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

Wen-Hsuan Hou  
Taipei Medical University

Yao-Mao Chang  
Taipei Medical University

Mu-Jean Chen  
National Health Research Institutes

Han-Wei Tsai  
Taipei Medical University

Chien-Tien Su  
Taipei Medical University

Der-Sheng Han  
National Taiwan University Hospital Beihu Branch

Ding-Cheng Chan  
National Taiwan University Hospital

KEN N. Kuo  
Taipei Medical University

Chung-Yi Li (cyli99@mail.ncku.edu.tw)  
National Cheng Kung University College of Medicine  https://orcid.org/0000-0002-0321-8908

Research article

Keywords: Health literacy, Prediction model, Older adults, Scoring algorithm

DOI: https://doi.org/10.21203/rs.3.rs-54229/v1

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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 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:
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:

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

where $p$ denotes the probability of low HL in older adults, $\alpha$ is the intercept of the multiple regression, and $\beta_i$ is the slope of the main predictor ($i = 1, 2, ..., n$). Odds ratio (OR) was estimated using $exp(\beta_i)$. The measured $\beta_i$, $exp(\beta_i)$ 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.
| Variables                              | Core data set (n = 648) | Training data set (n = 552) | Test data set (n = 96) |
|----------------------------------------|-------------------------|-----------------------------|------------------------|
|                                        | Low (n)  | High (n (%)) | Low (n)  | High (n (%)) | Low (n)  | High (n (%))  |
| 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)    |
|                                       | 151 (51.5)| 142 (48.5)   | 133 (52.4)| 121 (47.6)   | 18 (46.2)| 21 (53.8)    |
| 71–80                                  |           |               |           |               |           |               |
| ≥ 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
| Monthly income (NTD) | Core data set (n = 648) | Training data set (n = 552) | Test data set (n = 96) |
|----------------------|-------------------------|-----------------------------|------------------------|
| 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  | 23   | 6.5     | 0.011  |
| No                        | 287 | 222  |         |        |
| **Education level (n = 546)** |     |      |         |
| Illiterate or elementary school | 104 | 50   | 25.8    | < 0.001|
| Junior and senior high school | 117 | 86   | 23.6    | < 0.001|
| College degree or above   | 77  | 112  |         |        |
| **Past occupation (n = 489)** |     |      |         |
| Manager or professional   | 52  | 83   | 23.6    | < 0.001|
| Sales/administration/service | 67  | 54   | 24.4    |        |
| Technical/production/operators/laborers/forestry/farmer/fisher | 72  | 34   | 15.4    |        |
| Housewife/unemployed      | 77  | 50   | 22.6    |        |
| **Age (n = 552, years)**  |     |      |         |
| 65–70                     | 111 | 103  | 9.4     | 0.009  |
| 71–80                     | 133 | 121  |         |        |
| ≥81                       | 59  | 25   | 10.0    |        |
| **Monthly income (n = 542, NTD)** |     |      |         |
| No income                 | 95  | 64   | 6.4     | 0.094  |
| < 20,000                  | 95  | 69   | 28.0    |        |
| 20,001–50,000             | 69  | 68   | 27.6    |        |
| ≥ 50,001                  | 37  | 45   | 18.3    |        |
| Situational determinants  |     |      |         |
| **Marriage (n = 551)**    |     |      |         |
| Single/divorced/widowed   | 96  | 60   | 4.0     | 0.046  |
| Married                   | 206 | 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  | 41   | 71.2  | < 0.001 |
| Mandarin                                 | 148  | 208  |       |         |
| Residential area (n = 552)               |      |      |       |
| Taipei city                              | 158  | 157  | 6.6   | 0.010   |
| Other cities                             | 145  | 92   |       |         |
| Health service use                       |      |      |       |
| Having a family doctor (n = 548)         |      |      |       |
| Yes                                      | 16   | 24   | 4.0   | 0.046   |
| No                                       | 286  | 222  |       |         |
| Health costs                             |      |      |       |
| Pneumonia self-paid vaccination (n = 547)|      |      |       |
| Yes                                      | 85   | 100  | 8.6   | 0.003   |
| No                                       | 214  | 148  |       |         |
| Health behaviors                         |      |      |       |
| Exercise frequency (n = 550)             |      |      |       |
| No exercise                              | 63   | 27   | 9.9   | 0.007   |
| Every day                                | 114  | 107  |       |         |
| Weekly or monthly                        | 125  | 114  |       |         |
| Active seeking of health information (n = 549)|      |      |       |
| No                                       | 63   | 22   | 26.3  | < 0.001 |
| Sometimes                                | 172  | 130  |       |         |
| Always                                   | 66   | 96   |       |         |
| Health examination in past year (n = 539)|      |      |       |
| Yes                                      | 168  | 156  | 3.1   | 0.079   |
| No                                       | 128  | 87   |       |         |
| Searching online health information (n = 548)|      |      |       |
| Yes                                      | 75   | 107  | 20.7  | < 0.001 |
| No                                       | 226  | 140  |       |         |
| 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)|         |         |
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 | $\beta$ | 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                                      | \( \beta \) | 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).

| Cutoff value | Test data set (n = 92) | Overall accuracy\(^a\) | Sensitivity % | Specificity % | Positive predictive value % | Negative predictive value % |
|--------------|------------------------|------------------------|--------------|---------------|----------------------------|-----------------------------|
|              | n (%)                  |                        |              |               |                            |                             |
| 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 of 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 $\geq 5$) 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 $\geq 5$ 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

Funding:

This study was supported by research grants from the Taiwan National Health Research Institutes (MOHW107-TDU-M-212-133001-107-FR-04). The funder was not involved in study design, and will not be involved in the collection, analysis or interpretation of data.
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.

Acknowledgments:

We thank Wu-Shou Chang from the Asian Health Literacy Association for authorizing the use of the Mandarin Chinese version of the HLS-EU-Q47.

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Tables

Table 1. Sociodemographic characteristics of study participants across the core, training, and test data sets
| Variables                                              | Core data set (n = 648) | Training data set (n = 552) | Test data set (n = 96) |
|--------------------------------------------------------|-------------------------|----------------------------|------------------------|
|                                                       | 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/                        | 86 (66.7)               | 43 (33.3)                  | 72 (67.9)              | 34 (32.1)                  | 14 (60.9)              | 9 (39.1)               |
| laborers//forestry/farmer/fisher                       | 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)              |
|                | 118  | 78   | 95   | 69   | 23   | 9    |
|----------------|------|------|------|------|------|------|
|                | (60.2)| (39.8)| (57.9)| (42.1)| (71.9)| (28.1)|
| <20,000        |      |      |      |      |      |      |
| 20,001–50,000  | 81   | 81   | 69   | 68   | 12   | 13   |
|                | (50.0)| (50.0)| (50.4)| (49.4)| (48.0)| (52.0)|
| ≥50,001        | 42   | 56   | 37   | 45   | 5    | 11   |
|                | (42.9)| (57.1)| (45.1)| (54.9)| (31.3)| (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/             | 72 (26.9)  | 34 (15.4) |         |         |
| laborers/forestry/farmer/fisher             |             |          |         |
| 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 (%) | No (%) |
|------------------|---------|--------|
| **Hypertension** (n = 549) |
| Yes              | 58 (19.21) | 34 (13.77) | 2.9 | 0.090 |
| No               | 244 (80.79) | 213 (86.23) |    |      |
| **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                  | $\beta$ | 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<sup>a</sup> | Sensitivity | Specificity | Positive predictive value | Negative predictive value |
|--------------|------------------------|-----------------------------|-------------|-------------|--------------------------|--------------------------|
|              | n (%)                  |                             | %           | %           | %                        | %                        |
| 1            | 50 (54.3)              | 100.0                       | 0.0         | 54.3        | NA<sup>b</sup>            |                          |
| 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                     |                          |

<sup>a</sup> Agreement between predicted and observed level health literacy (low or high).

<sup>b</sup> 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 (n = 544)          |         |
| **Personal determinants**                 |                        |         |
| **Medical training**                      |                        |         |
| Yes                                       | 12 (4.0)               | 23 (9.4)| 6.5  0.011 |
| No                                        | 287 (96.0)             | 222 (90.6) |     |
| **Education level**                       |                        |         |
| 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**                       |                        |         |
| 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**                        |                        |         |
| 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       |        |        |       |      |       |
| Health behaviors | Yes | No |
|------------------|-----|----|
| **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)                                |
| 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)                                  |
|                                  | Yes | No  |  |  |  |  |
|----------------------------------|-----|-----|---|---|---|---|
| **Degenerative joint disease (n = 549)** |     |     |   |   |   |   |
| Yes                              | 71  | 50  | (23.5) | (20.1) | 0.8 | 0.358 |
| No                               | 231 | 197 | (76.5) | (79.8) |     |     |
| **Mental disease (n = 548)**     |     |     |   |   |   |   |
| Yes                              | 8   | 2   | (2.7)  | (0.8)  | 3.4 | 0.182 |
| No                               | 293 | 245 | (97.3) | (99.2) |     |     |
| **Cancer (n = 549)**             |     |     |   |   |   |   |
| Yes                              | 15  | 15  | (5.0)  | (6.1)  | 0.3 | 0.571 |
| No                               | 287 | 245 | (95.0) | (93.9) |     |     |
| **Self-care (n = 550)**          |     |     |   |   |   |   |
| Dependent                        | 20  | 4   | (6.6)  | (1.6)  | 8.2 | 0.004 |
| Independent                      | 282 | 244 | (93.4) | (98.4) |     |     |
| **Activities of daily living (n = 551)** |     |     |   |   |   |   |
| Having difficulty                | 32  | 8   | (10.6) | (3.2)  | 10.9 | 0.001 |
| No difficulty                    | 271 | 240 | (89.4) | (96.8) |     |     |
| **Anxiety (n = 548)**            |     |     |   |   |   |   |
| Yes                              | 63  | 32  | (20.9) | (13.0) | 5.8 | 0.016 |
| No                               | 239 | 214 | (79.1) | (87.0) |     |     |
| **Pain (n = 548)**               |     |     |   |   |   |   |
| Yes                              | 129 | 93  | (42.7) | (37.8) | 1.4 | 0.244 |
| No                               | 173 | 153 | (57.3) | (62.2) |     |     |
| **Health comparison (n = 548)**  |     |     |   |   |   |   |
| Better                           | 54  | 46  | (17.9) | (18.6) | 0.7 | 0.700 |
| Similar                          | 163 | 140 | (54.2) | (56.7) |     |     |
| Worse                            | 84  | 61  | (27.9) | (24.7) |     |     |
| **Participation**                |     |     |   |   |   |   |
| **Attending health classes (n = 547)** |     |     |   |   |   |   |
| No                               | 189 | 112 | (62.8) | (45.5) | 23.1 | <0.001 |
| Sometimes                        | 105 | 111 | (34.9) | (45.1) |     |     |
| Always                           | 7   | 23  | (2.3)  | (9.4)  |     |     |
| **Attending community activities (n = 547)** |     |     |   |   |   |   |
| Yes                              | 133 | 121 | (44.5) | (48.8) | 1.0 | 0.315 |
### Empowerment

#### Medication (n = 548)

| No | 166 (55.5) | 127 (51.2) |
|----|-------------|-------------|

#### Self-management during illness (n = 548)

| Yes | 67 (22.2) | 80 (32.5) |
|-----|-----------|-----------|
| No  | 235 (77.8) | 166 (67.5) |

#### Seeking a doctor (n = 547)

| Yes | 228 (75.5) | 167 (68.2) |
|-----|------------|------------|
| No  | 74 (24.5)  | 78 (31.8)  |

#### Taking dietary supplements (n = 548)

| Yes | 19 (6.3) | 17 (6.9) |
|-----|----------|----------|
| No  | 283 (93.7) | 229 (93.1) |

#### Taking Chinese medicine (n = 548)

| Yes | 28 (9.3) | 23 (9.4) |
|-----|---------|---------|
| No  | 274 (90.3) | 223 (90.7) |

#### Tendency to ignore the sickness (n = 548)

| Yes | 10 (3.3) | 9 (3.7) |
|-----|---------|-------|
| 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.