clinical prediction rules focus on short-term mortality in patients with specific diseases,[4–6] with few forecasting intermediate-term mortality in community-dwelling elderly populations.[7–10] A newly published systematic review identified 16 indexes that predicted mortality from 6 months to 5 years for older adults in a variety of clinical settings,[11] but no long-term mortality index has been developed. The aim of our study is to develop three parsimonious clinical prediction indexes for 1-, 5-, and 10-

year all-cause mortality among community-dwelling elderly people based on sociodemographics, impairments, associated morbidity, and activity limitations. The application of these three parsimonious clinical prediction indexes can assist clinicians in determining patient prognosis and help policy makers and epidemiologists monitor survival in older populations.

METHODS

Data Source

We used prospectively collected data from The Second Longitudinal Study of Aging (LSOA II).[12] The Second Supplement on Aging (SOA II), conducted in conjunction with the 1994 National Health Interview Survey (NHIS), served as baseline for the study. LSOA II is composed of a nationally representative sample of 9,447 civilian non-institutionalized sample persons (SPs) 70 years of age and over at the time of their SOA II interview.[13, 14] Baseline data from the SOA II were merged with the disability supplement follow-back of the 1994 National Health Interview Survey (NHIS-D), which added supplemental details for the subset with disabilities. The overall response rate to the LSOA II was 87.4%.[14] Information was collected mainly by self-report; 19.0% of the interviews were answered by proxy. Detailed interviewer instructions and questions are available at the Centers for Disease Control and Prevention (CDC) website.[15] This study was approved by the Institutional Review Board of the University of Pennsylvania.

Outcomes

The outcomes for analyses were 1-, 5-, and 10-year all-cause mortality. The updated LSOA II Linked Mortality Public-use File provided mortality follow-up data from the LSOA II baseline interview date through December 31, 2006.[16] This allowed us to assess 10-12 year mortality linking the follow-up mortality data with baseline interviews conducted in 1994–1996.

Predictors

When choosing candidate predictors for the predictive models, we considered clinical relevance and generalizability of the variables across different populations. Predictors were expressed in categories rather than as continuous measures to ease calculations, thus enhancing practical applications of the index. We categorized age as ≥70–<75, ≥75–<80, ≥80–<85, and ≥85 years, gender as female and male, race as white, and black/African American, and other. Educational level was dichotomized based on whether or not the SP graduated from high school. We grouped marital status as married and unmarried. Perceived health status was reported as excellent, very good, good, fair, or poor. Diagnoses were captured by asking whether a doctor had ever said that the SP had various illnesses. Illnesses were categorized into the following conditions: hypertension, diabetes, cancer of any kind, chronic bronchitis or emphysema, asthma, coronary artery disease, other heart disease, stroke, and arthritis. Additionally, SPs were asked whether they had major depression lasting two or more weeks in the past 12 months.

To capture impairments, the LSOA II asked whether SPs have blindness in both eyes and deafness in both ears. Individuals with vision from one eye and hearing from one ear may maintain normal lives. SPs were further asked if they ever had a broken hip or fallen in the past 12 months. Proxy use was recorded as yes versus no.

We derived instrumental activities of daily living (IADLs) stages to measure functional manifestations of elderly community-dwellers' cognitive and physical impairments,[17] which reflect functional hierarchies consistent with theories of development, loss, recovery, and models and measures of disability.[18–20] IADLs, referred to as "domestic life" activities, measure the tasks people must be able to perform if they are to care for themselves in the community.[21] The LSOA II asked whether SPs had difficulties performing any IADLs including using the telephone, managing money, doing light housework, preparing meals, shopping, and doing heavy housework.[22] Status on each IADL was rated as no difficulty, some difficulty, a lot of difficulty, and unable. IADL stages were developed by observing item responses in the LSOA II baseline data. Based on the hierarchical structure of the IADL activities,[18, 23] the IADL stages organize patterns of activity limitation into thresholds, which express the retained ability to perform activities with decreasing complexity as severity of stage increases. We summarize IADL stage assignment in Fig. 1. Additionally, the associations between IADL stages and SPs' sociodemographics, impairments, and associated morbidity are shown in online Table 1 (available online).

Analysis

The primary analysis was a complete-case analysis. We randomly selected 60% of the sample to develop the prediction score system, and used the remaining 40% as a validation cohort.[2, 24] We developed three separate multiple regression models for 1-, 5-, and 10-year mortality in three steps:[25] (1) predictor selection and predictive model development; (2) predictive index con-

Ordered IADL items	1 Using telephone	2 Managing money	3 Preparing meals	4 Doing light housework	5 Shopping	6 Doing heavy housework
No difficulty	☐	☐	☐	☐	☐	☐
Some or a lot of difficulty	☐	☐	☐	☐	☐	☐
Completely unable	☐	☐	☐	☐	☐	☐

IADL stage		
No limitations	0.	Has no difficulty in any IADL items.
Mild limitations	I.	Has no difficulty in IADL items 1, 2, 3, and 4.
Moderate limitations	II.	Has no difficulty in IADL items 1 and 2.
Severe limitations	III.	Does not meet any criteria defined above and below.
Complete limitations	IV.	Completely unable to perform any IADL items.

***Instructions:**
First, check the box indicating the difficulty level for each IADL activity from 1 through 6.
Next, assign IADL stage reading from 0 down through IV.

Figure 1. IADL stage assignment*.

struction; and (3) internal validation. Specific details are provided below.

Predictor Selection and Predictive Model Development

We first evaluated the univariate associations between each categorical predictor and 1-, 5-, and 10-year mortality separately in the development cohort using Chi-square tests. Predictors with $p<0.20$ were entered into the three multiple logistic regression models for 1-, 5-, and 10-year mortality separately. Then, manual backward selections were performed until p-values for all predictors were< 0.05 in the three final models.

Predictive Index Construction

We constructed three separate predictive indexes for 1-, 5-, and 10-year mortality from the three final models. We assigned points to each predictor by dividing each β-coefficient in the final logistic regression models by the lowest significant β-coefficient and rounding up to the nearest integer. A 0 was assigned to a non-significant β-coefficient. A risk score was established for each SP as the sum of points for all predictors present.[26]

Internal Validation

We applied the three mortality indexes to the validation cohort and calculated the proportion of SPs who died at each sum score. We calculated model discrimination and calibration to assess model predictive accuracy in both the development and validation cohorts. Model discrimination was assessed by calculating the *c*-statistics which are the areas under the receiver operating characteristic curves.[27] Model calibration was assessed by the Hosmer-Lemeshow statistic to test whether the predicted probabilities agree with the actual outcomes. To avoid over-fitting, we removed predictors if removal increased *c*-statistics in the validation cohorts.

Sensitivity Analysis

We performed sensitivity analyses to assess robustness of findings from the complete-case analysis. To determine if exclusion of SPs with missing data introduced bias, we applied multiple imputation procedures by using the SAS callable IVEware software 0.2 (University of Michigan's Survey Research Center, Ann Arbor).[28] Five multiple imputation datasets were generated. We then repeated all model development steps using imputed data.

We accounted for the multistage sample design of the LSOA II, including clustering, sample weights, and stratification in all analyses to obtain the correct point and variance estimates. We reported unweighted sample sizes and weighted proportions. All analyses (except for multiple imputation as noted above) were performed with Stata 11.0 (Stata Corp, College Station, Texas). The final tests of significance used a 2-sided $p<0.05$, except for Hosmer-Lemeshow statistics with $p<0.10$ indicating model fit was inadequate.

RESULTS

SPs' Characteristics

Of the 9,447 SPs in the LSOA II, 7,373 had complete data (78.0%) and were included, among which 3.7%, 23.3%, and 49.8% died within 1, 5, and 10 years, respectively. The development cohort consisted of 4,434 SPs, of whom 3.3%, 22.8%, and 49.5% died within 1, 5, and 10 years, respectively. The validation cohort consisted of 2,939 SPs, of whom 4.1%, 24.0%, and 50.3% died within 1, 5, and 10 years, respectively. Table 1 describes SPs' characteristics in the development and validation cohorts.

Table 1. Sample Persons' Characteristics

Characteristics	Total	Development	Validation
No. (weighted %)	N=7373	N=4434	N=2939
Age			
≥70–<75	3607(49.5)	2183(49.7)	1424(49.3)
≥75–<80	2016(27.4)	1202(27.2)	814(27.7)
≥80–<85	1143(15.2)	685(15.1)	458(15.2)
≥85	607(7.9)	364(8.0)	243(7.9)
Gender			
Female	4678(62.9)	2835(63.3)	1843(62.4)
Male	2695(37.1)	1599(36.7)	1096(37.6)
Race			
White	6340(88.8)	3822(89.2)	2518(88.3)
Black	762(7.4)	463(7.3)	299(7.5)
Other	271(3.8)	149(3.5)	122(4.3)
High school graduate			
No	3030(40.0)	1820(39.9)	1210(40.2)
Yes	4343(60.0)	2614(60.1)	1729(59.8)
Marital status			
Married	3860(53.0)	2332(53.3)	1528(52.5)
Unmarried	3513(47.0)	2102(46.7)	1411(47.5)
Health status			
Excellent	1119(15.6)	672(15.7)	447(15.3)
Very Good	1762(24.2)	1086(24.7)	676(23.5)
Good	2583(35.0)	1523(34.3)	1060(36.1)
Fair	1342(17.7)	816(17.9)	526(17.3)
Poor	567(7.5)	337(7.3)	230(7.8)
Hypertension			
No	4174(57.2)	2510(57.3)	1664(57.1)
Yes	3199(42.8)	1924(42.7)	1275(42.9)
Diabetes			
No	6502(88.4)	3890(88.1)	2612(88.8)
Yes	871(11.6)	544(11.9)	327(11.2)
Cancer			
No	6181(83.4)	3714(83.3)	2467(83.7)
Yes	1192(16.6)	720(16.7)	472(16.3)
Chronic bronchitis or emphysema			
No	6713(90.9)	4031(90.6)	2682(91.2)
Yes	660(9.1)	403(9.4)	257(8.8)
Asthma			
No	6960(94.5)	4180(94.3)	2780(94.8)
Yes	413(5.5)	254(5.7)	159(5.2)
Coronary artery disease			
No	5975(80.9)	3593(80.8)	2382(81.2)
Yes	1398(19.1)	841(19.2)	557(18.8)
Other heart disease			
No	6883(93.3)	4153(93.6)	2730(92.9)
Yes	490(6.7)	281(6.4)	209(7.1)
Stroke			
No	6826(92.7)	4104(92.7)	2722(92.6)
Yes	547(7.3)	330(7.3)	217(7.4)
Arthritis			
No	4012(54.5)	2400(54.0)	1612(55.2)
Yes	3361(45.5)	2034(46.0)	1327(44.8)
Major depression*			
No	7264(99.3)	4365(99.2)	2899(99.3)
Yes	52(0.7)	30(0.8)	22(0.7)
Blindness in both eyes*			
No	7172(98.5)	4312(98.6)	2860(98.5)
Yes	112(1.5)	63(1.4)	49(1.5)
Deafness in both ears*			
No	6807(93.4)	4076(93.0)	2731(94.0)
Yes	467(6.6)	297(7.0)	170(6.0)
Ever had broken hip*			
No	6995(96.0)	4186(95.6)	2809(96.5)
Yes	294(4.0)	191(4.4)	103(3.5)
Fall*			
No	5864(79.9)	3530(79.8)	2334(80.0)
Yes	1463(20.1)	876(20.2)	587(20.0)
Proxy use			
No	6226(84.7)	3745(84.6)	2481(84.8)
Yes	1147(15.3)	689(15.4)	458(15.2)
IADL stage			
No limitations	5134(70.0)	3090(70.0)	2044(69.8)
Mild limitations	1232(16.7)	750(16.9)	482(16.4)
Moderate limitations	454(6.0)	275(6.0)	179(5.9)
Severe limitations	439(5.8)	255(5.6)	184(6.2)
Complete limitations	114(1.5)	64(1.4)	50(1.7)
1-year mortality			
No	7103(96.3)	4285(96.7)	2818(95.9)
Yes	270(3.7)	149(3.3)	121(4.1)
5-year mortality			
No	5640(76.7)	3407(77.2)	2233(76.0)
Yes	1733(23.3)	1027(22.8)	706(24.0)
10-year mortality			
No	3675(50.2)	2220(50.5)	1455(49.7)
Yes	3698(49.8)	2214(49.5)	1484(50.3)

**Sample size is slightly less for these variables due to missing data: major depression (N= 7316, 4395, and 2921); blindness in both eyes (N= 7284, 4375, and 2909); deafness in both ears (N= 7274, 4373, and 2901); ever had broken hip (N= 7289, 4377, and 2912); fall (N= 7327, 4406, and 2921)*

Predictor Selection and Predictive Model Development

Table 2 shows the unadjusted associations between each predictor and 1-, 5-, and 10-year mortality separately in the development cohort. Table 3 shows the three final multiple logistic regression models for 1-, 5-, and 10-year mortality. The Hosmer-Lemeshow statistic showed a $p > 0.1$ for all three final models. The *c*-statistic of the 1-year mortality prediction model with four predictors (age, sex, coronary artery disease, and IADL stage) is 0.74, 0.74 for the 5-year mortality prediction model with 8 predictors (age, sex, perceived health status, cancer, coronary artery disease, other heart disease, diabetes, and IADL stage), and 0.76 for the 10-year mortality prediction model with ten predictors (age, sex, marital status, perceived health status, coronary artery disease, other heart disease, diabetes, chronic bronchitis or emphysema, stroke, and IADL stage).

Predictive Index Construction

The three indexes for 1-, 5-, and 10-year mortality are shown in Fig. 2. Age, sex, coronary artery disease, and IADL stage were the most essential predictors across all three indexes.

Internal Validation

After applying the three indexes in the validation cohort, we compared the 1-, 5-, and 10-year mortality probabilities at each sum score between the development and validation cohorts (available online as online Table 2). *C*-statistics of the three indexes in the development versus validation

Table 2. Unadjusted ORs for 1-, 5-, and 10-Year Mortality in the Development Cohort (N=4434)

Characteristics	1-year mortality	5-year mortality	10-year mortality
	Unadjusted OR (95% CI)		
Age			
≥70–<75	Reference	Reference	Reference
≥75–<80	1.16(0.75,1.78)	1.74(1.46,2.08)	2.19(1.87,2.55)
≥80–<85	2.05(1.31,3.21)	2.83(2.26,3.53)	4.01(3.23,4.96)
≥85	3.66(2.38,5.61)	5.73(4.43,7.42)	11.81(8.44,16.53)
Gender			
Female	Reference	Reference	Reference
Male	1.22(0.85,1.77)	1.45(1.26,1.67)	1.38(1.21,1.56)
Race			
White	Reference	Reference	Reference
Black	0.86(0.45,1.64)	1.14(0.88,1.47)	1.29(1.05,1.59)
Other	0.53(0.15,1.89)	0.92(0.60,1.42)	0.95(0.64,1.39)
High school graduate			
No	Reference	Reference	Reference
Yes	0.76(0.56,1.05)	0.75(0.65,0.87)	0.64(0.56,0.72)
Marital status			
Married	Reference	Reference	Reference
Unmarried	1.49(1.06,2.09)	1.29(1.12,1.49)	1.51(1.33,1.72)
Health status			
Excellent	Reference	Reference	Reference
Very Good	0.76(0.40,1.45)	1.18(0.91,1.54)	1.21(0.98,1.49)
Good	1.12(0.64,1.96)	1.65(1.29,2.10)	1.66(1.34,2.06)
Fair	1.45(0.81,2.59)	2.58(1.98,3.36)	2.52(1.99,3.20)
Poor	3.87(2.14,6.99)	6.42(4.68,8.80)	6.36(4.70,8.62)
Hypertension			
No	Reference	Reference	Reference
Yes	1.12(0.79,1.58)	1.19(1.02,1.38)	1.25(1.11,1.40)
Diabetes			
No	Reference	Reference	Reference
Yes	1.72(1.11,2.68)	2.11(1.70,2.62)	2.10(1.74,2.54)
Cancer			
No	Reference	Reference	Reference
Yes	1.87(1.23,2.84)	1.56(1.29,1.88)	1.30(1.10,1.54)
Chronic bronchitis or emphysema			
No	Reference	Reference	Reference
Yes	1.44(0.89,2.31)	1.64(1.28,2.10)	1.73(1.36,2.20)
Asthma			
No	Reference	Reference	Reference
Yes	1.40(0.72,2.72)	1.44(1.08,1.93)	1.27(0.97,1.66)
Coronary artery disease			
No	Reference	Reference	Reference
Yes	2.35(1.62,3.42)	1.84(1.54,2.19)	1.99(1.72,2.29)
Other heart disease			
No	Reference	Reference	Reference
Yes	2.05(1.17,3.61)	2.17(1.64,2.88)	1.83(1.44,2.33)
Stroke			
No	Reference	Reference	Reference
Yes	2.74(1.79,4.19)	2.46(1.90,3.19)	3.11(2.37,4.06)
Arthritis			
No	Reference	Reference	Reference
Yes	1.00(0.71,1.42)	0.96(0.82,1.11)	1.15(1.01,1.30)
Major depression*			
No	Reference	Reference	Reference
Yes	3.06(0.86,10.87)	1.65(0.72,3.76)	1.66(0.70,3.90)
Blindness in both eyes*			
No	Reference	Reference	Reference
Yes	2.02(0.70,5.81)	2.93(1.73,4.98)	6.22(3.22,12.02)
Deafness in both ears*			
No	Reference	Reference	Reference
Yes	1.78(0.98,3.25)	1.20(0.89,1.63)	1.51(1.17,1.96)
Ever had broken hip*			
No	Reference	Reference	Reference
Yes	1.26(0.63,2.55)	1.85(1.33,2.58)	2.24(1.62,3.09)
Fall*			
No	Reference	Reference	Reference
Yes	1.54(1.05,2.26)	1.31(1.11,1.56)	1.40(1.18,1.67)
Proxy use			
No	Reference	Reference	Reference
Yes	3.10(2.16,4.47)	2.22(1.82,2.70)	2.00(1.68,2.38)
IADL stage			
No limitations	Reference	Reference	Reference
Mild limitations	2.95(1.83,4.78)	1.91(1.57,2.32)	2.05(1.75,2.40)

Table 2. (continued)

Characteristics	1-year mortality	5-year mortality	10-year mortality
	Unadjusted OR (95% CI)		
Moderate limitations	4.59(2.80,7.50)	3.92(2.95,5.19)	4.16(3.15,5.51)
Severe limitations	6.97(4.20,11.55)	5.18(3.92,6.85)	6.89(4.82,9.85)
Complete limitations	18.28(9.98,33.46)	19.05(10.65,34.08)	13.75(6.23,30.35)

**Sample size is slightly less than 4,434 for these variables due to missing data: major depression (N= 4395); blindness in both eyes (N= 4375); deafness in both ears (N= 4373); ever had broken hip (N= 4377); fall (N= 4406)*

cohorts are 0.72 versus 0.72 for 1-year mortality, 0.74 versus 0.72 for 5-year mortality, and 0.75 versus 0.74 for 10-year mortality.

We further combined sum scores with similar mortality probabilities into 5 risk categories in Fig. 2. The 1-year mortality probabilities range from 1.8% to 41.9% across the 5 risk categories, the 5-year mortality probabilities range from 6.8% to 80.9%, and the 10-year mortality probabilities range from 23.9% to 92.5%.

Sensitivity Analysis

The majority of missing data were due to missing IADL stage or health status. Even though SPs with missing data were less healthy than those with complete data, after multiple imputation the results of multiple logistic regression models for 1-, 5-, and 10-year mortality from the imputed datasets were similar to the complete-case analyses.

DISCUSSION

Mortality prediction is often the basis for risk adjustment, and is essential for evaluating medical effectiveness and quality of care, and for informing health policy decisions. Focusing on the rapidly growing elderly population with complex chronic illness which is increasingly recognized as important in internal medicine, we evaluated the effects of multiple co-morbidities and functional status on mortality in efforts to identify parsimonious predictors. Our 10-year mortality index has a 0.75 probability of correctly assigning a higher score to a randomly chosen patient who died than to a randomly chosen patient who did not die, and thus fills a needed gap in the literature regarding a lack of long-term mortality prediction tools for community-dwelling elderly populations.[11] Our study adds the development of a long-term predictive mortality index, combined with parsimonious 1- and 5-year mortality indexes to the literature. Our 1-year mortality index applying only 4 predictors has a 0.72 probability of correctly assigning a higher score to a randomly chosen patient who died than to a randomly chosen patient who did not die. All three mortality predictive indexes show internal validity, and are simple to apply in community settings. Our 1-, 5-, and 10-year mortality predictive indexes can maximize the implementation of short-, intermediate- and long-term mortality estimation in community settings assisting clinical decision-making, and may serve as important screening tools for the impact of complex chronic illness on mortality. Thus, our mortality indexes have the potential to inform medical care decisions, identify high-risk persons for interventions, and provide a foundation for discussing care goals with community-dwelling elderly individuals. These rules can further provide surveillance measures to policy makers and epidemiologists when projecting the mortality of older populations.

IADL stage was one of the most important predictors for 1-, 5-, and 10-year mortality. The association between 1-year mortality and IADL stage was particularly strong and only age, sex, and coronary artery disease added explanatory power to the mortality index. Although functional status measured by various methods is known to be associated with mortality in elderly populations,[7–10, 29–36] only a few studies applied this knowledge to develop short- or intermediate-term mortality indexes.[7–10] Additionally, none expressed IADL as stages.[7–10] Unlike individual IADLs,[7, 8, 10] IADL stages summarize overall severity of disability across activities. Dissimilar to counts[9] where patterns of limitation are obscured, IADL stages define thresholds of function that specify severity but are also transparent to the specific patterns of activities limited reflecting the known hierarchical structure of IADL items.[18, 23] We derived IADL stages to capture the persons' functional status because IADL performance demands higher degrees of integration across individuals' cognitive and physical capacities, as compared to the self-care ADLs which evaluate personal bodily tasks[18, 37–39] IADL limitations can result from physical or cognitive impairments and can be used as a screening tool for cognitive impairment in elderly community-dwellers.[37–39] Thus, IADL stage is a strong predictor because it can serve as a proxy for multiple conditions simultaneously contributing to physical and cognitive impairments. The value of IADL stage to the internist is that it is easily determined by self-report and enables a more parsimonious subset of predictors simplifying mortality prediction and enhancing ease of implementation in community-dwelling elderly populations.

Coronary artery disease remained a significant predictor for 1-, 5-, and 10-year mortality, and other heart disease was significantly associated with 5- and 10-year mortality in the

Table 3. Adjusted ORs from the Final Multiple Logistic Regression Models for 1-, 5-, and 10- Year Mortality in the Development Cohort (N=4434)

Characteristics	1 year mortality	5 year mortality	10 year mortality
	Adjusted OR (95% CI)		
C-statistic	0.74	0.74	0.76
Age			
≥70–<75	Reference	Reference	Reference
≥75–<80	0.97 (0.62,1.53)	1.68 (1.39,2.04)	2.17 (1.84,2.56)
≥80–<85	1.49 (0.92,2.40)	2.65 (2.08,3.39)	3.83 (3.04,4.82)
≥85	1.99 (1.25,3.17)	5.23 (3.89,7.05)	10.58 (7.40,15.12)
Gender			
Female	Reference	Reference	Reference
Male	1.56 (1.05,2.32)	1.87 (1.60,2.19)	2.01 (1.73,2.34)
Marital status			
Married	-	-	Reference
Unmarried	-	-	1.32 (1.12,1.55)
Health status			
Excellent	-	Reference	Reference
Very Good	-	1.19 (0.90,1.57)	1.21 (0.97,1.51)
Good	-	1.55 (1.21,2.00)	1.60 (1.29,1.99)
Fair	-	1.85 (1.40,2.44)	1.85 (1.44,2.39)
Poor	-	3.40 (2.31,5.00)	3.35 (2.30,4.87)
Diabetes			
No	-	Reference	Reference
Yes	-	1.67 (1.31,2.13)	1.69 (1.36,2.10)
Cancer			
No	-	Reference	-
Yes	-	1.40 (1.13,1.73)	-
Chronic bronchitis or emphysema			
No	-	-	Reference
Yes	-	-	1.48 (1.13,1.95)
Coronary artery disease			
No	Reference	Reference	Reference
Yes	1.75 (1.16,2.65)	1.22 (1.01,1.47)	1.31 (1.12,1.53)
Other heart disease			
No	-	Reference	Reference
Yes	-	1.72 (1.27,2.33)	1.38 (1.06,1.80)
Stroke			
No	-	-	Reference
Yes	-	-	1.68 (1.23,2.31)
IADL stage			
No limitations	Reference	Reference	Reference
Mild limitations	2.79 (1.63,4.76)	1.42 (1.14,1.77)	1.42 (1.17,1.72)
Moderate limitations	3.92 (2.30,6.67)	2.23 (1.61,3.11)	2.16 (1.61,2.90)
Severe limitations	5.59 (3.31,9.44)	2.58 (1.88,3.53)	2.88 (1.90,4.37)
Complete limitations	13.55 (7.23,25.41)	8.18 (4.48,14.94)	3.88 (1.55,9.72)

"-" indicates not applicable as a predictor

final models. Heart disease is known to be the leading cause of death in the US.[40, 41] Other leading causes of death, including malignant neoplasms, cerebrovascular diseases, chronic lower respiratory diseases, and diabetes mellitus,[42] were all significantly associated with 5- and/or 10-year mortality in the final adjusted models. Most of these conditions were also significantly associated with 1-year mortality in the unadjusted analyses. These factors likely did not enter the final model for 1-year mortality prediction because of their strong correlations with IADL stages as shown in online Table 1. These leading causes of death have both acute and chronic impacts on the subjects' health although their long-term impact may be more significant.[42] An individual's IADL stage reflects current functional status as resulting from the person's active cognitive and physical conditions, but functional status as captured by IADL stage will likely change over time due to the progression or regression of various health conditions. Thus, the IADL stage's association with long-term mortality became attenuated over time while the chronic impact of certain medical diagnoses gained in importance for long-term mortality prediction. Further studies with more detailed clinical disease information are needed to confirm the association between IADL stage and acute and chronic disease burden over time.

We further evaluated the predictive ability of SPs' perceived health status and various impairments common in the elderly, including blindness, deafness, broken hip, and falls for 1-, 5-, and 10-year mortality. These factors were significantly associated with mortality in unadjusted analyses, but only SPs' perceived health status remained significantly associated with 5- and 10-year mortality in the final models. Blindness, deafness, broken hip, and falls were highly correlated with IADL stage in our study, and have been shown to have major impacts on functional status in other studies.[42–45] Thus, IADL stages likely capture the

	1-year mortality		5-year mortality		10-year mortality	
	Points	Score	Points	Score	Points	Score
IADL stage						
No limitations	0	☐	0	☐	0	☐
Mild limitations	2	☐	2	☐	1	☐
Moderate limitations	3	☐	4	☐	3	☐
Severe limitations	4	☐	5	☐	4	☐
Complete limitations	6	☐	11	☐	5	☐
Age						
≥70 - <75	0	☐	0	☐	0	☐
≥75 - <80	0	☐	3	☐	3	☐
≥80 - <85	0	☐	5	☐	5	☐
≥85	2	☐	8	☐	9	☐
Gender						
Female	0	☐	0	☐	0	☐
Male	1	☐	3	☐	3	☐
Unmarried	-	-	-	-	1	☐
Coronary artery disease	1	☐	1	☐	1	☐
Other heart disease	-	-	3	☐	1	☐
Diabetes	-	-	3	☐	2	☐
Cancer	-	-	2	☐	-	-
Chronic bronchitis or emphysema	-	-	-	-	1	☐
Stroke	-	-	-	-	2	☐
Health status						
Excellent	-	-	0	☐	0	☐
Health very good	-	-	0	☐	0	☐
Health good	-	-	2	☐	2	☐
Health fair	-	-	3	☐	2	☐
Health poor	-	-	6	☐	4	☐
Sum score		☐		☐		☐

Identify risk groups based on the sum score:

Risk groups	Sum Scores	1-year mortality probability (%)	Sum scores	5-year mortality probability (%)	Sum scores	10-year mortality probability (%)
Very Low	0-2	1.8	0-2	6.8	0-4	23.9
Low	3-4	4.8	3-6	12.7	5-9	46.8
Moderate	5-6	7.2	7-14	29.6	10-14	73
High	7-8	22.4	15-17	55.5	15-16	82.8
Very high	≥9	41.9	≥18	80.9	≥17	92.5

***Instructions**

1. The 1-, 5-, and 10-year mortality predictions involve 3 different scoring systems with different predictors. The " -" indicates not applicable as a predictor. Choose the scoring system according to whether 1-, 5-, or 10-year mortality risk is desired.
2. Score the person according to the presence of each relevant predictor. Enter the associated points in its score box.
3. Add the points associated with each predictor to obtain a sum score for the relevant scoring system.
4. In the box below, circle the range of the sum score to determine the person's risk group and the average likelihood of mortality.

Figure 2. 1-, 5-, and 10-year mortality predictive indexes and associated risk groups*.

effects of these conditions on mortality. Other studies showed self-rated health was a strong predictor for long-term mortality, and the association was only partly explained by medical conditions or sociodemographics.[46–49] In our study, though SPs' perceived health status did not contribute much to 1-year mortality, it was a significant predictor for 5- and 10-year mortality. Thus, SPs' perceived health status appears to be adding health risk information in addition to sociodemographics, medical conditions, and functional status to long-term rather than short-term mortality.

There are several limitations in our study. First, we used prospectively collected self-reported data from the LSOA II, a well-designed national survey. Although the use of self-reported information will reduce the healthcare resources needed for implementation, recall and non-response biases in self-reported data could cause misclassification of our predictors. However, the LSOA II has been standardized and extensively tested.[50, 51] Self-reported functional status has been validated,[37, 52] and self-reported co-morbidities are commonly used in national surveys[17, 23] and have been shown predictive of healthcare resource use and various

outcomes.[53–55] Second, excluding missing data from our complete-case analysis may have introduced bias. However, it is reassuring that we found similar results when we did multiple imputation as a sensitivity analysis. Third, 19.0% of the original sample used proxy-reports, while 15% of data from our complete-case analyses were reported by proxy due to the high prevalence of missing data in proxy-reports. We included proxy use as a variable in our analyses to adjust for the differences. However, this variable was not significant and hence was not included in the final models. Fourth, there are likely unmeasured predictors (unavailable in the data) that could increase prediction, such as cognitive status which is associated with mortality in the elderly population. [53–55] Although IADL stages[37–39] and stroke[56, 57] may be capturing some cognitive status information, further studies with directly measured cognition are needed. Finally, our baseline data was from the 1994-1996 national survey with mortality follow-up through 2006. The results may only be generalizable to the US community-dwelling population or developed countries with similar population structure.

In conclusion, the 1-, 5-, and 10-year mortality indexes developed from the LSOA II are practical for use in the community setting and can estimate prognosis for short-, intermediate-, and long-term mortality to assist with decision-making of clinicians, researchers, and policy makers. The use of IADL stage, which captures the cognitive and physical disease burden of the elderly population, can simplify mortality prediction in community settings when specific diagnostic information is lacking. If further studies demonstrate external validity of these mortality indexes in various community-dwelling elderly populations, these three mortality predictive indexes could become widely used tools for providing prognostic information and guiding therapeutic interventions among elderly community-dwellers.

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Corresponding Author: *Margaret G. Stineman, MD; Department of Biostatistics and Epidemiology, Center for Clinical Epidemiology and Biostatistics, Perelman School of Medicine, University of Pennsylvania, 904 Blockley Hall, 423 Guardian Drive, Philadelphia, Pennsylvania 19104, USA (e-mail: mstinema@exchange.upenn.edu).*

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