

# Tailored Education May Reduce Health Literacy Disparities in Asthma Self-Management

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**Rationale:** Although inadequate health literacy has been associated with lower asthma medication knowledge and worse metered-dose inhaler (MDI) technique, the relationship between health literacy and the capacity to learn asthma self-management skills is unknown. **Objectives:** In this prospective cohort study of adults hospitalized for severe asthma exacerbations at two inner-city hospitals, we examined the relationship between inadequate health literacy and difficulties learning and retaining instructions about discharge medications and appropriate MDI technique.

**Methods:** At hospital discharge, participants received one-on-one, 30-min, guideline-based, written and oral instruction about their asthma discharge regimen as well as appropriate MDI technique. **Measurements and Main Results:** Seventy-three patients were enrolled. Inadequate health literacy was identified in 16 (22%) participants. Before instruction, inadequate health literacy was associated with lower asthma medication knowledge (5.2/10 vs. 7.2/10,  $p < 0.001$ ) and worse MDI technique (3.2/6 vs. 3.9/6,  $p = 0.03$ ). However, inadequate health literacy was not associated with difficulty learning ( $p = 0.33$ ) or retaining ( $p = 0.35$ ) instructions about the discharge regimen. Similarly, inadequate health literacy was not associated with difficulty learning ( $p = 0.26$ ) or retaining ( $p = 0.97$ ) appropriate MDI technique. Results were similar in multivariable models adjusted for demographic characteristics and asthma severity indicators.

**Conclusions:** These findings suggest that inadequate health literacy is a surmountable barrier to learning and remembering key asthma self-management skills.

**Keywords:** asthma; education; functional 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” (1–4) and is most often measured by reading comprehension of health-related information (5, 6). Multiple studies indicate that inadequate health literacy is associated with worse health status and higher rates of hospitalization across a number of patient populations (4, 7, 8), including patients with diabetes mellitus, patients with HIV infection, and the elderly (9–12). However, there are relatively few data about the effects of inadequate health literacy in patients with asthma, a common chronic respiratory disorder affecting 5 to 10% of the U.S. population (13).

In cross-sectional studies, inadequate health literacy has been linked to lower asthma-related knowledge (14, 15) and improper use of metered dose inhalers (MDIs) (14). Although national asthma guidelines recommend patient education to improve patient–physician partnerships for care (16), no studies have evaluated the extent to which inadequate health literacy serves as a barrier for patients to learn and retain asthma self-management skills (17).

The objective of this study was to examine the relationship between inadequate health literacy and difficulties learning and retaining instructions about discharge medications and appropriate MDI technique. We recruited an inner-city predominately African-American patient population hospitalized for asthma exacerbations, a group at high risk for low health literacy and a two- to threefold risk of death from asthma exacerbations (18–20). We hypothesized that inadequate health literacy is associated with lower knowledge of asthma medications, improper use of MDI technique, as well as difficulty learning and retaining instructions about discharge medications and proper MDI technique. These hypotheses represent secondary goals of a study also intended to examine adherence to corticosteroid therapy after hospital discharge (21). Some results of the current study have been previously reported in the form of an abstract (22).

## METHODS

### Study Design

This was a prospective cohort study conducted from April 2001 through October 2002. Adults (age,  $\geq 18$  yr) admitted with a physician diagnosis of asthma exacerbation to two inner-city academic medical centers were screened for eligibility. Patients with other chronic lung diseases, those with a contraindication to corticosteroids, patients (or physicians) who declined consent, and investigators’ patients were excluded. The study was approved by the Johns Hopkins Institutional Review Board.

### Study Procedures

At hospital discharge (discharge study visit), eligible subjects were approached about participating in this study. Patients who provided written, informed consent were enrolled. Participants completed an interviewer-administered survey about sociodemographics (age, sex, ethnicity, education, income), smoking history (never, ever, current), and asthma-related health care use (emergency department or hospitalization) in the past year. On the basis of a review of medical records and interview responses, subjects were classified as having a history of near-fatal asthma exacerbation if they had ever been intubated due to asthma (yes vs. no).

Health literacy was measured with the Short Test of Functional Health Literacy in Adults and classified as having inadequate health literacy (yes [score  $\leq 16/36$ ] vs. no [score  $> 16/36$ ]), based on published recommendations (23, 24). The Short Test of Functional Health Literacy in Adults is a test of reading comprehension that takes 5 to 7 min to administer. The test has a set of sentences from medical scenarios with key words missing. Subjects select words to complete the sentences from a list provided. There are 36 items and each correct response is awarded 1 point (range of possible scores, 0–36). The test has high internal consistency (Cronbach’s  $\alpha = 0.97$ ) and is well correlated with the Rapid Estimate of Adult Literacy in Medicine (Spearman correlation, 0.81)

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and the full Test of Functional Health Literacy in Adults (Spearman correlation, 0.91) (25).

In addition, we also assessed patients' understanding of asthma medications. There were no previously validated measures to assess patients' understanding of asthma medications (inhaled corticosteroids, oral corticosteroids, and short-acting bronchodilators). Therefore, we developed 10 items based on existing asthma knowledge scales, professional opinion, and the desire for each item to be directly related to medication use. Participants were given 1 point for each correctly answered item. Based on a total possible score of 10, we calculated a mean asthma medication knowledge score (total score/10). Internal consistency reliability was adequate (Cronbach  $\alpha = 0.62$ ) and comparable to another published asthma knowledge scale (26).

Participants were asked to demonstrate use of an MDI. Participants' MDI technique was assessed on the basis of the following six criteria (16, 27–30): (1) shaking the MDI, (2) exhaling before actuation, (3) closing lips tightly around the mouthpiece, (4) pressing down once on the canister, (5) taking a full/deep breath without triggering the auditory "whistle" indicator of the spacer, and (6) holding breath for at least 5 s. One point was given for each step for a total possible score of 6 as follows: 0 (unable to perform any step) to 6 (perfect technique; Figure 1). The asthma discharge regimen was standardized to include both oral corticosteroids (prednisone: 20 mg/tablet, 2 tablets each morning for 7 d), inhaled corticosteroids (fluticasone MDI: 220  $\mu\text{g}/\text{puff}$ , 2 puffs twice/d), and a short-acting bronchodilator (albuterol MDI: 2 puffs every 4 h as needed). These medications and a spacer for use with MDIs were provided for free to study participants. Participants took part in a one-on-one, 30-min-long, guideline-based, written and oral asthma-education session about this discharge regimen. This session included education about appropriate MDI technique; the research assistant provided both verbal instructions and demonstrated proper technique to study participants. After the education intervention and before discharge, participants were asked to state the following: (1) the name of each medication, (2) the number of tablets or actuations to be taken each time, (3) the number of times per day the medication should be taken, and (4) the prescribed duration of medication use. Teaching was repeated until participants could successfully demonstrate mastery of the asthma discharge regimen (defined as correctly describing items 1–4 for all three of the medicines) and MDI technique (30). The number of rounds of teaching necessary to achieve mastery of the asthma discharge regimen and MDI technique was recorded.

Participants returned for a 2-wk follow-up visit. At the follow-up visit, participant's MDI technique and knowledge of the asthma discharge regimen were reevaluated. In addition, at follow-up, asthma symptom control was assessed using the six symptom items in the Asthma Control Questionnaire (31). The total possible asthma symptom control was (0, well controlled, to 6, extremely poorly controlled).

In a subset of participants ( $n = 46$ ) enrolled in the current study, we also electronically measured patients' use of inhaled and oral corticosteroids after hospital discharge. Adherence to inhaled corticosteroids was

assessed using the Doser CT (Meditrac, Inc., Hudson, MA), which records the number of actuations of the fluticasone MDI each day (32, 33). Adherence to oral corticosteroids was assessed using the MEMS TrackCap (AARDEX Ltd., Union City, CA), which records the number of prednisone bottle openings each day (34–36). Adherence was defined as percentage of prescribed use after hospital discharge (use/prescribed use  $\times 100\%$ ) and was calculated for both inhaled and oral corticosteroids. Poor adherence to corticosteroid therapy was defined *a priori* as electronically measured adherence to inhaled corticosteroids of less than 50% during the 2-wk period after hospital discharge or electronically measured adherence to oral corticosteroid therapy of less than 50% from hospital discharge through Day 7 (oral corticosteroids were prescribed for the first 7 d after discharge).

The data collection and educational intervention were conducted by a trained research assistant using standardized text and questionnaires. To minimize interviewer bias, the health literacy status of participants was not available to the interviewer at the follow-up visit. Also, electronic adherence data were collected after the interviewer-administered survey. Participants were informed that medication use was assessed, but were not told about precise monitoring abilities (i.e., that daily medication use was electronically measured).

Thus, at the discharge study visit, data regarding sociodemographics, asthma care, smoking history, morbidity, health literacy, asthma medication knowledge, and MDI technique were collected before any educational intervention. After the first and subsequent rounds of education, knowledge of the asthma discharge regimen and MDI technique were assessed. The education was repeated until participants could demonstrate mastery of the asthma discharge regimen and MDI technique. At the follow-up visit, knowledge of the asthma discharge regimen and MDI technique were tested again, adherence data for corticosteroid therapy were collected, and asthma symptom control was assessed.

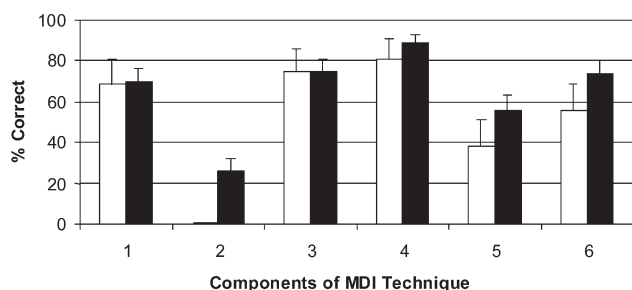
### Statistical Analyses

Descriptive statistics used means, medians, and proportions. Wilcoxon rank sum, matched pairs signed rank, or  $\chi^2$  tests were used in bivariate analyses. Logistic regression models were used to determine if inadequate health literacy was an independent predictor of the following outcomes: better asthma medication knowledge (yes [ $\geq$  mean score] vs. no), better MDI technique (yes [ $\geq$  mean score] vs. no), mastery of the discharge regimen after one round (yes vs. no), poor adherence to corticosteroid therapy (adherence  $< 50\%$ : yes vs. no) (21), and better asthma symptom control (yes [ $\geq$  mean score] vs. no). To determine if knowledge about medications mediated the relationship between inadequate health literacy and inferior self-management practices, we constructed additional models in which we included "better asthma medication knowledge" as a covariate in models to predict "better MDI technique" and "poor adherence to corticosteroid therapy."

Each regression model included the identical set of demographic and asthma severity indicators as independent variables: inadequate health literacy (yes vs. no; primary predictor of interest), age (quartiles), sex, ethnicity (African American vs. white), education level (high school graduate or equivalent degree; yes vs. no), income (annual combined household income  $\leq \$19,999$ : yes [ $\leq$  mean score] vs. no), history of near-fatal asthma (yes vs. no), asthma hospitalization in the prior 12 mo (yes vs. no), having a physician for asthma care (yes vs. no), and prior emergency department visits for asthma in the past 12 mo (yes vs. no). Results were similar when we analyzed outcomes as continuous or as binary variables; we presented the latter results to facilitate interpretation. To avoid overfitting the regression models, we elected to use a backward stepwise procedure in the multivariable logistic regression models to identify the most influential predictors for each of the outcomes ( $p < 0.2$  for removal) (37). A two-tailed  $p$  value of less than 0.05 defined statistical significance. Computations were performed using STATA, version 7.0. (StataCorp, College Station, TX). Additional details regarding the methods are available in the online supplement.

### RESULTS

Of 136 patients screened for eligibility, 36 met the following exclusion criteria: history of another chronic lung disease ( $n = 20$ ), discharged to location other than home ( $n = 8$ ), clinic patient of an investigator ( $n = 2$ ), and contraindication to corticosteroids



**Figure 1.** Proportion (%) of patients correctly performing each component of metered-dose inhaler (MDI) technique according to literacy level. Inadequate health literacy: white bars = yes; black bars = no. 1: shaking the inhaler ( $p = 0.91$ ); 2: exhaling before actuation ( $p = 0.02$ ); 3: closing lips around mouthpiece ( $p = 0.97$ ); 4: pressing down once ( $p = 0.38$ ); 5: taking a full/deep breath without triggering "whistle" ( $p = 0.19$ ); 6: holding breath  $> 5$  s ( $p = 0.18$ ).

(n = 6). Of 100 eligible patients, 8 patients were excluded because the physician declined consent and 19 were excluded because the patient declined consent.

Seventy-three patients (73% of eligible) were enrolled. Participants' mean age was 41 yr and they were mostly African American, female, unmarried, and employed. There was substantial evidence of previous asthma morbidity among participants, with more than three-quarters reporting at least one other emergency department visit for an asthma exacerbation in the previous 12 mo and nearly half with a history of near-fatal asthma. Fifty-six participants (77% of enrolled) returned for the 2-wk follow-up visit. Those not returning for the 2-wk visit were younger, had lower asthma medication knowledge scores, and tended to be African American. However, health literacy was similar, whether or not patients returned for the follow-up visit (Table 1).

### Health Literacy

At the discharge study visit, 16 (22%) participants had inadequate health literacy. Sociodemographic characteristics (including age) were similar in patients with and without inadequate health literacy (Table 2). However, participants with inadequate health literacy were significantly more likely to have been hospitalized for asthma in the past 12 mo (81 vs. 52%,  $p = 0.04$ ) and there was a trend toward a higher rate of near-fatal asthma in patients with inadequate health literacy (63 vs. 37%,  $p = 0.07$ ).

### Asthma Medication Knowledge Questionnaire

At the discharge study visit, the mean asthma medication knowledge score was 6.8 (of 10, SD = 2.1; Table 3). Participants with inadequate literacy had lower Asthma Medication Knowledge scores (odds ratio [OR] for better asthma medication knowledge score, 0.11; 95% confidence interval [CI], 0.03–0.42;  $p = 0.001$ ; Table 4). Participants with inadequate health literacy were less likely to correctly answer every question, with significant differences noted for 5 of 10 items. In a multivariate logistic model, inadequate health literacy was the only significant independent predictor of asthma medication knowledge (OR for better asthma medication knowledge score, 0.08; 95% CI, 0.02–0.38;  $p = 0.002$ ).

### MDI Technique

The mean MDI technique score at the discharge study visit was 3.8 (of 6, SD=1.4). Failure to exhale before actuation of the MDI was the most frequently missed step. Pressing once on the canister at the time of actuation was the step that was most frequently done correctly. At the discharge study visit, subjects with inadequate health literacy were less likely to have superior MDI technique (OR for better MDI technique, 0.27; 95% CI, 0.08–0.87;  $p = 0.03$ ). Having a history of near-fatal asthma was also associated with worse MDI technique at discharge study visit (OR for better MDI technique, 0.20; 95% CI, 0.1–0.7;  $p < 0.01$ ; Table 4). In a multivariate model, inadequate health literacy was the only significant independent predictor of MDI technique (OR for better MDI technique, 0.29; 95% CI, 0.08–1.00;  $p = 0.05$ ). When asthma medication knowledge was included as a covariate, inadequate health literacy was no longer a significant predictor of MDI technique (OR for better MDI technique, 0.53; 95% CI, 0.14–2.01), and asthma medication knowledge became the sole independent predictor of MDI technique (OR for better MDI technique, 1.48; 95% CI, 1.08–2.03).

After a single round of education, 59% (10/16) of subjects with inadequate health literacy and 73% (41/57) of subjects with higher health literacy exhibited mastery of MDI technique ( $p = 0.26$ ). Overall, 21% (15) of subjects required one additional round of education, 10% (7) required two additional rounds of education, and no subject needed more than two additional rounds of education to exhibit mastery of MDI technique. Inadequate health literacy was not associated with the number of rounds of education needed to exhibit master of MDI technique ( $p = 0.79$ ).

At the follow-up visit, the overall mean MDI technique score was 4.8 (SE = 0.14), which was significantly improved from the discharge study visit measurement (change = 1.1 [SE = 0.21],  $p < 0.001$ ). There was a greater increase in the proportion of subjects achieving better MDI technique in patients with inadequate health literacy ( $p = 0.02$ ; Figure 2), suggesting that this subgroup benefited most from the tailored education. At 2 wk, the proportion of participants with better MDI technique was no longer associated with health literacy ( $p = 0.57$ ).

TABLE 1. PATIENT CHARACTERISTICS FOR SUBJECTS WITH AND WITHOUT 2-WK DATA

	All (n = 73)	With 2-wk Data (n = 56)	Without 2-wk Data (n = 17)	p Value <sup>‡</sup>
Sociodemographics				
Age, mean yr (SD, range)	40.9 (10.9)	43.0 (11.1)	33.9 (7.1)	< 0.01
Female	48 (66)	35 (63)	13 (76)	0.29
Race				0.09
African American	58 (79)	42 (75)	16 (94)	
White	15 (21)	14 (25)	1 (6)	
High school graduate or GED	44 (60)	32 (57)	12 (71)	0.32
Income ≥ \$19,999*	36 (65)	27 (63)	9 (75)	0.43
Asthma-related health care use				
Hospitalization past 12 mo <sup>†</sup>	42 (58)	35 (63)	7 (44)	0.18
ED visit past 12 mo <sup>†</sup>	55 (77)	43 (78)	12 (75)	0.79
Near-fatal asthma	31 (42)	23 (41)	8 (47)	0.66
Inadequate health literacy	16 (22)	12 (21)	4 (24)	0.85
Cigarette smoking history				
Never smoker	32 (44)	26 (46)	6 (35)	
Past smoker	20 (27)	16 (29)	4 (24)	
Current smoker	21 (29)	14 (25)	7 (41)	
Physician for asthma care	37 (51)	30 (54)	7 (41)	0.37
Asthma knowledge score (SD)	6.9 (2.0)	7.2 (1.9)	6.2 (2.2)	0.07

Definition of abbreviations: ED = emergency department; GED = general equivalency diploma.

Values are given as numbers with percentages in parentheses unless otherwise noted.

\* Limited data due to nonresponse (n = 55).

<sup>†</sup> Excludes current hospitalization/ED visit.

<sup>‡</sup> Wilcoxon rank sum test or  $\chi^2$  test.

**TABLE 2. PATIENT CHARACTERISTICS BY LEVEL OF HEALTH LITERACY**

	Inadequate Health Literacy		p Value <sup>‡</sup>
	Yes (n = 16)	No (n = 57)	
<b>Sociodemographics</b>			
Age, mean yr (SD, range)	41.1 (12.9)	40.8 (10.5)	0.92
Female	9 (56)	39 (68)	0.37
<b>Race</b>			
African American	15 (94)	43 (75)	
White	1 (6)	14 (25)	0.11
High school graduate or GED	9 (56)	35 (61)	0.71
Income ≤ \$19,999*	8 (57)	28 (68)	0.45
<b>Asthma-related health care use</b>			
Hospitalization past 12 mo <sup>†</sup>	13 (81)	29 (52)	0.04
ED visit past 12 mo <sup>†</sup>	14 (88)	41 (75)	0.28
Near-fatal asthma	10 (63)	21 (37)	0.07
<b>Cigarette smoking history</b>			
Never smoker	6 (38)	26 (46)	0.31
Past smoker	3 (19)	17 (30)	
Current smoker	7 (44)	14 (25)	
Physician for asthma care	7 (44)	30 (53)	0.53

For definition of abbreviations, see Table 1.

Values are given as numbers with percentages in parentheses unless otherwise noted.

\* Limited data due to nonresponse (n = 55).

<sup>†</sup> Excludes current hospitalization/ED visit.

<sup>‡</sup> Wilcoxon rank sum test or  $\chi^2$  test.

### Understanding of Discharge Regimen

After a single round of education, 69% (11/16) of subjects with inadequate health literacy and 68% (39/57) of subjects with higher health literacy were able to exhibit mastery of the discharge regimen. The need for supplemental education to exhibit mastery of the discharge regimen at the discharge study visit was not associated with health literacy in bivariate and multivariable analyses ( $p = 0.73$  and  $p = 0.33$ , respectively). Overall, 17 (25%) subjects required one additional round of education, one subject

required two additional rounds of education, one subject required three additional rounds of education, and no subject required more than three additional rounds of education to exhibit mastery of the discharge regimen. At the follow-up visit, the proportion of patients having mastery of the discharge regimen was also similar between groups based on health literacy ( $p = 0.35$ ; Figure 2).

### Adherence

Data on adherence to corticosteroid therapy and asthma symptom control were available in a substudy of 46 participants (63% of participants for the current study). About half (22/46, 48%) of the patients had poor adherence to corticosteroid therapy. Inadequate health literacy was not associated with poor adherence to corticosteroid therapy (OR, 0.89; 95% CI, 0.2–3.3;  $p = 0.86$ ). In multivariable analyses, health literacy was not associated with adherence to corticosteroid therapy, whether ( $p = 0.45$ ) or not ( $p = 0.45$ ) the model included asthma medication knowledge.

### Asthma Symptom Control

At the follow-up visit, asthma symptom control was similar in patients with and without inadequate health literacy (mean [95% CI]: 1.6 [0.95–2.31] vs. 1.5 [1.22–1.75];  $p = 0.69$ ). In multivariable analyses, inadequate health literacy was not associated with asthma symptom control at the follow-up visit ( $p = 0.84$ ).

## DISCUSSION

Deficiencies in asthma medication knowledge, MDI technique, and mastery of the discharge regimen were common in inner-city adults hospitalized for asthma exacerbations. Observed deficiencies in asthma self-management skills could not be explained by sociodemographic characteristics (age, sex, ethnicity, and education) or past asthma-related health care use but were independently associated with inadequate health literacy. Inadequate health literacy was associated with a greater likelihood of hospitalization for asthma exacerbations in the past 12 mo and significantly less knowledge of asthma medication and improper

**TABLE 3. ASTHMA MEDICATION KNOWLEDGE ACCORDING TO LITERACY LEVEL**

Question (correct answer)	Inadequate Health Literacy		p Value <sup>‡</sup>
	Yes, % correct (n = 16)	No, % correct (n = 57)	
Even if I have no symptoms from my asthma, I should take (say $\beta_2$ -agonist they are on)* every day so that I can stop asthma attacks from starting (False)	10	60	< 0.01
If I am told to take two puffs, twice a day, then I should press down on the inhaler two times before I start to take a breath (False)	40	87	< 0.01
The longer I wait to treat an asthma attack after it begins, the easier it is to stop the attack (False)	75	96	< 0.01
When I am prescribed steroid tapers like prednisone for an asthma attack, I can stop taking them as soon as I start feeling well even if I have not finished the taper (False)	65	87	0.02
(Say inhaled steroid they are on) <sup>†</sup> should be taken only when I have asthma symptoms (False)	40	69	0.02
After I press down on the inhaler, I should take a normal, regular-sized breath (False)	25	49	0.06
(Say $\beta_2$ -agonist they are on)* should be taken only when I have asthma symptoms (True)	60	74	0.21
(Say $\beta_2$ -agonist they are on)* works within minutes to help you breathe better (True)	85	90	0.55
(Say inhaled steroid they are on) <sup>†</sup> takes days or weeks before it starts to help you breathe better (True)	50	55	0.68
Even if I have no symptoms from my asthma, I should take (say inhaled steroid they are on) <sup>†</sup> every day so that I can stop asthma attacks from starting (True)	70	73	0.78
Total test score, mean (95% CI)	5.2 (4.3–6.2)	7.2 (6.8–7.6)	< 0.01

Definition of abbreviation: CI = confidence interval.

Each question has a true, false, do not know format.

\* If participant did not list a short-acting  $\beta_2$ -agonist as a medication on hospital admission medication, then the phrase "medicines such as Ventolin, Proventil, Maxair, Alupent, or Albuterol" was used.

<sup>†</sup> If the participant did not list an inhaled steroid as a medication on hospital admission, then the phrase "medicines like Flovent, Pulmicort, Azmacort, Vanceril, or Advair" was used.

<sup>‡</sup>  $\chi^2$  test and Wilcoxon rank sum test.

**TABLE 4. PREDICTORS OF BETTER ASTHMA MEDICATION KNOWLEDGE AT DISCHARGE STUDY VISIT, BETTER METERED-DOSE INHALER TECHNIQUE AT DISCHARGE STUDY VISIT, AND MASTERY OF THE DISCHARGE REGIMEN AFTER INITIAL ROUND OF INSTRUCTION (BIVARIATE ANALYSES)**

	Better Asthma Medication Knowledge			Better MDI Technique			Mastery of Medication Discharge Regimen		
	OR	95% CI	P Value	OR	95% CI	p Value	OR	95% CI	P Value
Inadequate health literacy	0.1	0.0–0.4	< 0.01	0.3	0.1–0.9	0.03	0.7	0.2–2.6	0.64
Sociodemographics									
Age, quartiles	1.1	0.7–1.6	0.77	1.1	0.7–1.7	0.58	1.2	0.7–2.2	0.49
Female	1.1	0.4–2.9	0.85	1.7	0.6–4.4	0.32	1.0	0.3–2.9	1.00
White (Black is reference)	0.3	0.1–1.0	0.06	0.4	0.1–1.4	0.14	0.4	0.1–1.8	0.22
High school Graduate or GED	0.9	0.4–2.4	0.88	1.4	0.5–3.5	0.54	0.7	0.3–2.1	0.56
Asthma-related health care use									
Hospitalization past 12 mo*	1.3	0.5–3.3	0.60	0.6	0.2–1.8	0.36	0.7	0.3–2.1	0.58
ED visit past 12 mo*	2.1	0.7–6.4	0.20	1.0	0.9–1.0	0.23	0.8	0.2–2.8	0.71
Near-fatal asthma, ever	0.8	0.3–2.1	0.69	0.2	0.1–0.7	< 0.01	0.7	0.2–1.8	0.41
Cigarettes, smoked in past	0.6	0.2–1.8	0.37	0.8	0.3–2.5	0.68	0.6	0.2–2.0	0.42
Cigarettes, currently smoking	0.1	0.0–0.4	< 0.01	0.3	0.1–1.0	0.05	0.6	0.2–1.9	0.35
Asthma physician	2.5	1.1–5.7	0.03	1.6	0.6–4.2	0.30	1.0	0.4–2.8	0.97

Definition of abbreviations: CI = confidence interval; ED = emergency department; GED = graduate equivalency diploma; MDI = metered-dose inhaler; OR = odds ratio.

Asthma medication knowledge was dichotomized such that a score of  $\geq 7/10$  was considered better knowledge; MDI technique at the discharge study visit was dichotomized such that a score of  $\geq 4/6$  was considered better technique; mastery of the discharge regimen was dichotomized such that a score of 4/4 after initial instruction was considered mastery.

\* Excludes current hospitalization/ED visit.

MDI technique. Patients with inadequate health literacy also were more likely to have lower asthma medication knowledge scores and improper MDI technique before the educational intervention. Surprisingly, inadequate health literacy was not associated with difficulty learning or retaining instructions about discharge regimen and proper MDI technique.

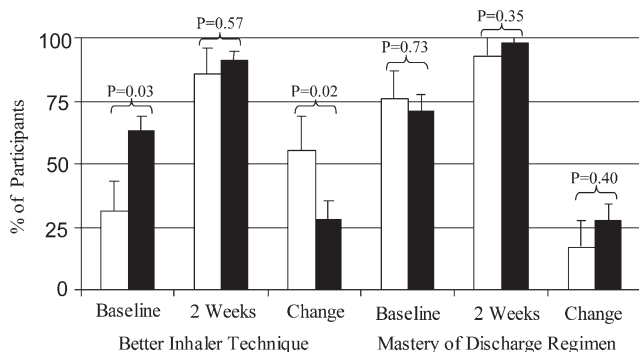
The link between inadequate health literacy and less knowledge of asthma medication and improper MDI technique reported here is consistent with prior reports (14, 15). A few studies in other disease models present evidence related to the role of health literacy in learning and retaining self-management skills in patients with other chronic diseases. For example, simplified materials have been shown to improve knowledge (38–44), health care use (45), and health behaviors (46, 47) for patients with diabetes mellitus, rheumatoid arthritis, obesity, and hypertension, irrespective of health literacy. In addition, subjects with low health literacy have been able to learn and retain self-

management skills in small studies of heart failure, obesity, and osteoarthritis (48–50).

Results of our study, however, are the first to provide data in asthma and indicate that interventions using tailored education can successfully overcome barriers related to inadequate health literacy and improve asthma self-management skills. These observations are reasons for patients, clinicians, and policymakers to be optimistic about the benefits of providing tailored education to vulnerable patient populations. Additional studies, however, are needed to determine whether these short-term gains in self-management are retained at subsequent points in time or whether “refresher” courses are necessary. Sustained success with asthma self-management may, for example, be related to specific health beliefs, which may be related to health literacy (51, 52). Also, future research should include interventions focused on other guideline-recommended self-management skills (e.g., allergen avoidance and other triggers), which are critical to maintaining effective asthma control.

We provided intensive asthma medication education at hospital discharge, which included both oral and written instructions during a one-on-one training session until mastery was achieved (“teach to goal” strategy). Although this study cannot clarify which aspects of the education were critical to ensure learning and retention (combined use of oral and written instruction, one-on-one personalized training, teach-to-goal until mastery was achieved, exhibiting appropriate MDI technique), we speculate that the physical exhibition of MDI technique by study personnel and structured assessment of participants’ understanding served to reinforce what was learned and overcome the barrier of inadequate health literacy (30). Because resources needed for this type of intensive inpatient education may not be routinely available, additional research is needed to identify key components of our multimodality intervention.

It is important to underscore the high prevalence of poor MDI technique and poor understanding of the discharge regimen we observed. Despite our intensive program to improve patients’ self-management skills provided in this study, fully 28% did not understand the discharge regimen and 30% had not mastered



**Figure 2.** Better MDI technique score (% with  $\geq 4/6$  correctly done) and mastery of discharge medication regimen (% exhibiting 4/4 questions correctly answered for all three medications in the standardized regimen) by literacy category at discharge study visit and at 2 wk. Inadequate health literacy: white bars = yes; black bars = no.

the MDI technique after one full round of education. These observations suggest that dramatic gains from the use of effective therapies in asthma are not reaching this high-risk population and highlight the need for evaluating patients' comprehension when providing discharge instructions and the development of systematic approaches to tailored inpatient asthma education.

Asthma self-management skills and use of acute medical services for asthma have been linked to various sociodemographic factors (18, 19, 53–56). In particular, fewer years of education completed has been implicated as an important risk factor in patients with asthma for cigarette smoking, worse MDI technique, and higher rates of emergency room visits, hospitalization, and mortality (19, 53–58). In this study, patients' level of education was not an independent predictor of asthma medication knowledge, MDI technique, or understanding of the discharge regimen. Instead, we found that health literacy was predictive of asthma medication knowledge and MDI technique. Moreover, our findings indicate that asthma medication knowledge plays a role in the causal pathway linking inadequate health literacy to poor MDI technique.

The prospective study design, uniform medication regimen after hospital discharge, and standardized education before discharge provided the unique opportunity to determine whether inadequate literacy served as a barrier to learning and retaining asthma self-management skills. Nonetheless, several potential limitations should be kept in mind. Although rates of follow-up were high (77%), bias may have been introduced due to incomplete follow-up, because not returning to the 2-wk follow-up visit was associated with age, race, and asthma medication knowledge. Also, without a control group, we cannot definitively conclude that our educational intervention was responsible for all the gains in asthma self-management that were noted. For example, it is possible but not certain that the lack of association we report between literacy and adherence was due to our educational intervention. Our data do, however, provide estimates of effect sizes that can be used to develop more definitive studies in this area (e.g., randomized clinical trial with an attention control group). Although interviewer bias is unlikely due to several safeguards put in place in our protocol, it is difficult to exclude completely the possibility that knowledge of health literacy status of participants influenced the teaching or assessment of self-management. Also, although we deliberately targeted an inner-city predominantly African-American population, a group at highest risk of complications resulting from asthma exacerbations, further research is needed to determine whether our findings are generalizable to other vulnerable patient populations (e.g., elderly with asthma).

Prior hospitalization strongly predicts risks of reexacerbations and death in the subsequent 12 mo (59–60). These poor outcomes are particularly common among African-American and inner-city patients for whom both hospitalizations and deaths related to asthma exacerbations are two to three times more likely than in other patient populations (64–66). These observations have led to a variety of inpatient programs to improve patients' self-management after hospital discharge (67, 68). The current study demonstrates that inpatient programs that embrace an intensive education program similar to ours are likely to overcome disparities in asthma self-management skills associated with inadequate health literacy.

In conclusion, this study presents evidence that inadequate asthma self-management skills are common and that inadequate health literacy is associated with worse asthma medication knowledge and MDI technique. However, inadequate health literacy was not associated with difficulty learning or retaining instructions about discharge regimen and proper MDI technique. Our results suggest the need for a systematic assessment of

patient comprehension of discharge instructions and medications at hospital discharge. In patients with deficiencies in asthma self-management, we recommended a tailored, teach-to-goal, asthma education program.

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