

## EDUCATION AND HEALTH LITERACY

**Asthma outcomes are poor among older adults with low health literacy**

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**Abstract**

**Objective:** To examine the association of health literacy (HL) with asthma outcomes among older asthmatics. **Methods:** The study included adults ages  $\geq 60$  with moderate to severe asthma in New York City and Chicago. We assessed asthma control with the Asthma Control Questionnaire (ACQ) and the percent predicted forced expiratory volume at 1 s (FEV<sub>1</sub>) by spirometry, hospitalizations and emergency department (ED) visits in the past 6 months, and quality of life. HL was assessed with the Short Test of Functional Health Literacy in Adults (S-TOFHLA). Multivariate logistic regression models controlled for age, sex, race, income, general health and years with asthma. **Results:** Among 433 individuals, 36% had low HL, 55% were over age 65, 38% were Hispanic and 22% were black. Poor asthma control was reported by 40% and 32% had FEV<sub>1</sub> <70% of predicted; 9% had a hospital stay, 23% had an ED and 38% had poor quality of life. In multivariable analysis, individuals with low HL were more likely to have FEV<sub>1</sub> <70% predicted (odds ratio [OR] 2.34, 95% confidence interval [CI] 1.39–3.94,  $p = 0.001$ ), hospitalizations (OR 2.53, 95% CI 1.17–5.49,  $p = 0.02$ ) and ED visits for asthma (OR 1.81, 95% CI 1.05–3.10,  $p = 0.03$ ). There were no differences in self-reported asthma control and quality of life. **Conclusions:** Low HL is associated with poor asthma control by objective measure, and greater likelihood of ED visits and hospitalization. HL is a modifiable target for interventions to improve asthma outcomes in the elderly.

**Keywords**

Asthma, control, elderly, emergency department, health literacy, hospitalization, outcomes, quality of life

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**Introduction**

Older adults experience worse outcomes with asthma compared to their younger counterparts, including more hospitalizations and emergency department visits, and a 54% higher rate of mortality [1]. A variety of physiological and behavioral factors contribute to the disparate outcomes for older asthmatics. For example, the lungs of older adults are stiffer and less responsive to bronchodilators [2], and older adults have low rates of adherence to controller medications [3,4].

In this study we focus on a potentially modifiable factor along the behavioral pathway of asthma outcomes in the elderly – health literacy. Health literacy is the degree to which individuals have the capacity to obtain, process and understand basic health information and services needed to make appropriate health decisions [5]. It has been established as a key enabling factor for effective self-management and positive outcomes for several chronic conditions [5–12], including

asthma [13–15]. However, health literacy's role in asthma outcomes for older adults is less clear, partly because there is little published research on this subject in the elderly [2,16] and because there are limitations to extrapolating health literacy and asthma outcome data from younger to older adults. Specifically, older adults are more prone to limitations of health literacy [17], yet little is known about the impact of health literacy on asthma outcomes in the elderly.

The objective of this study was to examine the association of health literacy with asthma outcomes in older adults. We conducted our analyses with data from the Asthma Beliefs and Literacy in the Elderly (ABLE) study, the largest prospective study of older adults with asthma in USA.

**Methods****Patients and settings**

We enrolled 452 patients ages 60 years and older [mean 67.4 years (SD 6.8)] who speak English or Spanish, and had physician-diagnosed asthma of moderate or greater severity [18]. Individuals with a smoking history of  $\geq 10$  pack-years, a diagnosis of chronic obstructive lung disease or other chronic respiratory illnesses were excluded. Although other studies of asthma in the elderly use age 65 years as the

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minimum age for study inclusion, we chose 60 as the minimum age for study eligibility because aspects of aging that influence response to asthma treatments can appear at earlier ages, such as airway remodeling [19], as do factors that complicate individual self-management of asthma, like cognitive impairment [20]. The planned sample size ( $n = 500$ ) was designed to enable the detection of a 15% absolute difference in the rate of asthma outcomes between patients with and without low health literacy.

Recruitment was conducted in English or Spanish at seven clinical venues in New York City, NY and Chicago, IL. The New York practices included the hospital-based general internal medicine, geriatrics primary care and pulmonary specialty practices of the Mount Sinai Medical Center, and an adult primary care practice of the Lutheran Family Health Services network of federally qualified health centers in Brooklyn. The Chicago-based practices included the general internal medicine clinic of Northwestern University Hospital, and two federally qualified health centers, the Mercy Health Clinic and the Erie Family Health Center. The study was approved by the Institutional Review Boards of the participating institutions. Study enrollment began in December 2009 and was completed in August 2012.

Patients were identified by review of the electronic clinic encounter databases at each site. A letter was mailed to introduce the study. Research assistants obtained verbal consent to administer a brief screening assessment over the phone to determine final eligibility. Eligible patients were invited to undergo in-person interviews.

### Outcome measures

Outcomes included measures of control, resource utilization and quality of life. Control and severity measures included the Asthma Control Questionnaire (ACQ) and percent predicted forced expiratory volume at 1 s ( $FEV_1$ ), respectively [21]. The ACQ is a 5-item survey of symptoms experienced in the past week and is scored on a 7-point scale. Poor asthma control was defined as  $\geq 1.5$  [22].

$FEV_1$  was calculated as actual  $FEV_1$ /predicted  $FEV_1$  (based on height and weight) to estimate the degree of bronchial obstruction [23] in the absence of a bronchodilator, and was conducted per American Thoracic Society guidelines [24] with a digital spirometer (model 4-000-0020, MidMark Diagnostics Group, Gardena, CA). We used  $FEV_1 < 70\%$  of predicted for age, sex, race and body mass index to indicate asthma of moderate or worse severity [25]. To evaluate the use of health care services, we asked patients, at baseline, how many times they were hospitalized or visited an ED because of asthma symptoms in the previous 6 months.

Asthma-related quality of life was assessed with the Mini Asthma Quality of Life Questionnaire (AQLQ) [26], which has 15 questions addressing activity limitations, symptoms, emotional function and environmental stimuli. Scores range from 1 to 7 and poor quality of life was defined as  $\geq 4.7$  [27].

### Independent variables

Health literacy was measured using the Short Test of Functional Health Literacy in Adults (S-TOFHLA) [28]. The S-TOFHLA is a 36-item reading and 4-item numeracy

assessment. There are two timed (7 min) clinically oriented reading passages that omit key words and phrases from sentences and the study participant chooses among four options to correctly complete the sentence. The numeracy section assesses the patient's ability to read health information, such as that found on a prescription label, and interpret numerical information. Overall scores range from 0 to 100. We dichotomized health literacy as adequate (score  $\geq 67$ ) or marginal and low (score  $< 67$ ) [29]. The S-TOFHLA has been validated for use in both English and Spanish [30].

Other covariates were age, sex, race/ethnicity and income, general health and asthma history (number of years since diagnosis and history of intubation) [31].

### Statistical analysis

We compared baseline characteristics of the sample by health literacy level (adequate versus marginal or low, hereafter noted as adequate versus low) using the chi-squared test, Student's *t*-test or Wilcoxon rank-sum test, as indicated. We modeled outcomes with logistic regression and controlled for demographic factors often associated with health literacy [8,29,32–39]. We also controlled for years of asthma which could influence patients' experience and understanding of the disease and therefore affect outcomes. All analyses were performed with SAS statistical software (SAS Institute, Cary, NC).

### Results

We identified 1972 patients, successfully contacted 1506, and consented and screened 1025 of whom 502 were eligible. Of these, 452 completed the baseline interview. Nineteen participants (4.2%) had incomplete data on health literacy and were excluded from these analyses. Those missing health literacy data were more likely than those with complete data to have low levels of educational achievement ( $p < 0.0001$ ), very low incomes ( $p = 0.006$ ) and to report poor general health ( $p = 0.02$ ). There was no difference by age, sex, race, use of asthma controller medications or history of intubation.

Among those included in our analyses ( $n = 433$ ), 31% were 70 years and older, 16% male, 39% non-Hispanic black and 39% Hispanic and 31% had less than a high school education (Table 1). The mean number of years with asthma was 31% and 45% reported fair or poor general health.

Thirty-five percent of subjects had low health literacy (Table 1) and were more often older, Hispanic, low income, have low educational attainment, fair or poor general health, and a history of intubation.

Poor asthma-related outcomes were common in this sample (Table 2). For asthma control, 40% reported poor control on the Asthma Control Questionnaire and 32% had a predicted  $FEV_1$  of  $< 70\%$ . As determined by spirometry, 68% had mild asthma, 16% moderate asthma, 8% moderately severe asthma, 6% severe asthma and 2% very severe asthma. Nine percent reported an asthma-associated hospitalization and 23% had an asthma-associated ED visit. Poor asthma-related quality of life was reported by 38%.

In unadjusted analyses, low health literacy was associated with poor asthma outcomes in nearly all cases (Tables 2–5). While rates of self-reported poor asthma control were not

Table 1. Patient characteristics.

|                              | All patients<br><i>n</i> = 433, (%) | Health literacy level         |                                     | <i>p</i> |
|------------------------------|-------------------------------------|-------------------------------|-------------------------------------|----------|
|                              |                                     | Low <i>n</i> = 155<br>(35.8%) | Adequate<br><i>n</i> = 278, (64.2%) |          |
| Age, years                   |                                     |                               |                                     |          |
| Mean (SD)                    | 67.4 (6.8)                          | 68.9 (7.4)                    | 66.6 (6.3)                          | 0.003    |
| 60–64                        | 194 (45.0)                          | 53 (34.4)                     | 141 (50.9)                          | 0.001    |
| 65–69                        | 104 (24.1)                          | 41 (26.6)                     | 63 (22.7)                           |          |
| 70+                          | 133 (30.9)                          | 60 (39.0)                     | 73 (26.4)                           |          |
| Male Sex                     | 70 (16.2)                           | 25 (16.1)                     | 45 (16.2)                           | 0.99     |
| Race                         |                                     |                               |                                     |          |
| Non-Hispanic White           | 95 (21.9)                           | 5 (3.2)                       | 90 (32.4)                           | <0.0001  |
| Non-Hispanic Black           | 132 (30.5)                          | 49 (32.6)                     | 83 (29.9)                           |          |
| Hispanic                     | 168 (38.8)                          | 92 (59.4)                     | 76 (27.3)                           |          |
| Other                        | 38 (8.8)                            | 9 (5.8)                       | 29 (10.4)                           |          |
| Income <\$1350/month         | 229 (54.1)                          | 121 (80.1)                    | 108 (39.7)                          | <0.0001  |
| Education                    |                                     |                               |                                     |          |
| <12 years                    | 141 (32.6)                          | 104 (67.5)                    | 37 (13.3)                           | <0.0001  |
| High school                  | 75 (17.4)                           | 25 (16.2)                     | 50 (18.0)                           |          |
| Some college                 | 89 (20.6)                           | 18 (11.7)                     | 71 (25.5)                           |          |
| College graduate             | 127 (29.4)                          | 7 (5.6)                       | 120 (43.2)                          |          |
| General health               |                                     |                               |                                     |          |
| Excellent or very good       | 101 (23.4)                          | 15 (9.7)                      | 86 (31.1)                           | <0.0001  |
| Good                         | 138 (31.9)                          | 34 (21.9)                     | 104 (37.6)                          |          |
| Fair or poor                 | 193 (44.7)                          | 106 (68.4)                    | 87 (31.4)                           |          |
| Years with asthma, mean (SD) | 31.4 (20.8)                         | 32.3 (20.0)                   | 31.0 (21.2)                         | 0.54     |
| Ever intubated               | 38 (8.9)                            | 23 (15.0)                     | 15 (5.5)                            | 0.001    |

Table 2. Baseline rates of asthma outcomes, by health literacy level.

|                                         | Overall | Health literacy                    |                               | <i>p</i> |
|-----------------------------------------|---------|------------------------------------|-------------------------------|----------|
|                                         |         | Low, marginal<br>( <i>n</i> = 155) | Adequate<br>( <i>n</i> = 278) |          |
| Poor asthma control by ACQ, %           | 40.3    | 46.4                               | 37.0                          | 0.06     |
| FEV <sub>1</sub> <70% Predicted, %      | 31.9    | 48.6                               | 23.1                          | <0.0001  |
| Hospitalizations past 12 months, %      | 8.9     | 14.4                               | 5.8                           | 0.003    |
| Emergency room visits past 12 months, % | 23.1    | 32.7                               | 17.8                          | 0.0005   |
| Poor asthma quality of life, %          | 38.2    | 47.7                               | 33.0                          | 0.003    |

ACQ, Asthma Control Questionnaire; FEV<sub>1</sub>, forced expiratory volume in 1 s.  
Sample size for FEV<sub>1</sub> assessment, *n* = 419; all others *n* = 433.

statistically different between low and adequate health literacy patients (46% versus 37%, *p* = 0.06), low literacy patients were more likely to have percent predicted FEV<sub>1</sub> <70% (49% versus 23%, *p* < 0.0001). Patients with low health literacy were also more likely to report asthma-related hospitalizations (14% versus 6%, *p* = 0.003) and emergency department visits (33% versus 18%, *p* = 0.0005). They also reported worse quality of life (48% versus 33% with adequate health literacy, *p* = 0.003).

In multivariate analysis, low health literacy was significantly associated with having a predicted FEV<sub>1</sub> <70% (OR 2.34, 95% CI 1.39–3.94, *p* = 0.001) (Table 3) and significantly associated with emergency department visits (OR 1.81, 95% CI 1.05–3.10, *p* = 0.03) and hospitalization for asthma (OR 2.53, 95% CI 1.17–5.49, *p* = 0.02) (Table 4). Health literacy was not significantly associated with poor asthma control as measured by the ACQ (OR 1.16, 95% CI 0.71–1.90, *p* = 0.55) (Table 3) or quality of life (OR 1.20, 95% CI 0.73–1.98, *p* = 0.48) (Table 5).

Other variables had significant associations with some of the outcomes in the multivariable analyses (Tables 3–5).

The oldest patients (>70 years), men, Latinos and those with poor general health were generally more likely to have poor asthma outcomes, though not consistently across all outcomes measured.

## Discussion

In this study, we report findings suggesting that low health literacy is a contributor to poor outcomes among older asthmatics. We found that older asthmatics with low health literacy have more than twice the rate of hospitalizations and nearly twice the rate of ED visits for asthma as those with higher literacy skills, and their percent predicted FEV<sub>1</sub> values are 11% lower. The association of health literacy with these asthma outcomes was independent of age, sex, race, income and number of years with asthma.

The literature on health literacy and asthma outcomes has paid little attention to older asthmatics despite the severity of outcomes in this population [16]. Some have explored the health literacy-outcomes association among younger adults. For example, Mancuso found that non-elderly adults with low

Table 3. Unadjusted and adjusted associations of health literacy and other variables with poor asthma control.

|                      | Self-reported poor asthma control |                      | FEV <sub>1</sub> <70%  |                      |
|----------------------|-----------------------------------|----------------------|------------------------|----------------------|
|                      | Unadjusted OR (95% CI)            | Adjusted OR (95% CI) | Unadjusted OR (95% CI) | Adjusted OR (95% CI) |
| Low health literacy  | 1.84 (1.32–2.55)***               | 1.16 (0.71–1.90)     | 2.78 (1.87–4.14)****   | 2.34 (1.39–3.94)**   |
| Age                  |                                   |                      |                        |                      |
| 60–64                | Ref.                              | Ref.                 | Ref.                   | Ref.                 |
| 65–69                | 0.61 (0.40–0.94)                  | 0.58 (0.34–0.97)*    | 0.98 (0.62–1.54)       | 0.73 (0.41–1.32)     |
| 70+                  | 0.40 (0.22–0.72)                  | 0.36 (0.21–0.61)***  | 1.04 (0.58–1.89)       | 0.83 (0.48–1.44)     |
| Male                 | 0.63 (0.37–1.09)                  | 0.60 (0.33–1.11)     | 2.70 (1.58–4.62)***    | 3.23 (1.75–5.94)***  |
| Race                 |                                   |                      |                        |                      |
| Non-Hispanic white   | Ref.                              | Ref.                 | Ref.                   | Ref.                 |
| Non-Hispanic black   | 1.98 (1.12–3.50)*                 | 1.03 (0.53–2.03)     | 1.64 (0.87–3.09)       | 0.95 (0.44–2.08)     |
| Hispanic             | 2.56 (1.48–4.41)***               | 0.94 (0.47–1.94)     | 2.78 (1.54–5.04)***    | 1.29 (0.58–2.86)     |
| Other                | 0.95 (0.41–2.22)                  | 0.55 (0.21–1.42)     | 1.58 (0.65–3.84)       | 1.05 (0.39–2.81)     |
| Income <\$1350/month | 2.24 (1.50–3.36)****              | 1.50 (0.90–2.48)     | 2.30 (1.49–3.56)***    | 1.53 (0.87–2.71)     |
| Poor general health  | 3.84 (2.23–6.62)****              | 3.40 (1.82–6.35)***  | 1.92 (1.13–3.25)*      | 1.39 (0.73–2.65)     |
| Years with asthma†   | 0.97 (0.88–1.07)                  | 0.98 (0.88–1.09)     | 1.21 (1.09–1.35)***    | 1.21 (1.08–1.35)**   |

†By 10-year intervals.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ , \*\*\*\* $p < 0.0001$ .

OR, odds ratio; CI, confidence interval.

Table 4. Unadjusted and adjusted associations of health literacy and other variables with emergency department visits and hospitalizations for asthma.

|                      | Emergency department visits |                      | Hospitalizations       |                      |
|----------------------|-----------------------------|----------------------|------------------------|----------------------|
|                      | Unadjusted OR (95% CI)      | Adjusted OR (95% CI) | Unadjusted OR (95% CI) | Adjusted OR (95% CI) |
| Low health literacy  | 2.24 (1.42–3.54)***         | 1.81 (1.05–3.10)*    | 2.72 (1.38–5.35)**     | 2.53 (1.17–5.49)*    |
| Age                  |                             |                      |                        |                      |
| 60–64                | Ref.                        | Ref.                 | Ref.                   | Ref.                 |
| 65–69                | 0.95 (0.59–1.54)            | 0.99 (0.56–1.77)     | 0.96 (0.47–1.97)       | 1.04 (0.46–2.32)     |
| 70+                  | 0.56 (0.27–1.15)            | 0.53 (0.29–0.97)*    | 0.74 (0.27–2.09)       | 0.51 (0.21–1.26)     |
| Male                 | 0.39 (0.18–0.84)*           | 0.34 (0.15–0.80)*    | 0.59 (0.20–1.71)       | 0.64 (0.21–1.92)     |
| Race                 |                             |                      |                        |                      |
| Non-Hispanic white   | Ref.                        | Ref.                 | Ref.                   | Ref.                 |
| Non-Hispanic black   | 3.07 (1.39–6.79)**          | 2.53 (1.06–6.04)*    | 3.24 (0.90–11.7)       | 2.12 (0.54–8.38)     |
| Hispanic             | 4.21 (1.96–9.01)***         | 3.43 (1.37–8.58)**   | 4.06 (1.17–14.1)*      | 2.15 (0.52–8.85)     |
| Other                | 1.40 (0.44–4.48)            | 1.51 (0.44–5.19)     | 1.65 (0.26–10.3)       | 1.22 (0.18–8.25)     |
| Income <\$1350/month | 1.76 (1.10–2.82)*           | 1.08 (0.61–1.92)     | 1.51 (0.76–3.01)       | 0.70 (0.31–1.57)     |
| Poor general health  | 1.18 (0.68–2.03)            | 0.57 (0.29–1.10)     | 2.78 (0.96–8.05)       | 1.94 (0.61–6.22)     |
| Years with asthma†   | 1.02 (0.92–1.14)            | 1.03 (0.92–1.17)     | 1.05 (0.89–1.24)       | 1.06 (0.89–1.27)     |

†By 10-year intervals.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ , \*\*\*\* $p < 0.0001$ .

OR, odds ratio; CI, confidence interval.

Table 5. Unadjusted and adjusted associations of health literacy and other variables with asthma quality of life.

|                      | Unadjusted OR (95% CI) | Adjusted OR (95% CI) |
|----------------------|------------------------|----------------------|
| Low health literacy  | 2.07 (1.46–2.94)****   | 1.20 (0.73–1.98)     |
| Age                  |                        |                      |
| 60–64                | Ref.                   | Ref.                 |
| 65–69                | 0.95 (0.62–1.45)       | 0.76 (0.44–1.32)     |
| 70+                  | 0.39 (0.21–0.75)**     | 0.49 (0.28–0.84)*    |
| Male                 | 0.46 (0.26–0.83)*      | 0.42 (0.21–0.84)*    |
| Race                 |                        |                      |
| Non-Hispanic white   | Ref.                   | Ref.                 |
| Non-Hispanic black   | 1.89 (0.99–3.61)       | 1.13 (0.54–2.37)     |
| Hispanic             | 6.14 (3.33–11.3)****   | 2.97 (1.40–6.33)**   |
| Other                | 1.63 (0.67–4.01)       | 1.07 (0.40–2.89)     |
| Income <\$1350/month | 2.45 (1.62–3.71)****   | 1.22 (0.73–2.05)     |
| Poor general health  | 5.10 (2.78–9.36)****   | 3.00 (1.52–5.92)**   |
| Years with asthma†   | 0.95 (0.86–1.05)       | 0.94 (0.84–1.05)     |

†By 10-year intervals.

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ , \*\*\*\* $p < 0.0001$ .

OR denotes odds ratio; CI, confidence interval.

health literacy had worse quality of life and more ED visits for asthma [15]. Other studies have had similar findings [13,14,16,32,40].

Our study extends these findings to an older population and enhances their generalizability. Our cohort is larger than that of previous studies, and in contrast consists exclusively of patients over age 60. It was also drawn from multiple hospital and community-based clinical settings in two major metropolitan areas of USA. Moreover, we included spirometry as an objective measure of asthma control. Although we anticipated that health literacy would impact older adults in a fashion similar to that observed in younger adults, the extent of the impact has not been clear. The elderly may be more susceptible to poor asthma outcomes related to limited literacy, not just as a result of higher prevalence of limited literacy in this population [38,41,42], but because of a number of potential compounding factors that occur more commonly in the elderly, including physical and cognitive impairments and multi-morbidity. In addition to finding generally higher

rates of limited health literacy (36%) than that reported in studies of younger asthmatics (18–33%) [13,15,32], the rates of ED visits and hospitalizations occurring in the prior year were also higher in our sample than reported in other studies. Moreover, the magnitude of the association of health literacy with asthma outcomes was generally larger in our cohort than that reported in other studies. We note, however, that analyses directly comparing older and younger adults are needed to draw firm conclusions about differences in the associations of health literacy with asthma outcomes across age groups.

Health literacy warrants attention as a potential target for interventions to improve asthma control and outcomes in the elderly. Yet, further research is needed to illuminate the pathways through which health literacy influences asthma outcomes and to test strategies for effectively teaching older patients how to manage their chronic illness. Paasche-Orlow and Wolf postulated that a number of factors lie on these pathways [43], including illness and medication beliefs, asthma knowledge and self-management and self-efficacy, all of which may be modifiable via educational interventions [44,45]. Health beliefs, in particular, are an important target for educational efforts to improve asthma outcomes [29,46–48]. Health literacy appropriate interventions are few in number, the studies are small in sample size and their impact has been modest [44–46]. Moreover, none address the barriers to effective asthma self-management that are so common among the elderly.

We found that older age (70 years and older) and Hispanic ethnicity were significantly associated with several of the asthma morbidity measures. These findings highlight the disparities in health outcomes often exhibited by older patients and members of ethnic minority groups. Age-related changes in the lung may contribute to worsened outcomes for older asthmatics, as well as multi-morbidity [2]. Poor language proficiency [49] and other markers of sociodemographic vulnerability may also contribute to worse asthma outcomes among older, Hispanic asthmatics. Strategies to improve asthma outcomes for older adults must consider a wide variety of barriers to self-management to achieve better health outcomes. One-size-fits all approaches are insufficient to meet the complex needs of an aging population.

Finally, we note that health literacy and cognitive function have a close association [37]. Reading and other functions related to processing information are inherently cognitive in nature. To this point, we have found that measures of cognitive function are collinear with health literacy in our assessment of asthma outcomes. We therefore chosen to omit measures of cognitive function from the analyses presented here. Moreover, controlling for cognitive function would diminish the association of health literacy with asthma outcomes and in so doing would nullify the important message that clear health communication is likely to be important for supporting asthma self-management and achieving asthma control in older adults.

Our study has limitations that merit discussion. First, 19 individuals were excluded from our analyses because of missing data on health literacy. Because they had lower education and income and reported worse general health, their exclusion may have diminished the association between health literacy and the asthma outcomes we measured.

Similarly, 20 were missing data on percent predicted FEV<sub>1</sub> and were more likely to have low incomes. Second, some outcomes were self-reported and may be subject to under-reporting use of health services because of recall problems. However, we used spirometry, an objective assessment of asthma morbidity, to determine lung function and found its association with health literacy to be consistent with those of health literacy and self-reported ED visits and hospitalizations. Third, our data are observational and thus preclude conclusions about causality, though our research design and analytic designed were theory-based [43]. Fourth, because this is a cohort of older adults cognitive dysfunction could account in part for problems with chronic illness self-management and subsequently asthma outcomes. However, we did not control for cognition in our analyses because the measure of health literacy we used is highly correlated with measures of cognition [37] and therefore presents problems of collinearity in multiple regression. Finally, the sample was drawn from low-income, inner-city communities. Generalization of the findings to other populations should be made with caution.

## Conclusions

Low health literacy is one among multiple factors that might contribute to the disproportionately poor outcomes experienced by older asthmatics [2]. Improving outcomes for this population with require multi-modal approaches to enhance self-management behaviors like medication adherence, as well as the development of new therapies. Addressing low health literacy is an important step in this direction.

## Declaration of interest

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