A Simple Scoring Algorithm for Health Literacy in Community-Dwelling Older Adults

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Abstract

Background:

Health literacy (HL) is the capacity to access, understand, appraise, and apply health information to make appropriate health decisions. This study aimed to establish a predictive algorithm for identifying community-dwelling older adults at a high risk of low HL.

Methods:

A total of 648 older adults were included and 85% was used to generate the prediction model for scoring algorithm while 15% was used to test the fitness of the model. Pearson's chi-squared test and multiple logistic regression were used to identify the factors associated with the HL level. An optimal cutoff point was identified based on the maximum sensitivity and specificity.

Results:

350 patients (54.6%) was classified as the low HL level. Twenty-four variables were identified for significantly differentiating between high and low HL. Eight factors including socio-environmental determinant and health outcome related factors significantly predicted low HL. The scoring algorithm yielded an area under the curve of 0.71 and optimal cutoff of 5 represented mediocre sensitivity (62.0%) and good specificity (76.2%).

Conclusion:

This simple scoring algorithm efficiently and effectively identify community-dwelling older adults a low HL.

1. Introduction

Health literacy (HL) is defined as the ability to access, understand, appraise, and apply health information or health services for obtaining appropriate health care (HC), disease prevention (DP), and health promotion (HP) (1). HL has been identified as the newest vital sign that emphasizes the importance of early and precise access to intervention strategies from clinicians and health care administrators to for the public (2). However, the construct of HL is complex and dynamic and encompasses many aspects of individuals' use of health information and the health care system. Therefore, the European Health Literacy Survey Consortium has proposed a theoretical model that integrates medical and public health views of HL to demonstrate various antecedents such as personal, contextual, social, and environmental determinants. Therefore, the level of HL determines the health service use, health costs, health behavior, health outcomes, participation, and empowerment among individuals (1).

Older adults generally have more chronic illnesses and less formal education than their younger counterparts (3). Moreover, older adults experience unique problems related to physical and cognitive functioning, which can make finding accurate health information and using appropriate healthcare services difficult for them (4). Several national surveys have reported that more than half of the older adults have low HL (5–7). Previous studies have documented that level of HL in older adults is significantly lower than that in young people (8–10). Moreover, low HL levels result in poor health outcomes (11) and health behaviors (12), more health care expenditures (13) and health services

usage (14), and inadequate empowerment (15) and participation (16). Therefore, early and accurate prediction of the high risk of low HL among older adults has become essential worldwide in order to provide prompt and appropriate health care strategies.

Various HL measures been developed for older adults (17). However, most of them lack underlying theoretical basis and fail to sufficiently cover comprehensive dimensions of HL across different clinical environments. Furthermore, to the best of our knowledge, no HL prediction model that can enable early and precise identification of HL levels in older adults has been developed. Therefore, developing a simple, cost-effective algorithm that can be applied in clinical settings to accurately identify older adults at a potential high risk of low HL is essential. For this purpose, this study conducted a survey among community-dwelling older adults to identify the factors influencing low HL and constructed an optimal scoring algorithm for predicting HL.

2. Methods

2.1. Participants

In this cross-sectional study, by convenience sampling, we recruited eligible community participants who were 65 years or older from six senior service centers and three health check-up clinics in northern, central, and southern Taiwan between June and September 2018. Individuals with cognitive impairment based on screening by using the Mini-Cog instrument were excluded (18).

2.2. Procedure

The objective of the study was explained to respondents before they expressed their willingness to participate by trained interviewers. The survey was anonymous, and the respondents were allowed to suspend the interview at any time. This study was approved by Taipei Medical University-Joint Institutional Review Board (N201804046) and National Taiwan University Hospital (201804057RIND). After signing informed consent forms for participation in the study, the participants completed a self-administered questionnaire of 52 potential predictors, including personal, situational, and socio-environmental determinants and factors related to health service use, health costs, health behavior, health outcomes, participation, and empowerment, based on the theoretical model of the European Health Literacy Survey Consortium (19).

2.3. Outcome Measures

The 47-item European Health Literacy Survey Questionnaire (HLS-EU-Q), developed by the European Health Literacy Consortium, was used to assess the HL of the study participants. The HLS-EU-Q measures four HL competencies (access, understand, appraise, and apply health information) required under three health domains: HC (16 items), DP (15 items), and HP (16 items). Each item assesses the self-perceived difficulty in performing selected health-related tasks on a 4-point scale ranging from “very easy” (4) to “very difficult” (1). Higher scores indicate higher HL. For ease of comparison, each domain (i.e., HC, DP, and HP) score was linearly transformed to a score between 0 and 50 by using a scale validated with satisfactory psychometric properties used in the European Health Literacy Survey (20). Based on the scores, HL was divided into four categories as following: inadequate (0–25), problematic (26–33), sufficient (34–42), and excellent (43–50) (21, 22). We dichotomized the HL into “high” and ” low” based on the cutoff value of 34, as defined by the European Health Literacy Survey (21).

2.4 Statistical analysis

The dichotomized outcome is defined using the HL level as follows:

$$y = \begin{cases} 1, \text{low HL } [probability = p] \\ 0, \text{high HL } [probability = 1 - p] \end{cases}$$

To develop a scoring algorithm for predicting low HL, the core data set was divided using stratified random sampling without the replacement method as follows: 85% of the core data set was categorized into the training data set that was used for training the prediction model to create the scoring rule, and 15% of the data set was categorized as the validation test data set that was used for validating the scoring algorithm (23). The prediction model was generated using the training data set as follows: (1) Pearson's chi-squared test was used to assess the association of the HL level with each of the 52 self-administrated HL predictors. To select the most relevant predictors, variables with a p value of < 0.1 were included in the multiple logistic regressions. (2) Multiple logistic regressions with forward selection were used to examine relationships between low HL and the potential predictors classified into domains of personal determinants, situational determinants, socio-environmental determinants, health service use, health costs, health behavior, health outcomes, participation, and empowerment. The potential predictors with a p value of < 0.05 were further identified from the multiple logistic regression models (24, 25). The multiple regression equation is as follows:

$$\text{logit}\left[\frac{p}{1-p}\right] = \alpha + \beta_1 x_1 + \cdots + \beta_i x_i$$

$$p = \frac{1}{1 + exp^{\theta(\alpha + \beta_1 x_1 + \cdots + \beta_i x_i)}}, 0 \le p \le 1$$

where p denotes the probability of low HL in older adults, α is the intercept of the multiple regression, and β_i is the slope of the main predictor (i = 1, 2, …, n). Odds ratio (OR) was estimated using exp(β_i). The measured β_i, exp(β_i) or p is usually applied to calculate the clinical score for predicting health risk (26, 27). A total of eight significant predictors were identified from multiple logistic regressions. (3) A simple algorithm was created based on the significant predictors identified from the multiple logistic regressions. Significant predictors that were positively associated with low HL were assigned a value of + 1, whereas those that were negatively associated with low HL were assigned a value of − 1.

A separate 15% of the participants were used to validate the proposed scoring algorithm. Based on the algorithm obtained from the training data set, the total score for each older adult in the test data set ranged from 0 to 8. Overall accuracies of low HL were classified with sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) (28). The model fit was assessed on the basis of McFadden's pseudo R-square (measuring the reduction in maximized log-likelihood from the intercept only model) and c-statistic [area under receiver operating characteristic (ROC) curve, AUC] values (29, 30). A two-sided 95% confidence interval (CI) for AUC was used to denote the uncertainty (31), and a p value of > 0.05 in the Hosmer–Lemeshow fitting test was used to indicate the algorithm performance. The optimal cutoff score denoting the optimal classification threshold was the maximum value of sensitivity + specificity. All statistical analyses were computed using the SAS 9.4 software (SAS Institute, NC, USA).

3. Results

A total of 648 older adults were recruited. Figure 1 presents the age-specific HL levels, which indicate that nearly half (41.6–46.1%) of the participants had problematic HL. A large portion of participants (72.6%) aged ≥ 81 years old had low HL. The sociodemographic characteristics of participants in the training and test data sets are presented in Table 1. Sex, age, education level, marital status, occupation, and monthly income were similarly distributed between the training and test data sets.

Table 1
Sociodemographic characteristics of study participants across the core, training, and test data sets

	Core data set (n = 648)		**Training data set (n = 552)**		**Test data set (n = 96)**	
	Health literacy, n (%)					
Variables	Low	High	Low	High	Low	High
Sex						
Male	138 (57.3)	103 (47.7)	117 (57.9)	85 (42.1)	21 (53.9)	18 (46.1)
Female	216 (53.3)	189 (46.7)	184 (52.9)	164 (47.1)	32 (56.1)	25 (43.9)
Age (years)						
65–70	131 (51.8)	122 (48.2)	111 (51.9)	103 (48.1)	20 (51.3)	19 (48.7)
71–80	151 (51.5)	142 (48.5)	133 (52.4)	121 (47.6)	18 (46.2)	21 (53.8)
≥ 81	74 (72.6)	28 (27.4)	59 (70.2)	25 (29.8)	15 (83.3)	3 (16.7)
Education level						
Illiterate or elementary school	124 (69.3)	55 (30.7)	104 (67.5)	50 (32.5)	20 (80.0)	5 (20.0)
Junior and senior high school	139 (57.2)	104 (42.8)	117 (57.6)	86 (42.4)	22 (55.0)	18 (45.0)
College degree or above	88 (40.2)	31 (58.8)	77 (40.7)	112 (59.3)	11 (36.7)	19 (63.3)
Marital status						
Married	240 (51.8)	223 (48.2)	206 (52.2)	189 (47.8)	34 (50.0)	34 (50.0)
Single/divorced/widowed	115 (62.5)	69 (37.5)	96 (61.5)	60 (38.5)	19 (67.9)	9 (32.1)
Past occupation (n = 579)						
Manager or professional	59 (37.6)	98 (62.4)	52 (38.5)	83 (61.5)	7 (31.8)	15 (68.2)
Sales/administration/service	84 (57.5)	62 (42.5)	67 (55.4)	54 (44.6)	17 (68.0)	8 (32.0)
Technical/production/operators/ laborers//forestry/farmer/fisher	86 (66.7)	43 (33.3)	72 (67.9)	34 (32.1)	14 (60.9)	9 (39.1)
Housewife/unemployed	90 (61.2)	57 (38.8)	77 (60.6)	50 (39.4)	13 (65.0)	7 (35.0)

NTD: New Taiwan Dollar

	Core data set (n = 648)		Training data set (n = 552)		Test data set (n = 96)	
Monthly income (NTD)						
No income	108 (59.3)	74 (40.7)	95 (59.8)	64 (40.2)	13 (56.5)	10 (43.5)
< 20,000	118 (60.2)	78 (39.8)	95 (57.9)	69 (42.1)	23 (71.9)	9 (28.1)
20,001–50,000	81 (50.0)	81 (50.0)	69 (50.4)	68 (49.4)	12 (48.0)	13 (52.0)
≥ 50,001	42 (42.9)	56 (57.1)	37 (45.1)	45 (54.9)	5 (31.3)	11 (68.7)
NTD: New Taiwan Dollar						

In the training data set (n = 552), of the 52 variables of the original self-administrative questionnaire (Appendix Table 1), 24 factors (i.e., 5 personal determinants, 2 situational determinants, 2 socio-environmental determinants, 1 factor related to health service use, 1 factor related to health costs, 3 factors related to health behavior, 6 factors related to health outcomes, 1 factor related to participation, and 3 factors related to empowerment of HL) associated with the HL level ($p < 0.1$) were identified using Pearson's chi-squared tests (Table 2).

Table 2
The 24 factors significantly correlated with health literacy level based on Pearson's chi-squared tests in the training data set (n = 552)

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Personal determinants						
Medical training (n = 544)						
Yes	12	(4.0)	23	(9.4)	6.5	0.011
No	287	(96.0)	222	(90.6)		
Education level (n = 546)						
Illiterate or elementary school	104	(34.9)	50	(20.2)	25.8	< 0.001
Junior and senior high school	117	(39.3)	86	(34.7)		
College degree or above	77	(25.8)	112	(45.2)		
Past occupation (n = 489)						
Manager or professional	52	(19.4)	83	(37.6)	23.6	< 0.001
Sales/administration/service	67	(25.0)	54	(24.4)		
Technical/production/operators/ laborers/forestry/farmer/fisher	72	(26.9)	34	(15.4)		
Housewife/unemployed	77	(28.7)	50	(22.6)		
Age (n = 552, years)						
65–70	111	(36.6)	103	(41.4)	9.4	0.009
71–80	133	(43.9)	121	(48.6)		
≥81	59	(19.5)	25	(10.0)		
Monthly income (n = 542, NTD)						
No income	95	(32.1)	64	(26.0)	6.4	0.094
< 20,000	95	(32.1)	69	(28.0)		
20,001–50,000	69	(23.3)	68	(27.6)		
≥ 50,001	37	(12.5)	45	(18.3)		
Situational determinants						
Marriage (n = 551)						
Single/divorced/widowed	96	(31.8)	60	(24.1)	4.0	0.046
Married	206	(68.2)	189	(75.9)		
Socioenvironmental determinants						

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Dominant spoken dialect (n = 551)						
Taiwanese, Hakka, or other dialect	154	(51.0)	41	(16.5)	71.2	< 0.001
Mandarin	148	(49.0)	208	(83.5)		
Residential area (n = 552)						
Taipei city	158	(52.1)	157	(63.1)	6.6	0.010
Other cities	145	(47.9)	92	(36.9)		
Health service use						
Having a family doctor (n = 548)						
Yes	16	(5.3)	24	(9.8)	4.0	0.046
No	286	(94.7)	222	(90.2)		
Health costs						
Pneumonia self-paid vaccination (n = 547)						
Yes	85	(28.4)	100	(40.3)	8.6	0.003
No	214	(71.6)	148	(59.7)		
Health behaviors						
Exercise frequency (n = 550)						
No exercise	63	(20.9)	27	(10.9)	9.9	0.007
Every day	114	(37.7)	107	(43.1)		
Weekly or monthly	125	(41.4)	114	(46.0)		
Active seeking of health information (n = 549)						
No	63	(20.9)	22	(8.9)	26.3	< 0.001
Sometimes	172	(57.1)	130	(52.4)		
Always	66	(21.9)	96	(38.7)		
Health examination in past year (n = 539)						
Yes	168	(56.8)	156	(64.2)	3.1	0.079
No	128	(43.2)	87	(35.8)		
Searching online health information (n = 548)						
Yes	75	(24.9)	107	(43.3)	20.7	< 0.001
No	226	(75.1)	140	(56.7)		
Health outcomes						

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Assistance while visiting a doctor (n = 549)						
Need assistance	50	(16.6)	11	(4.4)	20.4	< 0.001
No assistance needed	251	(83.4)	237	(95.6)		
Diabetes mellitus (n = 549)						
Yes	58	(19.21)	34	(13.77)	2.9	0.090
No	244	(80.79)	213	(86.23)		
Hypertension (n = 549)						
Yes	155	(51.3)	101	(40.9)	5.9	0.015
No	147	(48.7)	146	(59.1)		
Self-care (n = 550)						
Dependent	20	(6.6)	4	(1.6)	8.2	0.004
Independent	282	(93.4)	244	(98.4)		
Activities of daily living (n = 551)						
Having difficulty	32	(10.6)	8	(3.2)	10.9	0.001
No difficulty	271	(89.4)	240	(96.8)		
Anxiety (n = 548)						
Yes	63	(20.9)	32	(13.0)	5.8	0.016
No	239	(79.1)	214	(87.0)		
Participation						
Attending health classes (n = 547)						
No	189	(62.8)	112	(45.5)	23.1	< 0.001
Sometimes	105	(34.9)	111	(45.1)		
Always	7	(2.3)	23	(9.4)		
Empowerment						
Medication (n = 548)						
Without prescription	19	(6.3)	4	(1.6)	7.3	0.007
With prescription	283	(93.7)	242	(98.4)		
Self-management during illness (n = 548)						
Yes	67	(22.2)	80	(32.5)	7.4	0.007
No	235	(77.8)	166	(67.5)		

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Seeking a doctor (n = 547)						
Yes	228	(75.5)	167	(68.2)	3.6	0.057
No	74	(24.5)	78	(31.8)		

These 24 factors including personal, situational, socio-environmental determinants, health service use, health costs, health behaviors, health outcomes, participation, and empowerment were entered in the multiple logistic regressions, as shown in Table 2. Low HL was significantly associated with less health service use or self-paid vaccination in preventive medicine, such as not having a family doctor (adjusted odds ratio [AOR]: 1.46, 95% CI: 1.00–2.14) or not receiving self-paid vaccination (AOR: 1.28, 95% CI: 1.05–1.57). Older adults with poorer health behavior in the items searching online health information (AOR: 1.24, 95% CI: 1.01–1.52), less social participation while attending health classes (AOR: 1.38, 95% CI: 1.12–1.70), and worse empowerment of self-management during illness (AOR: 1.28, 95% CI: 1.05–1.57) also had low HL. In addition, the poorer health outcomes in older adults, such as having difficulty in daily living activities (AOR: 1.58, 95% CI: 1.00–2.52) and requiring assistance while seeing a doctor (AOR: 1.70, 95% CI: 1.16–2.48), may be associated with low HL. Particularly, we found that older adults whose dominant dialect other Mandarin had higher odds of low HL (AOR: 2.13, 95% CI: 1.72–2.64; Table 3). The indicators of model performance revealed a reasonably good fit in the training data set, including an acceptable pseudo R^2 = 0.27, and non-significance (p = 0.923) in the Hosmer–Lemeshow test.

Table 3
Estimations and statistics of selected predictors as revealed by multiple logistic regression. The goodness of fit is measured by McFadden's R^2 = 0.27 and *p* value of 0.92 in the Hosmer–Lemeshow test

Determining factors	*β*	SE	Adjusted ORs (95% CIs)	*p* value	*HL point*
Socioenvironmental determinants					
Dominant spoken dialect					
Taiwanese, Hakka, or other dialect	0.76	0.11	2.13 (1.72, 2.64)	< 0.001	+ 1
Mandarin	ref.				
Health service use					
Having family doctors					
No	0.38	0.19	1.46 (1.00, 2.14)	0.049	+ 1
Yes	ref.		1.00		
Health costs					
Self-paid pneumonia vaccination					
No	0.25	0.10	1.28 (1.05, 1.57)	0.016	+ 1
Yes	ref.		1.00		
Health behaviors					
Searching online health information					
No	0.21	0.10	1.24 (1.01, 1.52)	0.039	+ 1
Yes	ref.		1.00		
Health outcomes					
Assistance while visiting a doctor					
Need assistance	0.53	0.19	1.70 (1.16, 2.48)	0.006	+ 1
No assistance needed	ref.		1.00		
Activities of daily living					
Having difficulty	0.46	0.24	1.58 (1.00, 2.52)	0.052	+ 1
No difficulty	ref.		1.00		
Participation					
Attending health classes					
No	0.32	0.11	1.38 (1.12, 1.70)	0.003	+ 1
Yes	ref.		1.00		
Empowerment					

SE: standard error; ORs: odds ratios; CIs: confidence intervals

Determining factors	*β*	SE	Adjusted ORs (95% CIs)	*p* value	*HL point*
Self-management during illness					
No	0.25	0.10	1.28 (1.05, 1.57)	0.016	+ 1
Yes	ref.		1.00		
SE: standard error; ORs: odds ratios; CIs: confidence intervals					

Cross-validation was performed in the test data set (n = 96), among which, 92 participants finished all responses in the measurement of classification accuracy. The overall accuracy in classifying low literacy with various cutoff points is presented in Table 4. The optimal cutoff point was considered to be 5, yielding a sensitivity and specificity of 62.0% and 76.2%, respectively. By using a score of 5 out of 8 to predict the low HL level, the obtained PPV and NPV were 75.6% and 62.7%, respectively. Figure 2 presents the predictive ability of the scoring algorithm among older adults in the test data set. The indicators of model performance revealed a reasonably satisfactory performance with an AUC of 0.71 (95% CI: 0.61–0.81).

Table 4
Overall accuracy of low health literacy classification with various cut-off points (optimal cutoff = 5)

Cutoff value	Test data set (n = 92)				
	Overall accuracy[a] n (%)	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %
1	50 (54.3)	100.0	0.0	54.3	NA[b]
2	51 (55.4)	100.0	2.4	54.9	100.0
3	53 (57.6)	90.0	19.0	57.0	61.5
4	57 (62.0)	74.0	47.6	62.7	60.6
5	63 (68.5)	62.0	76.2	75.6	62.7
6	58 (63.0)	38.0	92.9	86.4	55.7
7	44 (47.8)	4.0	100.0	100.0	46.7
8	43 (46.7)	2.0	100.0	100.0	46.2

[a] Agreement between predicted and observed level health literacy (low or high).

[b] NA: not available; denominator is zero.

4. Discussion And Conclusion

4.1. Discussion

To the best or our knowledge, this is the first study to develop a model for predicting the HL of community-dwelling older adults. This algorithm-based model was well calibrated by integrating HL-related factors in the model of the

European Health Literacy Survey Consortium and is useful in HL risk prediction among older adults. In addition, it has a modest ability to discriminate between older adults with high HL and low HL.

In this study, we integrated variables associated with both medical and public health perspectives in the aforementioned HL model of the European Health Literacy Survey Consortium and proposed a simple scoring algorithm. The scoring system dichotomizes older adults into high-risk (cutoff ≥ 5) and low-risk (cutoff < 5) populations to maximize the sensitivity and specificity of low HL prediction. Based on the proposed cutoff points, among the 92 older adults in the test data set, 63 (68.5%) with a cutoff ≥ 5 were recommended to undergo further HL intervention, although only 31 (62.0%) actually had low HL, resulting in a positive predictive value of 75.6%. Given the importance of early identification and strategy provision for community-dwelling older adults at high risk of low HL, the proposed scoring algorithm proposed can be considered useful in community practice.

This conceptual framework integrating medical and public health perspectives developed by the European Health Literacy Survey Consortium is suitable for exploring the most relevant determinants of HL levels in older adults. Eight predictors were identified to be significantly associated with HL levels: one socio-environmental determinant (i.e., dominant spoken dialect) and seven HL-related factors including health services (i.e., having a family doctor), health cost (i.e., self-paid pneumonia vaccination), health behaviors (i.e., searching online health information), health outcomes (i.e., assistance while visiting a doctor and activities of daily living), participation (i.e., attending health classes), and empowerment (i.e., self-management during illness). The results for seven identified predictors of HL-related factors were consistent with those of previous studies, for example, having a family doctor (7), costs for self-paid vaccination (32), searching online health information (9), functional status such as difficulty in daily activities and assistance while visiting doctors (32, 33), participation in health classes (34), and self-efficacy in disease management (35). However, our study found that personal and situational factors did not affect the HL among older adults. Previous studies have documented that personal determinants of age, education level, and working status as well as situational and environmental determinants including marriage and residential area were significantly associated with HL levels (14, 36). This difference might be because personal and situational determinants were proximal factors of HL, which are influenced and displaced by a more distal and upstream factor (societal and environmental determinants) (37).

Our risk prediction tool provides primary public health workers with an easy-to-use scoring system that examines relevant variables. Users can rapidly predict low HL and thus identify community-dwelling older adults who may require further health assistance by evaluating their HL-related personal, situational, and environmental factors as well as the health behavior and outcomes. Hospitalization and mortality due to poor HL in older adults can be avoided through early identification and intervention. Therefore, this assessment tool should be promptly extended to broader communities.

Our study had some limitations. First, this was a cross-sectional study by convenience sampling from northern, central, and southern Taiwan. Therefore, potential selection bias might also exist. Second, this study relied on the 47-item HLS-EU-Q self-reported questionnaire for the criteria for HL. Further more objective HL assessments might be required to recognize the functional HL in order to avoid the potential for outcome misclassification bias. Third, the high prevalence rate of low HL (54.9%) among our sample may influence the capacity of prediction (i.e., PPV) of this algorithm when applied in other populations. Therefore, when it applies to a population with a lower prevalence of low HL, the older adults with positive results of low HL may in fact have higher HL. Additionally, we excluded older adults who could not pass the Mini-Cog screening or follow instructions to complete the assessment. Our model may, therefore, not be generalizable to the entire population of older adults. Thus, this model is not

recommended to be used in individuals with cognitive impairments or dementia who may have difficulty understanding the instructions. Larger population studies with prospective longer term outcome measures are necessary to validate our study.

4.2. Conclusion

We proposed a simple clinical scoring algorithm with substantial sensitivity and satisfactory specificity to assess the risk of low HL among community-dwelling older adults.

4.3 Practice implications

This scoring algorithm not only helps clinicians to assess and identify the HL level in older adults but also assists researchers to establish intervention strategies for predictors of low HL. However, for further population-based application for early detection of older adults at a high risk of low HL, prospective trials should study the implementation and utility of this algorithm in the community.

Abbreviations

HL: Health literacy; HC:Health care; DP:Disease prevention; HP:Health promotion; OR:Odds ratio; PPV:Positive predictive value; NPV:Negative predictive value; ROC:Receiver operating characteristic; AUC:Area under curve; AOR:Adjusted odds ratio

Declarations

Ethics approval and consent to participate:

This study was approved by Taipei Medical University-Joint Institutional Review Board (N201804046) and National Taiwan University Hospital (201804057RIND).

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

All of authors declare that have no competing interests

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Authors' contributions

WHH is expected to have made substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data and have drafted the work or substantively revised it; YMC is expected to have made substantial contributions to the conception; MJC is expected to have made substantial contributions to the acquisition, analysis, interpretation of data; HWT is expected to have made substantial contributions to design of the work and analysis, interpretation of data; CTS is expected to have made substantial contributions to the conception, the acquisition of data and have drafted the work or substantively revised it; DSH is expected to have made substantial contributions to the conception, the acquisition of data and have drafted the work or substantively revised it; DCC is expected to have made substantial contributions to the conception and have drafted the work or substantively revised it; KNK is expected to have made substantial contributions to the conception and have drafted the work or substantively revised it; CYL is expected to have made substantial contributions to have drafted the work or substantively revised it. The author (s) read and approved the final manuscript.

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Tables

Table 1. Sociodemographic characteristics of study participants across the core, training, and test data sets

	Core data set (n = 648)		Training data set (n = 552)		Test data set (n = 96)	
	Health literacy, n (%)					
Variables	Low	High	Low	High	Low	High
Sex						
Male	138 (57.3)	103 (47.7)	117 (57.9)	85 (42.1)	21 (53.9)	18 (46.1)
Female	216 (53.3)	189 (46.7)	184 (52.9)	164 (47.1)	32 (56.1)	25 (43.9)
Age (years)						
65–70	131 (51.8)	122 (48.2)	111 (51.9)	103 (48.1)	20 (51.3)	19 (48.7)
71–80	151 (51.5)	142 (48.5)	133 (52.4)	121 (47.6)	18 (46.2)	21 (53.8)
≥81	74 (72.6)	28 (27.4)	59 (70.2)	25 (29.8)	15 (83.3)	3 (16.7)
Education level						
Illiterate or elementary school	124 (69.3)	55 (30.7)	104 (67.5)	50 (32.5)	20 (80.0)	5 (20.0)
Junior and senior high school	139 (57.2)	104 (42.8)	117 (57.6)	86 (42.4)	22 (55.0)	18 (45.0)
College degree or above	88 (40.2)	31 (58.8)	77 (40.7)	112 (59.3)	11 (36.7)	19 (63.3)
Marital status						
Married	240 (51.8)	223 (48.2)	206 (52.2)	189 (47.8)	34 (50.0)	34 (50.0)
Single/divorced/widowed	115 (62.5)	69 (37.5)	96 (61.5)	60 (38.5)	19 (67.9)	9 (32.1)
Past occupation (n = 579)						
Manager or professional	59 (37.6)	98 (62.4)	52 (38.5)	83 (61.5)	7 (31.8)	15 (68.2)
Sales/administration/service	84 (57.5)	62 (42.5)	67 (55.4)	54 (44.6)	17 (68.0)	8 (32.0)
Technical/production/operators/ laborers//forestry/farmer/fisher	86 (66.7)	43 (33.3)	72 (67.9)	34 (32.1)	14 (60.9)	9 (39.1)
Housewife/unemployed	90 (61.2)	57 (38.8)	77 (60.6)	50 (39.4)	13 (65.0)	7 (35.0)
Monthly income (NTD)						
No income	108 (59.3)	74 (40.7)	95 (59.8)	64 (40.2)	13 (56.5)	10 (43.5)

<20,000	118 (60.2)	78 (39.8)	95 (57.9)	69 (42.1)	23 (71.9)	9 (28.1)
20,001–50,000	81 (50.0)	81 (50.0)	69 (50.4)	68 (49.4)	12 (48.0)	13 (52.0)
≥50,001	42 (42.9)	56 (57.1)	37 (45.1)	45 (54.9)	5 (31.3)	11 (68.7)

NTD: New Taiwan Dollar

Table 2. The 24 factors significantly correlated with health literacy level based on Pearson's chi-squared tests in the training data set (n = 552)

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Personal determinants						
Medical training (n = 544)						
Yes	12	(4.0)	23	(9.4)	6.5	0.011
No	287	(96.0)	222	(90.6)		
Education level (n = 546)						
Illiterate or elementary school	104	(34.9)	50	(20.2)	25.8	<0.001
Junior and senior high school	117	(39.3)	86	(34.7)		
College degree or above	77	(25.8)	112	(45.2)		
Past occupation (n = 489)						
Manager or professional	52	(19.4)	83	(37.6)	23.6	<0.001
Sales/administration/service	67	(25.0)	54	(24.4)		
Technical/production/operators/ laborers/forestry/farmer/fisher	72	(26.9)	34	(15.4)		
Housewife/unemployed	77	(28.7)	50	(22.6)		
Age (n = 552, years)						
65–70	111	(36.6)	103	(41.4)	9.4	0.009
71–80	133	(43.9)	121	(48.6)		
≥81	59	(19.5)	25	(10.0)		
Monthly income (n = 542, NTD)						
No income	95	(32.1)	64	(26.0)	6.4	0.094
<20,000	95	(32.1)	69	(28.0)		
20,001–50,000	69	(23.3)	68	(27.6)		
≥50,001	37	(12.5)	45	(18.3)		
Situational determinants						
Marriage (n = 551)						
Single/divorced/widowed	96	(31.8)	60	(24.1)	4.0	0.046
Married	206	(68.2)	189	(75.9)		
Socioenvironmental determinants						
Dominant spoken dialect (n = 551)						
Taiwanese, Hakka, or other dialect	154	(51.0)	41	(16.5)	71.2	<0.001

Mandarin	148	(49.0)	208	(83.5)		
Residential area (n = 552)						
Taipei city	158	(52.1)	157	(63.1)	6.6	0.010
Other cities	145	(47.9)	92	(36.9)		
Health service use						
Having a family doctor (n = 548)						
Yes	16	(5.3)	24	(9.8)	4.0	0.046
No	286	(94.7)	222	(90.2)		
Health costs						
Pneumonia self-paid vaccination (n = 547)						
Yes	85	(28.4)	100	(40.3)	8.6	0.003
No	214	(71.6)	148	(59.7)		
Health behaviors						
Exercise frequency (n = 550)						
No exercise	63	(20.9)	27	(10.9)	9.9	0.007
Every day	114	(37.7)	107	(43.1)		
Weekly or monthly	125	(41.4)	114	(46.0)		
Active seeking of health information (n = 549)						
No	63	(20.9)	22	(8.9)	26.3	<0.001
Sometimes	172	(57.1)	130	(52.4)		
Always	66	(21.9)	96	(38.7)		
Health examination in past year (n = 539)						
Yes	168	(56.8)	156	(64.2)	3.1	0.079
No	128	(43.2)	87	(35.8)		
Searching online health information (n = 548)						
Yes	75	(24.9)	107	(43.3)	20.7	<0.001
No	226	(75.1)	140	(56.7)		
Health outcomes						
Assistance while visiting a doctor (n = 549)						
Need assistance	50	(16.6)	11	(4.4)	20.4	<0.001
No assistance needed	251	(83.4)	237	(95.6)		
Diabetes mellitus (n = 549)						

Yes	58	(19.21)	34	(13.77)	2.9	0.090
No	244	(80.79)	213	(86.23)		
Hypertension (n = 549)						
Yes	155	(51.3)	101	(40.9)	5.9	0.015
No	147	(48.7)	146	(59.1)		
Self-care (n = 550)						
Dependent	20	(6.6)	4	(1.6)	8.2	0.004
Independent	282	(93.4)	244	(98.4)		
Activities of daily living (n = 551)						
Having difficulty	32	(10.6)	8	(3.2)	10.9	0.001
No difficulty	271	(89.4)	240	(96.8)		
Anxiety (n = 548)						
Yes	63	(20.9)	32	(13.0)	5.8	0.016
No	239	(79.1)	214	(87.0)		
Participation						
Attending health classes (n = 547)						
No	189	(62.8)	112	(45.5)	23.1	<0.001
Sometimes	105	(34.9)	111	(45.1)		
Always	7	(2.3)	23	(9.4)		
Empowerment						
Medication (n = 548)						
Without prescription	19	(6.3)	4	(1.6)	7.3	0.007
With prescription	283	(93.7)	242	(98.4)		
Self-management during illness (n = 548)						
Yes	67	(22.2)	80	(32.5)	7.4	0.007
No	235	(77.8)	166	(67.5)		
Seeking a doctor (n = 547)						
Yes	228	(75.5)	167	(68.2)	3.6	0.057
No	74	(24.5)	78	(31.8)		

Table 3. Estimations and statistics of selected predictors as revealed by multiple logistic regression. The goodness of fit is measured by McFadden's R^2 = 0.27 and *p* value of 0.92 in the Hosmer–Lemeshow test

Determining factors	*β*	SE	Adjusted ORs (95% CIs)	*p* value	*HL point*
Socioenvironmental determinants					
Dominant spoken dialect					
Taiwanese, Hakka, or other dialect	0.76	0.11	2.13 (1.72, 2.64)	<0.001	+1
Mandarin	ref.				
Health service use					
Having family doctors					
No	0.38	0.19	1.46 (1.00, 2.14)	0.049	+1
Yes	ref.		1.00		
Health costs					
Self-paid pneumonia vaccination					
No	0.25	0.10	1.28 (1.05, 1.57)	0.016	+1
Yes	ref.		1.00		
Health behaviors					
Searching online health information					
No	0.21	0.10	1.24 (1.01, 1.52)	0.039	+1
Yes	ref.		1.00		
Health outcomes					
Assistance while visiting a doctor					
Need assistance	0.53	0.19	1.70 (1.16, 2.48)	0.006	+1
No assistance needed	ref.		1.00		
Activities of daily living					
Having difficulty	0.46	0.24	1.58 (1.00, 2.52)	0.052	+1
No difficulty	ref.		1.00		
Participation					
Attending health classes					
No	0.32	0.11	1.38 (1.12, 1.70)	0.003	+1
Yes	ref.		1.00		
Empowerment					
Self-management during illness					
No	0.25	0.10	1.28 (1.05, 1.57)	0.016	+1
Yes	ref.		1.00		

SE: standard error; ORs: odds ratios; CIs: confidence intervals

Table 4. Overall accuracy of low health literacy classification with various cut-off points (optimal cutoff = 5)

Cutoff value	Test data set (n = 92)				
	Overall accuracy[a] n (%)	Sensitivity %	Specificity %	Positive predictive value %	Negative predictive value %
1	50 (54.3)	100.0	0.0	54.3	NA[b]
2	51 (55.4)	100.0	2.4	54.9	100.0
3	53 (57.6)	90.0	19.0	57.0	61.5
4	57 (62.0)	74.0	47.6	62.7	60.6
5	63 (68.5)	62.0	76.2	75.6	62.7
6	58 (63.0)	38.0	92.9	86.4	55.7
7	44 (47.8)	4.0	100.0	100.0	46.7
8	43 (46.7)	2.0	100.0	100.0	46.2

[a] Agreement between predicted and observed level health literacy (low or high).

[b] NA: not available; denominator is zero.

Appendix

Appendix Table 1

Association of health literacy level in the training data set (n = 552) with 52 predictors obtained using Pearson's chi-squared tests

Scope and predictor	Health literacy, n (%)					*p* value
	Low		High			
Personal determinants						
Medical training (n = 544)						
Yes	12	(4.0)	23	(9.4)	6.5	0.011
No	287	(96.0)	222	(90.6)		
Education level (n = 546)						
Illiterate or elementary school	104	(34.9)	50	(20.2)	25.8	<0.001
Junior and senior high school	117	(39.3)	86	(34.7)		
College degree or above	77	(25.8)	112	(45.2)		
Past occupation (n = 489)						
Manager or professional	52	(19.4)	83	(37.6)	23.6	<0.001
Sales/administration/service	67	(25.0)	54	(24.4)		
Technical/production/operators/ laborers/forestry/farmer/fisher	72	(26.9)	34	(15.4)		
Housewife/unemployed	77	(28.7)	50	(22.6)		
Age (n = 552, years)						
65–70	111	(36.6)	103	(41.4)	9.4	0.009
71–80	133	(43.9)	121	(48.6)		
≥81	59	(19.5)	25	(10.0)		
Sex (n = 552)						
Male	117	(38.9)	85	(34.1)	1.3	0.252
Female	184	(61.1)	164	(65.9)		
Monthly income (n = 542, NTD)						
No income	95	(32.1)	64	(26.0)	6.4	0.094
<20,000	95	(32.1)	69	(28.0)		
20,001–50,000	69	(23.3)	68	(27.6)		
≥50,001	37	(12.5)	45	(18.3)		
Situational determinants						
Marriage (n = 551)						
Single/divorces/widowed	96	(31.8)	60	(24.1)	4.0	0.046
Married	206	(68.2)	189	(75.9)		

Relationship with neighborhood (n = 547)						
Good	183	(61.0)	140	(56.7)	1.1	0.306
Poor	117	(39.0)	107	(43.3)		
Need to be accompanied (n = 548)						
Always	144	(48.0)	109	(44.0)	1.8	0.405
Sometimes	68	(22.7)	53	(21.4)		
No	88	(29.3)	86	(34.7)		
Socioenvironmental determinants						
Dominant spoken dialect (n = 551)						
Taiwanese, Hakka, or other dialect	154	(51.0)	41	(16.5)	71.2	<0.001
Mandarin	148	(49.0)	208	(83.5)		
Residential area (n = 552)						
Taipei city	158	(52.1)	157	(63.1)	6.6	0.010
Other cities	145	(47.9)	92	(36.9)		
Attending religious activities (n = 545)						
Yes	122	(40.8)	108	(43.9)	0.5	0.466
No	177	(59.2)	138	(56.1)		
Health service use						
Having family doctor (n = 548)						
Yes	16	(5.3)	24	(9.8)	4.0	0.046
No	286	(94.7)	222	(90.2)		
Medical tracking for chronic diseases in past year (n = 497)						
Yes	209	(77.1)	163	(72.1)	1.6	0.201
No	62	(22.9)	63	(27.8)		
Hospitalization in past year (n = 546)						
Yes	44	(14.7)	40	(16.2)	0.2	0.664
No	255	(85.3)	207	(83.8)		
Emergency hospitalization in past year (n = 546)						
Yes	55	(18.5)	47	(19.0)	0.0	0.883
No	243	(81.5)	201	(81.1)		
Cancer screening in past year (n = 546)						
Yes	86	(28.9)	85	(34.3)	1.8	0.174

No	212	(71.1)	163	(65.7)		
Influenza vaccine in past year (n = 548)						
Yes	168	(55.8)	147	(59.5)	0.8	0.383
No	133	(44.2)	100	(40.5)		
Health costs						
Pneumonia self-paid vaccination (n = 547)						
Yes	85	(28.4)	100	(40.3)	8.6	0.003
No	214	(71.6)	148	(59.7)		
Cost for health-related products or foods (n = 547)						
Yes	173	(57.7)	150	(60.7)	0.5	0.469
No	127	(42.3)	97	(39.3)		
Health behaviors						
Exercise frequency (n = 550)						
No exercise	63	(20.9)	27	(10.9)	9.9	0.007
Every day	114	(37.7)	107	(43.1)		
Weekly or monthly	125	(41.4)	114	(46.0)		
Active seeking of health information (n = 549)						
No	63	(20.9)	22	(8.9)	26.3	<0.001
Sometimes	172	(57.1)	130	(52.4)		
Always	66	(21.9)	96	(38.7)		
Health examination in past year (n = 539)						
Yes	168	(56.8)	156	(64.2)	3.1	0.079
No	128	(43.2)	87	(35.8)		
Betel nut consumption (n = 549)						
Yes	16	(5.3)	11	(4.4)	0.2	0.649
No	286	(94.7)	236	(95.6)		
Smoking (n = 549)						
Yes	60	(19.9)	39	(15.8)	1.5	0.216
No	242	(80.1)	208	(84.2)		
Alcohol drinking (n = 544)						
Yes	51	(17.1)	40	(16.3)	0.1	0.791
No	247	(82.9)	206	(83.7)		

Searching online health information (n = 548)						
Yes	75	(24.9)	107	(43.3)		
No	226	(75.1)	140	(56.7)	20.7	<0.001
Health or working priority (n = 546)						
Health priority	228	(76.3)	171	(69.2)	4.4	0.108
Working priority	33	(11.0)	29	(11.7)		
Both	38	(12.7)	47	(19.0)		
Health outcomes						
Assistance while visiting a doctor (n = 549)						
Need assistance	50	(16.6)	11	(4.4)	20.4	<0.001
No assistance needed	251	(83.4)	237	(95.6)		
Need to have any drug (n = 548)						
Yes	302	(100.0)	246	(100.0)	NA	NA
No	0	(0.0)	0	(0.0		
Diabetes mellitus (n = 549)						
Yes	58	(19.21)	34	(13.77)	2.9	0.090
No	244	(80.79)	213	(86.23)		
Hypertension (n = 549)						
Yes	155	(51.3)	101	(40.9)	5.9	0.015
No	147	(48.7)	146	(59.1)		
Gout (n = 549)						
Yes	15	(5.0)	12	(4.9)	0.0	0.953
No	287	(95.0)	235	(95.1)		
Cardiovascular disease (n = 549)						
Yes	58	(19.2)	38	(15.4)	1.4	0.241
No	244	(80.8)	209	(84.6)		
Chronic obstructive pulmonary disease (n = 549)						
Yes	3	(1.0)	2	(1.0)	0.1	0.822
No	299	(99.0)	245	(99.0)		
Asthma (n = 549)						
Yes	9	(3.0)	11	(4.4)	0.8	0.359
No	293	(97.0)	236	(95.6)		

Degenerative joint disease (n = 549)						
Yes	71	(23.5)	50	(20.1)	0.8	0.358
No	231	(76.5)	197	(79.8)		
Mental disease (n = 548)						
Yes	8	(2.7)	2	(0.8)	3.4	0.182
No	293	(97.3)	245	(99.2)		
Cancer (n = 549)						
Yes	15	(5.0)	15	(6.1)	0.3	0.571
No	287	(95.0)	232	(93.9)		
Self-care (n = 550)						
Dependent	20	(6.6)	4	(1.6)	8.2	0.004
Independent	282	(93.4)	244	(98.4)		
Activities of daily living (n = 551)						
Having difficulty	32	(10.6)	8	(3.2)	10.9	0.001
No difficulty	271	(89.4)	240	(96.8)		
Anxiety (n = 548)						
Yes	63	(20.9)	32	(13.0)	5.8	0.016
No	239	(79.1)	214	(87.0)		
Pain (n = 548)						
Yes	129	(42.7)	93	(37.8)	1.4	0.244
No	173	(57.3)	153	(62.2)		
Health comparison (n = 548)						
Better	54	(17.9)	46	(18.6)	0.7	0.700
Similar	163	(54.2)	140	(56.7)		
Worse	84	(27.9)	61	(24.7)		
Participation						
Attending health classes (n = 547)						
No	189	(62.8)	112	(45.5)	23.1	<0.001
Sometimes	105	(34.9)	111	(45.1)		
Always	7	(2.3)	23	(9.4)		
Attending community activities (n = 547)						
Yes	133	(44.5)	121	(48.8)	1.0	0.315

No	166	(55.5)	127	(51.2)		
Empowerment						
Medication (n = 548)						
Without prescription	19	(6.3)	4	(1.6)	7.3	0.007
With prescription	283	(93.7)	242	(98.4)		
Self-management during illness (n = 548)						
Yes	67	(22.2)	80	(32.5)	7.4	0.007
No	235	(77.8)	166	(67.5)		
Seeking a doctor (n = 547)						
Yes	228	(75.5)	167	(68.2)	3.6	0.057
No	74	(24.5)	78	(31.8)		
Taking dietary supplements (n = 548)						
Yes	19	(6.3)	17	(6.9)	0.1	0.771
No	283	(93.7)	229	(93.1)		
Taking Chinese medicine (n = 548)						
Yes	28	(9.3)	23	(9.4)	0.0	0.975
No	274	(90.3)	223	(90.7)		
Tendency to ignore the sickness (n = 548)						
Yes	10	(3.3)	9	(3.7)	0.1	0.825
No	292	(96.7)	237	(96.3)		

Figures

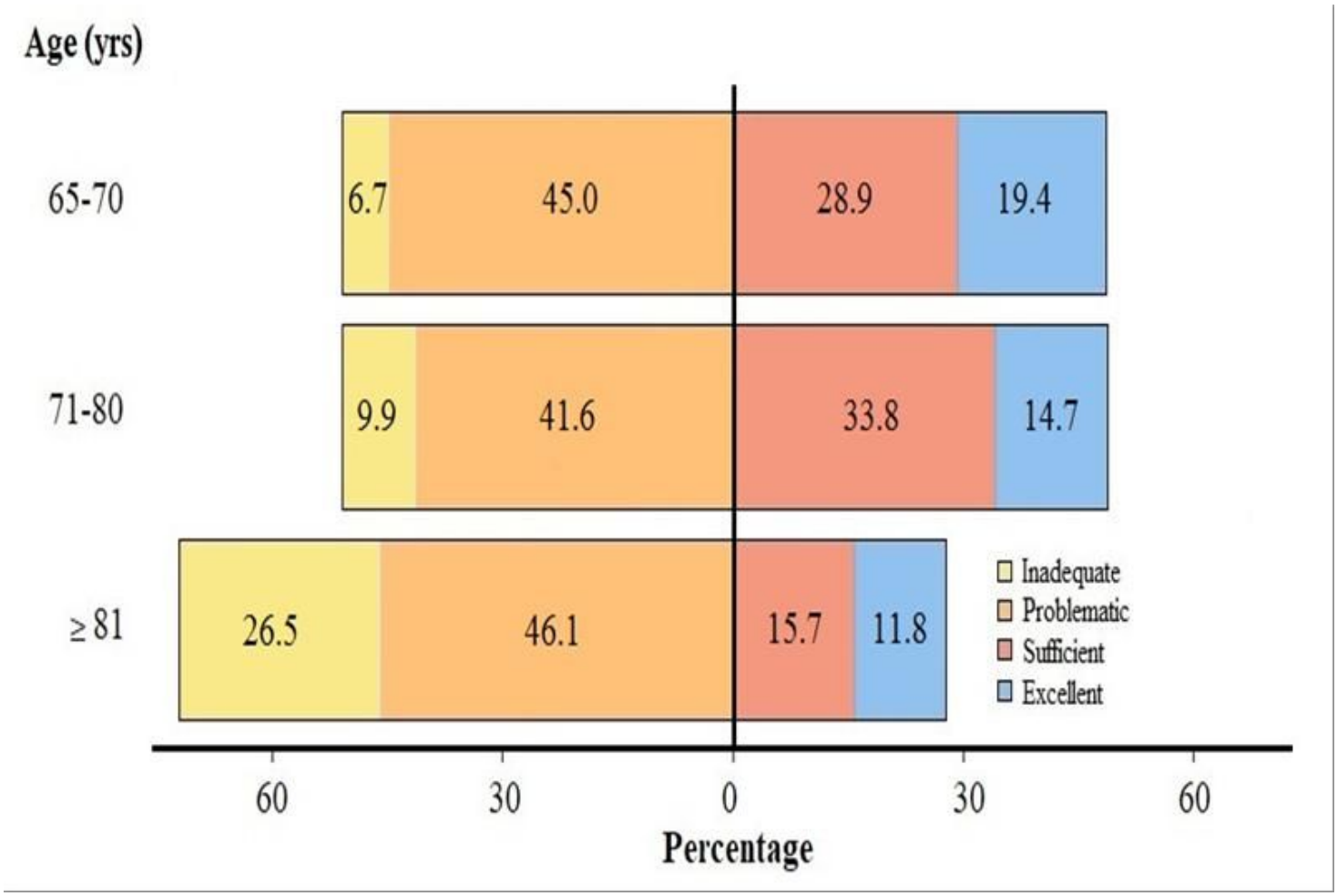

Figure 1

Age-specific health literacy levels

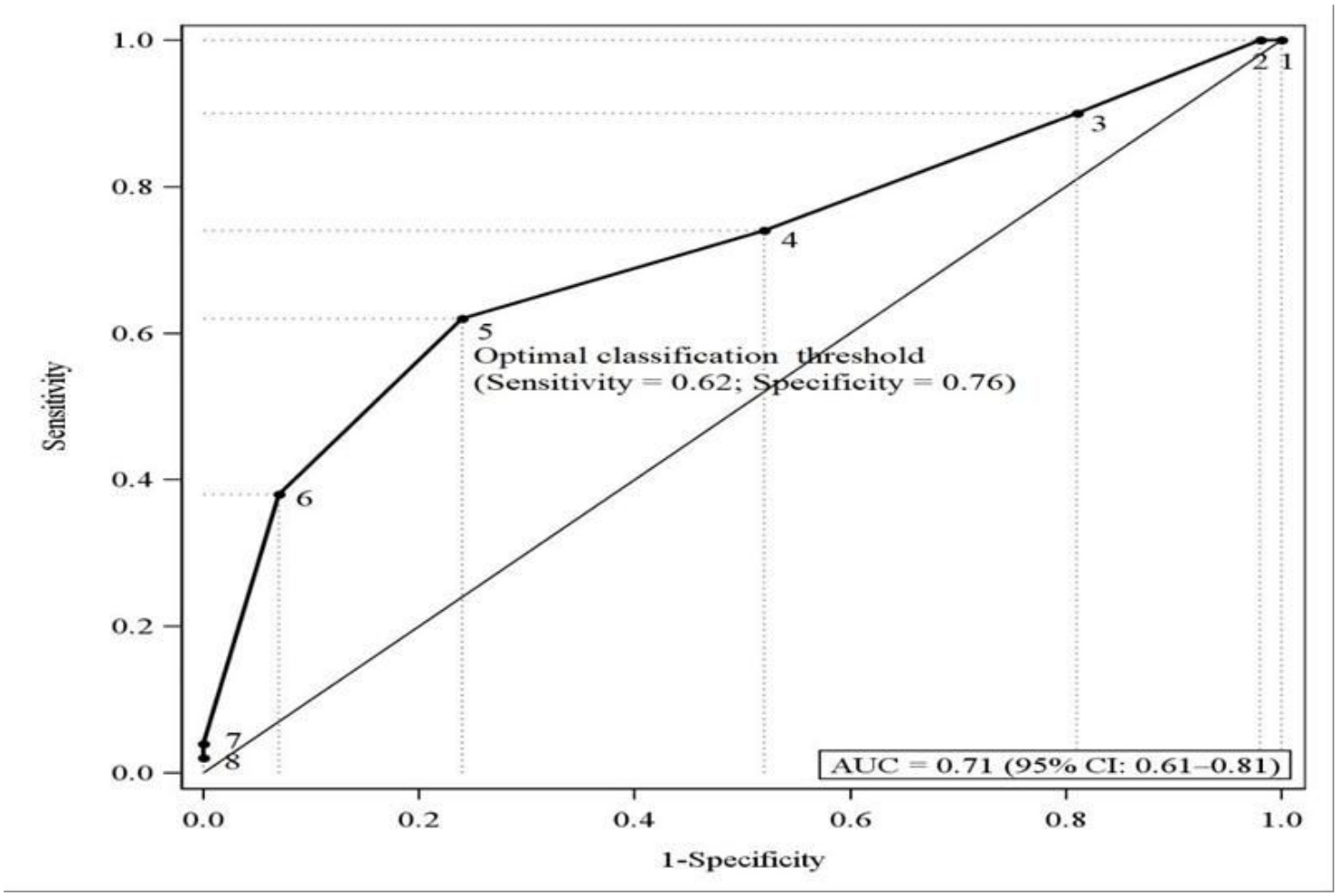

Figure 2

ROC curve and c-statistics of the fitting test in the test data set. The AUC was 0.71 (95% CI: 0.61–0.81), indicating acceptable discrimination