Development and Validation of an Index to Predict Activity of Daily Living Dependence in Community-Dwelling Elders

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Background: Maintaining independence in daily functioning is an important health outcome in older adults. A key measure of functional independence in elders is the ability to do activities of daily living (ADL) without the assistance of another person. However, few prognostic indices have been developed that stratify elders into groups at variable risk for developing ADL dependence.

Objective: We sought to develop and validate a prognostic index that distinguishes between elders at different risk of ADL dependence.

Research Design, Subjects, and Measures: We studied subjects enrolled in Asset and Health Dynamics Among the Oldest Old (AHEAD), a nationally representative cohort of elders older than the age of 70. We included 5239 subjects (mean age, 77) reporting that they could do each of 5 ADL (bathing, dressing, toileting, transferring, and eating) without the assistance of another person at baseline. Subjects were divided into development (n = 3245) and validation (n = 1994) samples based on region of the United States. Our primary outcome was the need for help (dependence) with at least one ADL at 2 years. We used logistic regression to select among predictor variables encompassing several domains: demographic characteristics, comorbid conditions, functional status, cognitive status, and general health indicators.

Results: The 9 independent predictors of 2-year ADL dependence were age older than 80, diabetes, difficulty walking several blocks, difficulty bathing or dressing, need for help with personal finances, difficulty lifting 10 pounds, inability to name the Vice President, history of falling, and low body mass index. We created a risk score by assigning 1 point to each risk factor. In the development sample, rates of 2-year ADL dependence in subjects with 0, 1, 2, 3, 4, and 5 or more risk factors were 1.3%, 2.8%, 3.8%, 10%, 22%, and 33%, respectively ($P < 0.001$, roc area = 0.79). In the validation sample, the rates were 0.7%, 4.3%, 8.7%, 11%, 18%, and 40% ($P < 0.001$, roc area = 0.77). The risk score also discriminated between subjects at variable risk for a combined outcome of either ADL decline or death (4.3%, 7.6%, 15%, 21%, 30%, and 47%).

Conclusion: Using data available from patient reports, we validated a simple risk index that distinguished between elders at variable risk of ADL dependence. This index may be useful for identifying elders at high risk of poor outcomes or for risk adjustment.

Key Words: activities of daily living, disability, prognosis, frail elderly, health status

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Maintaining independence is an important goal of health care in older adults.[1] A key measure of functional independence is the ability to do activities of daily living (ADLs), such as bathing, dressing, using a toilet, transferring from a bed to a chair, and eating without the assistance of another person.[2] Elders who become dependent by needing assistance in one or more of these ADLs generally will need the help of caregivers or require nursing home placement.

Risk factors for ADL dependence have been well described. They encompass diverse risk domains such as diseases, cognitive impairment, demographic, and psychosocial factors. In addition, less-severe degrees of functional impairment, such as self-reported difficulty completing ADLs, also are strong predictors of subsequent dependence on ADL assistance.[2–4] These risk factors often are considered measures of vulnerability or frailty because they identify elders who have limited reserve and respond poorly to stressors.[5,6] In addition to its adverse impact on quality of life, ADL dependence is among the strongest of risk factors for other adverse outcomes in the elderly, including death, nursing home placement, and high health expenditures.[7–9]

Many studies have examined risk factors for functional dependence in community living elders.[9–16] However, although many risk factors for ADL dependence have been described, there are few prognostic indices that combine information about these risk factors into tools to efficiently stratify elders into groups at differential risk of ADL dependence.[6,17] There are many reasons why such an index could improve the care of older people.[18] First, it could be useful for care planning and counseling patients and caregivers. Second, it would be useful for more optimally targeting interventions designed to prevent ADL dependence to the highest risk elders.[19] Third, it would be useful in observational studies of risk factors for functional dependence by making it possible to account for baseline differences in the

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risk for functional decline. Fourth, an ADL dependence index would be useful for comparing the quality of care provided to elders across different providers.

Therefore, our goal for this study was to develop and validate an easy to use prognostic index that could differentiate between elders at high and low risk of developing ADL dependence during the course of 2 years. The design of studies that develop prognostic indices differs significantly from studies that aim to understand etiology. A study that aimed to understand the etiology of functional dependence would examine risk factors hypothesized but not known to be associated with functional dependence. In contrast, we only considered variables already known to be associated with functional dependence. Our goal was to select a parsimonious set of variables from the many variables known to be associated with functional dependence that could efficiently stratify elders into groups at differential risk of developing functional dependence. We considered variables from multiple domains of risk factors that could easily be obtained by talking to a patient.[16] To evaluate the generalizability of our index, we developed it in one group of subjects and tested its validity in a second group, using data from a nationally representative sample.

METHODS

Subjects

We studied subjects enrolled from 1993 to 1995 in the Asset and Health Dynamics Among the Oldest Old (AHEAD) study.[20] The AHEAD study is a nationally representative study of U.S. community-dwelling elders age 70 and older. Data were collected through interviews with subjects during the baseline interview in 1993 and the follow-up interview in 1995. A total of 7447 subjects were enrolled in AHEAD. Since our goal was to predict incident ADL dependence, we excluded 958 subjects who were ADL dependent at baseline. We also excluded 539 subjects who died before the 2-year follow-up interview. Of the 5950 potentially eligible subjects, we excluded 367 (6%) subjects because the baseline interview was obtained from a proxy respondent and 344 (6%) subjects because we were missing data on ADL function at 2 years. As a result, our analysis included 5239 subjects. We developed the index in 3245 subjects in the Eastern, Central, and Western regions of the United States and validated the index in the 1994 subjects in the Southern region. This validation strategy tests the geographic transportability of the index and is a more stringent test of validation than a random split sample.[21]

Measures

Outcome

Our primary outcome was dependence in ADL function at 2 years.[22] Subjects were asked if they received help with each of 5 ADL: bathing, dressing, transferring from a bed to chair, using a toilet, and eating. Subjects were told not to include help they were likely to need for less than 3 months. Patients reporting receiving help with any of the 5 ADL were classified as ADL dependent.

Predictor Variables

We only considered variables that we felt could be obtained in clinical practice with minimal effort by talking to a patient. We classified predictor variables into 5 conceptual domains: demographic characteristics, comorbid conditions, functional measures, cognitive measures, and general health indicators. Demographic characteristics included age and gender. Comorbid conditions were measured by asking the subject if a doctor had ever told them that they had a series of conditions.[20]

Functional measures included difficulty bathing or dressing, the need for assistance with shopping or personal finances, difficulty walking several blocks, difficulty climbing 1 flight of stairs, difficulty pulling or pushing heavy objects, difficulty lifting 10 pounds, and difficulty picking up a dime. Although the need for help with bathing and dressing is a component of the outcome variable, we considered difficulty with bathing or dressing as a predictor variable because of prior research demonstrating that self-reported difficulty completing an ADL often precedes ADL dependence (the need for help).[4]

Cognitive measures included components of a validated battery developed for the AHEAD study.[23,24] This included the ability to do serial 7's (serially subtracting 7 from 100), count backward from 20, name the prickly plant that grows in the desert (cactus), name the U.S. president (Bill Clinton), and Vice President (Al Gore). Depression was assessed with an 8-item modified CES-D scale with depression defined as 3 or more symptoms.[23,25]

General health indicators included general measures of health not included in other domains. Subjects rated their self-assessed health on a 5-point scale from excellent to poor. Subjects rated their corrected vision and hearing from excellent to poor. Body mass index (BMI) was calculated from self-reported height and weight. Subjects one standard above (>30 for men and women) or below (<20 for women, <22 for men) the mean BMI for their gender were classified as having high and low BMI respectively. Incontinence was measured by asking the subject if they had lost any amount of urine beyond their control in the past 12 months. Falls were assessed by asking the subject if they had fallen down in the past 12 months. Subjects were also asked if they were current smokers and whether their activities were limited by pain.

Analyses

Development of ADL Dependence Index

First, we used χ^2 tests to examine the relationship between each potential risk factor and ADL dependence at 2 years. We then performed multivariable analyses, including as candidate variables all the risk factors that were associated with 2-year ADL dependence in the bivariate analyses ($P < 0.05$). Multivariable analyses were performed in several stages. First, we created models for each group of risk factors: comorbid conditions, functional status, cognitive function, and general health indicators. Within each group, the variables were entered into a backward logistic regression model ($P < 0.05$ to stay) in which the outcome was ADL dependence at 2 years. The variables from each model that re-

mained significant after stepwise elimination were then placed into a final backward elimination logistic regression model along with age and gender. The variables that remained in this model were then included in our final index. At all stages, forward and stepwise elimination produced the same results. Although it is possible that prediction models including all candidate variables may be more accurate, we chose this approach to variable reduction because we believed a simpler model with fewer variables is more likely to be used by clinicians. Also, models with fewer variables often validate better than models with many variables. To examine the degree to which variable reduction decreased the discrimination of our prediction index, we calculated c-statistics at each modeling stage.

After developing the index, we constructed a point scoring system in which we assigned one point to each risk factor that was present. We also examined other scoring systems, including assigning points in direct proportion to the B-coefficient, and calculating risk scores directly from the multivariable model. However, these alternative systems resulted in only very small improvements in discrimination of the index that was outweighed by greater complexity.

To validate the index, we applied the risk factor score created in the development cohort to each subject in the validation cohort. We determined the calibration of the index by comparing the predicted rate of ADL dependence from the development cohort to the observed rate in the validation cohort.[26] We determined the discrimination of the index in the development and validation cohorts by calculating the c-statistic. The c-statistic is the probability that for each possible pair of subjects in which one developed ADL dependence and the other did not, the index assigned a higher risk to the subject who did develop dependence.[27]

Because functional decline is a strong predictor of mortality, it is likely that many of the subjects excluded from our study because they died before the 2-year follow-up interview declined in ADL function before death. Further, those wishing to use this index to identify subjects at risk for adverse outcomes may wish to consider a combined outcome of death or functional dependence. Therefore, we conducted an additional analysis in which we tested the accuracy of our final index for the prediction of a combined of death or functional decline.

Sensitivity Analyses

We examined several additional models to examine whether the discrimination of our model would have differed with the selection of different variables. First, because many of the risk variables in each domain were highly collinear, we reran our models excluding the risk factor in each domain that was mostly strongly associated with ADL dependence, and allowed alternative risk factors to enter the model in the place of these variables. We compared the discrimination of this alternative model to the actual model. Second, because only one comorbid condition was selected for our final model (diabetes), we examined whether forcing other comorbid conditions or different specification of comorbid conditions into the model improved the fit. Third, we repeated our analyses classifying subjects with missing ADL outcome data as ADL dependent.

RESULTS

Characteristics of Subjects

The mean age of subjects in the development cohort was 77; 62% were women, and 86% were white. Nearly half (49%) had hypertension. 21% were unable to name the U.S. Vice President, and 30% had difficulty walking several blocks (Table 1). The overall rate of ADL dependence at 2 years was 6.5%. Of those who developed ADL dependence, 51% became dependent in a single ADL whereas 49% became dependent in 2 or more ADL. Among those dependent in at least one ADL, 75% were dependent in bathing, 56% in dressing, 29% in transferring, 25% in eating, and 19% in toileting.

The mean age of subjects in the validation set was 77; 63% were women, and 76% were white. Nearly half (49%) had hypertension. 31% were unable to name the U.S. Vice-President, and 34% had difficulty walking several blocks (Table 1). The overall rate of ADL dependence at 2 years was 9.5%. Of those who developed ADL dependence 42% became dependent in a single ADL whereas 58% became dependent in 2 or more ADL. Among those dependent in at least one ADL, 76% were dependent in bathing, 67% in dressing, 34% in transferring, 29% in eating, and 31% in toileting.

Risk Factors

Virtually every risk factor was associated with 2-year ADL dependence in the bivariate results except for gender, hypertension, and cancer (Table 2). Table 3 presents the results of 2 preliminary stages of our modeling: a logistic regression model including all variables that were significant in bivariate analysis, and a model that included all variables that remained significant after we ran backward selection models for each risk domain. Table 4 presents the risk factors that were independently associated with ADL dependence in our final model. These variables included age older than 80 years, a history of diabetes, difficulty bathing or dressing, need for help with personal finances, difficulty lifting 10 lbs, difficulty walking several blocks, inability to name the U.S. Vice President, a fall in the past year, and low BMI. We tested a series of interaction terms including age by all variables in the final model. However, none were statistically significant.

Performance of Risk Score

We divided subjects into groups based on the number of risk factors they had (Table 5-top half). In subjects with 1 or 2 risk factors, the most common risk factor was age greater than 80. In subjects with 3 or more risk factors, the most common risk factor was difficulty walking. In the development cohort, rates of 2-year ADL dependence ranged from 1.3% in subjects with 0 risk factors to 33% in subjects with 5 or more risk factors (Table 5-top half). The index demonstrated good discrimination with a c-statistic of 0.79. In the validation cohort, discrimination only dropped slightly

TABLE 1. Characteristics of Subjects

Variable	Development Cohort (n = 3245)	Validation Cohort (n = 1994)
Age, mean (SD)	76.7 (5.3)	77.0 (5.4)
69–74, %	42	41
75–79, %	30	28
≥80%	28	31
Gender		
Women, %	62	63
Ethnicity		
White, %	86	76
Black, %	11	16
Hispanic, %	3	8
Comorbid conditions, %		
Hypertension	49	49
Diabetes	11	12
Arthritis	24	25
Cancer	14	12
Lung disease (activity limiting)	3	4
MI	6	6
Angina	6	9
CVA	5	6
Functional status, %		
Difficulty walking several blocks	30	34
Difficulty dressing or bathing	5	7
Needs help grocery shopping	8	9
Needs help with personal finances	9	11
Difficulty climbing 1 flight of stairs	19	31
Difficulty pulling/pushing heavy objects	29	34
Difficulty lifting 10 lbs	26	27
Difficulty picking up a dime	6	7
Cognitive function, %		
Depression†	21	24
Unable to do serial 7's	63	71
Unable to count backward from 20	5	9
Unable to name cactus	12	20
Unable to name U.S. president	6	11
Unable to name U.S. vice president	21	31
General health indicators		
Fair or poor self-assessed health	27	33
Fair or poor vision	20	25
Fair or poor hearing	21	25
Low BMI*	10	12
Incontinence	17	17
Fall in past year	23	22
Pain that limits activity	14	16
Current smoker	9	10

*≤20 for women, ≤22 for men.
†Depression score ≥3 on CESD-8.

(c-statistic = 0.77), with good calibration. The overall index had considerably better discrimination than whether or not the subject had difficulty in ADL function at baseline (c-statistic of 0.57 in development cohort and 0.59 in validation cohort). The index also predicted a combined outcome of ADL dependence or death at 2 years (Table 5-bottom half), with a risk ranging from 4.3% in subjects with 0 risk factors to 46% in subjects with 5 or more risk factors (c-statistic = 0.73).

Clinical Use of Risk Score

To describe the clinical implications of using our risk score, we considered a clinical scenario in which a health care system used our risk score to select patients for an intervention to prevent ADL dependence that is too expensive to administer to all older patients. On the basis of the performance of the model in the validation data set, if the intervention were applied to all patients with scores of 5 or more, the intervention would be applied to 29% of patients who become ADL dependent and 7% of overall patient population. These rates would be 46% and 14%, respectively, for a cutoff of 4 or more points and 65% and 30%, respectively, for a cutoff of 3 or more points.

Performance of Alternative Models

The risk model that included all the variables significant in the bivariate analysis (first result column of Table 3) had a c-statistic of 0.81 in the development cohort and 0.77 in the validation cohort. The risk model including all the candidate variables selected after backward regression models were run in each risk domain (second column of Table 2) had a c-statistic of 0.80 in the development cohort and 0.78 in the validation cohort. The c-statistic of a model based on the actual coefficients in our final 9 variable model had a c-statistic of 0.79 in the development cohort and 0.77 in the validation cohort. These results suggest that the simplification of our risk index had minimal impact on model accuracy as the validation c-statistic (0.77) of the risk score based on the number of risk factors was virtually identical to the validation c-statistic of the more complex models.

Sensitivity Analyses

To examine whether the selection of alternative variables would have produced a risk index of similar accuracy, we redeveloped our model eliminating the risk factor from each risk domain that was most strongly associated with functional dependence (diabetes, BMI, unable to name vice president, difficulty walking several blocks). The revised risk index included the following risk factors: age, current smoking, unable to name president, dressing or bathing difficulty, needs help with personal finances, difficulty grocery shopping, difficulty lifting 10 pounds, difficulty pulling or pushing). A risk score based on the number of these risk factors present had a c-statistic of 0.760 in the development dataset and 0.759 in the validation dataset.

We conducted several analyses to consider whether other specifications of the comorbid conditions improved model fit. Models that included comorbidity counts, or replaced the diabetes risk factor with "diabetes, or stroke, or MI" had slightly lower c-statistics than the final model. Furthermore, when we forced the other comorbid conditions into the final model, none were significantly associated with ADL dependence. Finally, repeating our analyses classifying subjects with missing follow-up data on ADL function as

TABLE 2. Predictors of 2-Year ADL Dependence in the Development Cohort

Domain	Characteristic	Category	Rate of ADL Dependence at 2 Years (%)	*P**
Demographic	Age	69–74 (n = 1368)	3.8	<0.001
		75–79 (n = 957)	5.5	
		≥80 (n = 920)	12	
	Gender	Male (n = 1241)	5.6	0.116
		Female (n = 2002)	7.0	
Comorbidities	Hypertension	No (n = 1646)	6.7	0.672
		Yes (n = 1599)	6.3	
	Diabetes	No (n = 2887)	5.8	<0.001
		Yes (n = 358)	12	
	Arthritis	No (n = 2484)	5.7	0.001
		Yes (n = 761)	9.1	
	Cancer	No (n = 2787)	6.2	0.140
		Yes (n = 458)	8.1	
	Lung disease	No (n = 3138)	6.3	0.004
		Yes (n = 105)	13	
	MI	No (n = 3061)	6.2	0.017
		Yes (n = 177)	12	
	Angina	No (n = 3038)	6.1	<0.001
		Yes (n = 206)	13	
	Stroke	No (n = 3080)	6.1	<0.001
		Yes (n = 165)	13	
Measures of function	Difficulty walking several blocks	No (n = 2257)	3.5	<0.001
		Yes (n = 987)	14	
	Difficulty dressing or bathing	No (n = 3071)	5.6	<0.001
		Yes (n = 174)	22	
	Help required for grocery shopping	No (n = 3001)	5.2	<0.001
		Yes (n = 244)	23	
	Help required for finances	No (n = 2943)	5.5	<0.001
		Yes (n = 302)	16	
	Difficulty climbing one flight of stairs	No (n = 2617)	4.9	<0.001
		Yes (n = 626)	13	
	Difficulty pulling/pushing heavy objects	No (n = 2297)	4.2	<0.001
		Yes (n = 945)	12	
	Difficulty lifting more than 10 pounds	No (n = 2377)	3.7	<0.001
		Yes (n = 813)	14	
	Difficulty picking up dime	No (n = 3057)	6.0	<0.001
		Yes (n = 182)	14	
Measures of cognition	Depression	No (n = 675)	5.5	<0.001
		Yes (n = 2570)	10	
	Subtract series of 7s (starting from 100)	Correct (n = 1188)	4.7	0.002
		Incorrect (n = 2057)	7.5	
	Count backwards from 20	Correct (n = 3038)	6.2	<0.001
		Incorrect (n = 164)	13	
	Name cactus	Correct (n = 2828)	5.9	<0.001
		Incorrect (n = 390)	11	
	Name president	Correct (n = 3028)	6.0	<0.001
		Incorrect (n = 199)	15	
	Name vice president	Correct (n = 2510)	5.3	<0.001
		Incorrect (n = 681)	11	
General health measures	BMI	High (n = 331)	4.4	<0.001
		Normal (n = 2464)	6.2	
		Low (n = 430)	11	

(*Continued*)

TABLE 2. (*Continued*)

Domain	Characteristic	Category	Rate of ADL Dependence at 2 Years (%)	*P**
	Current smoker	No (n = 2946)	6.2	0.035
		Yes (n = 299)	9.4	
	Self-assessed eyesight	Good or better (n = 2592)	5.6	<0.001
		Fair/poor (n = 653)	10	
	Self-assessed hearing	Good or better (n = 2576)	5.9	0.004
		Fair/poor (n = 669)	9.0	
	Self-assessed health	Good or better (n = 2372)	4.5	<0.001
		Fair/poor (n = 873)	12	
	Any falls in past year	No (n = 2514)	5.2	<0.001
		Yes (n = 731)	11	
	Incontinence	No (n = 2680)	6.1	0.035
		Yes (n = 565)	8.5	
	Activity limited by pain	No (n = 2784)	5.8	<0.001
		Yes (n = 459)	11	

ADL dependent resulted in the selection of the same 9 variable model.

DISCUSSION

We developed and validated a prognostic index that differentiates between community living elders at markedly different risk for ADL dependence within 2 years. Using a simple count of 9 risk factors that can be obtained from a brief patient interview, rates of 2-year ADL dependence varied over 50-fold in the validation cohort, ranging from 0.7% in subjects with no risk factors to 40% in subjects with 5 or more risk factors. Our risk index also differentiated between subjects at variable risk for a combined outcome of ADL dependence or death.

Our index demonstrates that ADL disability is best predicted by considering multiple domains of risk rather than any single risk factor. The 9 risk factors included in the final index included age, a comorbid condition (diabetes), a measure of cognitive function (inability to name the vice-president), low BMI, and 5 measures of functional limitation (difficulty walking several blocks, difficulty bathing or dressing, difficulty lifting 10 pounds, and a fall in the prior year, and need for help with personal finances). Although it was expected that older age would be associated with ADL dependence, it is perhaps surprising that by itself, the risk associated with old age is modest. A person older than the age of 80 with none of the other risk factors had a predicted risk for ADL of only 4.3% in the validation cohort. Although older subjects were more likely to have most of the other risk factors, our findings suggest that the risk for ADL dependence is better assessed by careful risk assessment, than by age alone.

The predominance of functional limitation measures in our index is consistent with Verbrugge's and Jette's model of disability in which functional limitations generally precede disability.[28] The measures of functional limitation cover multiple domains. For example, the inclusion of need for help in personal finances, an instrumental activity of daily living (IADL) is consistent with evidence that IADL dependence often precedes ADL dependence.[29] The inclusion of difficulty with bathing or dressing is consistent with Gill's report that self-reported ADL difficulty often precedes dependence.[4] The inclusion of a fall history provides further evidence that there may be a common underlying etiologies among different geriatric syndromes such as falling and ADL dependence.[14]

It is notable that only one comorbid condition (diabetes) was included in our final risk score. It is important to recognize that the absence of other comorbid conditions from our index does not imply that they do not play an important etiologic role in the development of disability. In contrast, it is likely that some of these comorbid conditions were the cause of the functional limitations that are included in our index. We believe that the extent to which a disease has caused a functional limitation is probably a much more important predictor of whether that disease will eventually result in ADL dependence than the presence or absence of the disease. To the extent that this belief is true, it is to be expected that many diseases will have not have a strong association with disability once one adjusts for the functional limitations that are caused those diseases.

Our index has practical clinical uses. For example, the ability to predict risk of ADL dependence will be useful in counseling patients and caregivers about future care needs. More importantly, our index will be useful in identiftying elders in whom interventions to prevent ADL dependence may be most appropriate. This use will become more important as additional programs to prevent ADL dependence in at risk elders are developed.[30] Although some have argued that the inability to identify elders at risk for ADL dependence is one of the greatest impediments to the practical application of geriatric assessments and interventions, we have demonstrated that it is possible to identify large groups of elders at high risk in whom interventions and geriatric assessment may be best targeted, and such low risk that assessment and intervention may be unnecessary.[19] The 2-year time horizon of our index is short enough to be of clear clinical relevance to patients but long enough to plan interventions.[30]

TABLE 3. Preliminary Logistic Regression Models Including All Significant Bivariate Results and All Variables Selected in Each Risk Domain

Variable	Model Including All Variables Significant in Bivariate Analysis OR (95% CI)	Model Including All Variables Selected in Domain Specific Regression Models OR (95% CI)
Age (≥80 yr vs. 70–75)	1.94 (1.38–2.72)	1.91 (1.38–2.63)
Comorbid conditions		
Diabetes	2.09 (1.36–3.20)	2.12 (1.41–3.20)
Arthritis	0.97 (0.66–1.43)	0.89 (0.62–1.27)
Lung disease (activity limiting)	1.10 (0.53–2.27)	1.13 (0.56–2.30)
Angina	1.16 (0.65–2.05)	1.23 (0.72–2.11)
Stroke	0.87 (0.47–1.60)	0.86 (0.47–1.58)
Heart attack	1.08 (0.58–2.01)	—
Functional measures		
Difficulty walking	2.09 (1.41–3.09)	2.13 (1.47–3.07)
Difficulty bathing or dressing	2.38 (1.44–3.93)	2.15 (1.34–3.45)
Needs help with personal finances	1.99 (1.30–3.04)	2.01 (1.34–3.02)
Difficulty lifting 10 pounds	1.93 (1.30–2.86)	1.82 (1.27–2.63)
Difficulty grocery shopping	1.43 (0.89–2.30)	1.41 (0.90–2.18)
Difficulty climbing one flight of stairs	0.97 (0.65–1.46)	—
Difficulty pulling/pushing	1.13 (0.76–1.66)	—
Difficulty picking up a dime	0.85 (0.47–1.53)	—
Cognitive measures		
Unable to name vice president	1.57 (1.09–2.28)	1.51 (1.06–2.15)
Unable to name president	1.51 (0.88–2.60)	1.57 (0.95–2.62)
Subtract series of 7s incorrectly	1.01 (0.70–1.45)	1.06 (0.75–1.52)
Depression	0.79 (0.53–1.16)	0.81 (0.56–1.18)
Count back from 20 incorrectly	1.29 (0.73–2.26)	—
Unable to name cactus	1.02 (0.65–1.60)	—
General Health Measures		
Fall in past year	1.66 (1.18–2.34)	1.65 (1.18–2.29)
BMI (low vs. high)	1.83 (1.17–2.85)	1.88 (1.23–2.88)
Fair/poor self-rated health		
Fair/poor vision		
Fair/poor hearing		
Current smoker	1.79 (1.09–2.94)	—
Pain limits activity	0.68 (0.43–1.07)	—
Incontinence	1.09 (0.74–1.62)	—

TABLE 4. Independent Predictors of ADL Dependence at 2 Years (Development Cohort)

Variable	Odds Ratio (95% CI)
Age older than 80 years	1.95 (1.42–2.67)
Diabetes	2.27 (1.52–3.37)
Difficulty walking several blocks	2.25 (1.58–3.20)
Difficulty bathing or dressing	2.20 (1.39–3.48)
Needs help with personal finances	2.20 (1.50–3.28)
Difficulty lifting 10 pounds	1.96 (1.39–2.77)
Unable to name vice president	1.71 (1.23–2.37)
Fall in past year	1.67 (1.21–2.31)
Low BMI	1.95 (1.28–2.97)

Although an extensive literature has examined predictors of ADL dependence in community-living elders, few have combined information about predictors to stratify elders into groups at variable risk.[6,16,17] One of these prior indices, the Sarkisian index, which is difficult to compare with our index because it only considers potentially modifiable risk factors, included performance based measures and was limited to women.[17] Interestingly, Sarkisian found high BMI to be a risk factor for a decline in ADL ability, whereas we found elders with low BMI to be at higher risk. This difference may be explained by an overall healthier population and low prevalence of underweight subjects in Sarkisian's study. The items in our index include some items similar to those included in the vulnerable elders survey, such as difficulty walking and difficulty lifting heavy objects.[6] The key differences between our index and the vulnerable elders survey

TABLE 5. Performance of Risk Index in Development and Validation Cohorts

	Rate of ADL Dependence	
No. Risk Factors*	Development Cohort, n/N (%)	Validation Cohort, n/N (%)
0	10/795 (1.3)	3/407 (0.7)
1	26/933 (2.8)	23/535 (4.3)
2	23/604 (3.8)	33/380 (8.7)
3	42/418 (10)	33/292 (11)
4	53/245 (22)	29/163 (18)
≥5	41/123 (33)	49/124 (40)
c-statistic	0.79	0.77
Rate of ADL dependence or death, overall cohort, n/N (%)		
0	53/1242 (4.3)	
1	117/1536 (7.6)	
2	165/1093 (15)	
3	169/804 (21)	
4	140/466 (30)	
≥5	137/294 (47)	
c-statistic	0.73	

*The risk score was based on the number of the following risk factors that were present: age older than 80 years, fall in the past year, diabetes, unable to name vice president, difficulty walking several blocks, difficulty bathing or dressing, difficulty with personal finances, difficulty lifting 10 lbs, low BMI.

include the validation of our index in an independent sample, our focus on subjects independent in ADL function at baseline, and our inclusion of cognitive measures.

Indices that can reliably identify the functional risk of patients in a particular setting may have important policy uses. For example, our index may provide a simple method of comparing the functional status of patients in different Medicare health maintenance organizations. This comparison could be useful when risk adjusting outcomes in different organizations, or for setting payment rates.[18] Our index may be particularly important in the home care setting, in which prevention of ADL dependence is a crucial outcome and measure of quality and may provide a more rational method of risk assessment and quality adjustment than the voluminous assessments currently required of home care providers.[31] However, before any index is used for these types of purposes, additional validation studies examining multiple domains of generalizability would be needed.[21] Also, before such uses become practical, a consensus would need to emerge among payers and the public that functional outcomes are a critical measure of quality that should be measured. Finally, although information from surveys might provide additional important information for risk adjustment, survey data for this purpose requires more effort and expense and is currently not widely used.

The likelihood that our index will be generalizable to other settings is enhanced by the use of a population-based cohort and rigorous test of the validation of our index, that tested both the internal and external validity of our index.[21] Several limitations of our analysis should also be considered. First, our analysis was limited to subjects who survived 2 years, and it is likely that many of the subjects who died became ADL dependent before death. However, since we demonstrated that our index also performs well when predicting a combined outcome of ADL dependence or death, it is likely that the bias that resulted from excluding nonsurvivors was minimal. Second, ADL dependence is sometimes temporary.[32] As a result, some subjects who were independent at the 2-year follow-up may have had prior transient periods of ADL dependence. Similarly, some subjects who were ADL dependent at 2 years may have subsequently recovered.[33] Third, while we considered an extensive range of predictors of ADL dependence, we did not have data on some potentially important predictors such as social support.

In conclusion, our index provides a useful method of predicting risk of ADL dependence in community living elders. Our index retained its accuracy in an independent sample, demonstrating good calibration and discrimination. These characteristics suggest our index may be useful in clinical care and for risk adjustment.

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