Association of Brief Health Literacy Screening and Blood Pressure in Primary Care

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Health literacy impacts health outcomes. However, the relationship to blood pressure is inconsistent. This study aimed to determine whether health literacy, assessed by clinic staff, is associated with blood pressure among patients with hypertension. The design was a cross-sectional study of a large sample of primary care patient encounters in 3 academic medical center clinics in Nashville, Tennessee. Health literacy was assessed using the Brief Health Literacy Screen, with higher scores indicating higher health literacy. Blood pressure was extracted from the electronic health record. Using 23,483 encounters in 10,644 patients, the authors examined the association of health literacy with blood pressure in multivariable analyses, adjusting for age, gender, race, education, and clinic location. Independent of educational attainment, 3-point increases in health literacy scores were associated with 0.74 mmHg higher systolic blood pressure (95% CI [0.38, 1.09]) and 0.30 mmHg higher diastolic blood pressure (95% CI [0.08, 0.51]). No interaction between education and health literacy was observed (p = .91). In this large primary care population of patients with hypertension, higher health literacy, as screened in clinical practice, was associated with a small increase in blood pressures. Future research is needed to explore this unexpected finding.

Thirty-six percent of Americans function at or below a basic health literacy level (Kutner, Greenberg, Jin, Paulsen, & White, 2006). This often impacts the ability to perform tasks such as understanding basic written health information or reading a
prescription bottle correctly. Low health literacy is associated with worse chronic disease control, increased utilization of the emergency department and hospital care, and increased mortality (Berkman et al., 2011; Bostock & Steptoe, 2012). However the relationships to specific diseases remain unclear.

Lower health literacy has been associated with increased prevalence of hypertension (Kim, 2009; Shibuya et al., 2011), as well as worse hypertension-related knowledge (Gazmararian, Williams, Peel, & Baker, 2003; Pandit et al., 2009; Williams, Baker, Parker, & Nurss, 1998), lower ability to identify hypertension medications (i.e., during medication reconciliation; Persell, Osborn, Richard, Skripkauskas, & Wolf, 2007), and reduced adherence to cardiovascular medication refills (Gazmararian et al., 2003). However, the relationship between health literacy and blood pressure values is inconsistent. Some studies have found that higher health literacy is associated with better control of hypertension (Kripalani, Little, Bengtzen, Robertson, & Jacobson, 2006; Pandit et al., 2009), but another study among veterans with hypertension found the opposite relationship (Powers, Olsen, Oddone, Thorpe, & Bosworth, 2008).

The relationship between higher educational attainment and improved hypertension knowledge and outcomes is well established (Kaplan & Keil, 1993). However, levels of education and health literacy do not always correlate (Kutner et al., 2006). A study by Pandit and colleagues demonstrated that, in patients with low educational attainment, health literacy mediated the relationship of education with hypertension knowledge but not with control of hypertension (Pandit et al., 2009). Additional research on relationships between health literacy and hypertension outcomes and the interaction with education is needed. Given the small sample size of most previous investigations of health literacy, large population-based studies would be valuable.

In October 2010, as part of the Health Literacy Screening (HEALS) study, the Vanderbilt University Medical Center implemented routine assessment of patient health literacy and educational attainment by clinic staff survey during the primary care clinic check-in process (Cawthon, Mion, Willens, Roumie, & Kripalani, in press). Our aim was to examine the relationship between health literacy and blood pressure, independent of educational attainment, among a primary care patient population with hypertension. We also aimed to assess any interaction between health literacy and patient-reported educational attainment. Our hypothesis was that patients with lower health literacy would have higher systolic blood pressure.

Method

Study Design and Setting

We conducted a cross-sectional study in three primary care clinics at the Vanderbilt University Medical Center, in Nashville, Tennessee, from November 11, 2010, to October 1, 2011. The clinics serve approximately 30,000 patients each year. In total at these three locations are 48 attending physicians and 84 resident physicians. All data were extracted from the medical center’s Enterprise Data Warehouse, which is populated from clinical and administrative information from the patient’s electronic health record. The Vanderbilt University Institutional Review Board approved this study.

Study Population

The cohort included patients who had at least one primary care encounter during the observation period. Patients could contribute more than one encounter. Encounters
Measurement of Health Literacy

Health literacy was assessed by the Brief Health Literacy Screen (BHLS), a verbally administered, three-question survey (Chew, Bradley, & Edward, 2004; Chew et al., 2008). Upon primary care clinic check-in, clinic staff verbally administered the BHLS and then assessed educational attainment. The BHLS questions are as follows (Chew et al., 2004):

1. How confident are you filling out medical forms by yourself?
2. How often do you have someone help you read hospital materials?
3. How often do you have problems learning about your medical condition because of difficulty understanding written information?

Staff were trained in BHLS administration by study personnel in group and one-on-one sessions. The BHLS was conducted in private by clinic staff and the screen was normalized by informing the patients that the questions were given to everyone. Study personnel trained clinic staff to be sensitive to the possibility of shame associated with low health literacy, and feedback was used to refine administration technique.

Patient BHLS responses were recorded in the electronic medical record on a 5-point Likert scale. The first question was reverse-coded. The score for the three questions was summed to equal between 3 and 15 points, with higher scores indicating higher health literacy (Peterson et al., 2011). These questions have been previously shown to correlate with the Short Test of Functional Health Literacy in Adults (S-TOFHLA) and Rapid Estimate of Adult Literacy in Medicine as criterion standards (Chew et al., 2008; Chew et al., 2004; Powers, Trinh, & Bosworth, 2010; Wallace, Rogers, Roskos, Holiday, & Weiss, 2006; Wallace et al., 2007). On the basis of past examination (Chew et al., 2008; Wallace et al., 2007), the response cutoff that optimized sensitivity and specificity for low health literacy defined on each question was ≤3 (i.e., “somewhat” or “some of the time”) on the Likert scale. Summing the three items did not reduce discriminatory efficacy. Therefore, a summative BHLS score ≤9 was considered to indicate low health literacy. A psychometric evaluation of the BHLS, as administered by clinic staff, demonstrated that it serves as a valid and reliable estimate of patients’ health literacy (Wallston et al., 2013).

Outcomes: Systolic and Diastolic Blood Pressure and Blood Pressure Control

The primary outcome was the systolic BP at the encounter. This was chosen on the basis of a recommendation by the National High Blood Pressure Education Program that it be the principal measure for diagnosing and managing hypertension (Stamler, Stamler, & Neaton, 1993). Secondary outcomes were diastolic blood pressure and blood pressure control at the encounter. BP control was defined as BP < 140/90 mmHg.
or <130/80 mmHg among patients with diabetes (American Diabetes Association, 2011; Chobanian et al., 2003). Only outpatient BP measurements were included. If more than one value was available on the encounter day, then the mean value was used. Out-of-range values were filtered and rejected as likely data entry errors (systolic BP values <60 or >250 mmHg, diastolic BP values <30 or >130 mmHg, and cases in which systolic minus diastolic BP was <10 mmHg). Filtered and excluded BP values corresponded to 0.14% of all hypertension patient encounters in the dataset.

Covariates

Covariates at the time of each encounter were also recorded. These included age (continuous), gender, race (White, Black, Asian, or other), and educational attainment (less than high school or equivalent, high school or equivalent only, up to 4 years after high school, 4 to <6 years after high school, or ≥6 years after high school), and clinic site (A, B, or C). The number of primary care clinic encounters during the study period was also recorded.

Handling Multiple Encounters and Missing Values

We considered health literacy and educational attainment to be stable patient characteristics during the time period of study. If a patient had multiple encounters and had only one BHLS recorded, that value was carried across to other encounters. If a patient had multiple encounters with different responses to the BHLS recorded across those encounters, then the median BHLS was calculated and applied to all of that patient’s encounters. Variation across multiple administrations of BHLS over multiple patient encounters was minimal with the estimated intra-subject correlation in BHLS score was 0.91. If a patient had reported differing levels of educational attainment then we used the highest value recorded per patient. On the basis of past literature showing an inverse relationship between education and blood pressure (Kaplan & Keil, 1993), this assumption would bias our evaluation of education and systolic BP toward the null hypothesis. Reports of educational attainment among patients who were observed on more than one occasion were consistent for 90% of patients.

Some encounters were missing data on health literacy (43%), educational attainment (46%), or race (5%), predominantly as a result of time pressures at clinic check-in affecting administration of these questions. We addressed this by performing multiple imputation (Dempster, Laird, & Rubin, 1977). Given that the aforementioned reasons are unlikely related to blood pressure, a missing-at-random mechanism was assumed. We also conducted three sensitivity analyses to determine whether our results were sensitive to these assumptions. First, we used encounters with complete data to determine whether the multiple imputation could affect our results. Second, we conducted a patient-level analysis using as the exposure only the first BHLS administration and as an outcome the first available blood pressure to determine whether a patient-level analysis would differ from the encounter-level. Third, an analysis was performed that adjusted for the number of clinic visits to determine if more clinic contact could influence the results.

Statistical Analysis

The unit of analysis was each eligible encounter. Unadjusted, bivariate analysis compared systolic and diastolic blood pressures of the low and adequate health literacy groups using the Wilcoxon rank-sum test. BP control rates of each group were compared using Pearson’s chi-square test.
Multiple linear regression was used to examine the effect on systolic BP and diastolic BP, respectively, of the BHLS sum (range = 3 to 15) adjusting for educational attainment, patient age, gender, race, and clinic site. Multiple logistic regression was used for the binary BP control outcome adjusting for the same covariates. These covariates were chosen a priori on the basis of their potential to be confounders. The interaction between BHLS and educational attainment was examined in the systolic BP, diastolic BP, and BP control models. Because patients could contribute more than one encounter to the analysis, within-patient response dependence could lead to invalid estimates of uncertainty. To acknowledge within-patient response dependence, we used robust standard errors (Zeger & Liang, 1986).

To address missing BHLS, education, and race data, we used multiple imputation with 30 imputed datasets for adjusted analyses. Imputation datasets were generated using information from all covariate and outcome data, and to fully acknowledge the uncertainty in generating imputed data, bootstrapped samples were used to draw from the posterior predictive distribution. To display covariates and unadjusted analysis by health literacy level, a single imputed data set was used. Analyses were conducted using G*Power version 3.1.3, Stata version 11, and the rms library in R (R Development Core Team, 2009).

On the basis of previous studies (Kripalani et al., 2006; Powers et al., 2008) and knowledge of local clinic sites, we assumed the prevalence ratio of adequate to low health literacy was 9:1 and the standard deviation of systolic blood pressure was 15 mmHg. We needed 19,626 encounters to achieve 80% power to detect a difference of at least 1 mmHg in mean systolic BP between adequate and low health literacy groups.

Results

At the three VUMC primary care clinics, 28,701 patients had a total of 56,680 clinical encounters during the study timeframe. Among these encounters, 24,111 (42.5%) met criteria for a hypertension diagnosis. After we excluded encounters with incomplete or invalid BP data, the final cohort consisted of 23,483 encounters in 10,644 unique patients (Figure 1).

Table 1 describes encounter-level patient characteristics by health literacy and overall. Of the 23,483 encounters, 3,414 (14.5%) had a BHLS score ≤9 (low health literacy). Encounters with BHLS scores ≤9 corresponded to older patients (median = 73 years vs. 64 years), and they were less predominantly White (66.8% vs. 76.4%) and more often had not achieved the equivalent of a high school education (33.2% vs. 12.2%), compared with those who scored >9 on the BHLS. The prevalence of low health literacy varied among Clinics A (12.6%), B (10.6%), and C (16.0%), p < .001.

Patients with low health literacy, in comparison with patients with adequate health literacy, had significantly more encounters (3.30 vs. 3.09, p < .001). The BHLS scores and characteristics of the sample with complete data (13,775 encounters [58.7%]) were similar to the full cohort with missing data imputed (Appendix Table 1).

**Unadjusted Relationship Between Health Literacy and Blood Pressure**

In unadjusted analyses, the median systolic BP did not differ between the groups with BHLS ≤9 (130 mm Hg) and BHLS >9 (131 mm Hg), p = .482 (Table 2). Diastolic BP was lower in encounters with BHLS ≤9 versus those >9, median of 70 mmHg vs. 74 mmHg, respectively, (p < .001). The percentages of patients with controlled blood pressure and BHLS ≤9 versus >9 were 56.5% vs. 55.6% (p = .855), respectively.
In multivariable analyses, higher health literacy was associated with higher systolic and diastolic BP (Table 3). After adjusting for the age, gender, race, education and clinic location, for every three-point increase in BHLS, systolic BP increased 0.74 mmHg (95% CI [0.38, 1.09]), and the diastolic BP increased 0.30 mmHg (95% CI [0.08, 0.51]). Adjusting for the same covariates, patients with higher health literacy had slightly lower odds of controlled blood pressure (odds ratio = 0.94; 95% CI [0.91, 0.98]).

Compared with a recorded educational attainment of high school or equivalent only, having 4 to 6 years of post–high school education was associated with 1.67 mmHg lower systolic BP, and having ≥6 years after high school was associated with 2.30 mmHg lower systolic BP. There was no interaction between education and health literacy for systolic BP, diastolic BP, or BP control.

In sensitivity analyses that were restricted to patient encounters with complete BHLS and covariates, results were consistent with the primary findings (see Appendix Table 2 and Appendix Table 3). In a patient-level sensitivity analysis using the first BHLS administration and blood pressure, results were also essentially identical. For every three-point increase in BHLS, systolic BP increased 0.60 mmHg (95% CI [0.18, 1.03]), and the diastolic BP increased 0.27 mmHg (95% CI [0.01, 0.52]). Results were also similar in an analysis that adjusted for the number of patient encounters.
Discussion

In this large sample of primary care patients with hypertension, higher health literacy, as assessed by clinic staff using the BHLS, was associated with higher systolic and diastolic BP, independent of education and demographic factors. Educational attainment was associated with lower blood pressure independent of health literacy and demographic factors. No interaction between education and health literacy was demonstrated. To our knowledge, this is the largest study to date describing the relationships between health literacy, educational attainment, and blood pressure. It is also one of the only studies describing the association of BHLS scores and clinical parameters collected under real-world clinical conditions.

Although our hypothesis predicted higher systolic blood pressure in patients with lower health literacy, our result was the inverse. One possible explanation is that patients with low health literacy in this study may not be reflective of the general population with low health literacy. Patients in this study had health insurance and were for the Table 2. Encounter-level primary blood pressure outcomes ($N = 23,483$)

|                         | Encounters with BHLS ≤9 ($n = 3,414$) | Encounters with BHLS >9 ($n = 20,069$) | $p$  |
|-------------------------|---------------------------------------|----------------------------------------|------|
| Systolic BP median (IQR), mmHg | 130 (120–142)                         | 131 (120–142)                          | .482 |
| Diastolic BP, median (IQR), mmHg | 70 (64–79)                           | 74 (67–82)                             | <.001|
| BP controlled, n (%)*    | 1,929 (56.5)                          | 11,163 (55.6)                          | .339 |

Note. *BP <140/90 mmHg or <130/80 mmHg among patients with diabetes.
BP = blood pressure, IQR = interquartile range, mmHg = millimeters mercury, BHLS = Brief Health Literacy Screen.
### Table 3. Adjusted relationship between BHLS sum and BP ($N = 23,483$)

|                           | SBP, mmHg (95% CI) | DBP, mmHg (95% CI) | BP control, odds ratio (95% CI) |
|---------------------------|--------------------|--------------------|---------------------------------|
| **Intercept, mmHg or odds ratio** | 128.22 (127.5, 129.0)* | 72.89 (72.48, 73.29)* | 0.95 (0.87, 1.03) |
| **BHLS sum (per 3-point change)** | 0.74 (0.38, 1.09)* | 0.30 (0.08, 0.51)† | 0.94 (0.91, 0.98)† |
| **Age, years (per 10-year change)** | 0.95 (0.77, 1.14)* | −2.66 (−2.78, −2.55)* | 1.05 (1.03, 1.07)* |
| **Male gender** | −1.80 (−2.26, −1.34)* | 1.65 (1.37, 1.92)* | 1.20 (1.13, 1.26)* |
| **Race (versus White)** | | | |
| Black | 3.14 (2.52, 3.76)* | 2.27 (1.89, 2.65)* | 0.87 (0.81, 0.93)* |
| Asian | −0.33 (−2.23, 1.58) | 0.31 (−0.89, 1.52) | 1.10 (0.88, 1.38) |
| Other | 0.66 (−2.01, 3.33) | 1.33 (−0.37, 3.02) | 1.02 (0.72, 1.46) |
| **Education, years (versus high school level only)** | | | |
| <HS or equivalent | 0.20 (−1.33, 1.73) | −0.14 (−0.98, 0.70) | 1.05 (0.89, 1.23) |
| >HS or equivalent to >4 years after HS | −0.83 (−1.92, 0.26) | 0.07 (−0.48, 0.62) | 1.06 (0.94, 1.19) |
| 4 to <6 years after HS | −1.67 (−2.62, −0.72)† | 0.32 (−0.24, 0.89) | 1.05 (0.94, 1.18) |
| ≥6 years after HS | −2.30 (−3.35, −1.26)* | 0.42 (−0.15, 0.98) | 1.13 (1.00, 1.28) |
| **Location (versus Clinic A)** | | | |
| Clinic B | 8.59 (7.8, 9.37)* | 4.10 (3.58, 4.62)* | 0.52 (0.48, 0.57)* |
| Clinic C | 4.76 (4.20, 5.34)* | −0.88 (−1.22, −0.55)* | 0.87 (0.81, 0.93)* |

The BHLS sum and age were mean-centered before fitting these models at 12 and 65, respectively. The intercepts for the systolic BP and diastolic BP models represent the expected or mean value for the population of people who have a BHLS score equal to 12, are 65 years old, White, female, have a high school or equivalent education only, and were seen at Clinic A.

**Note.** BHLS = Brief Health Literacy Screen, DBP = diastolic blood pressure, HS = high school, mmHg = millimeters mercury, SBP = systolic blood pressure.

* $p \leq .001$. † $p \leq .01$. 


most part established in primary care. The study design required that patients have one inpatient or two outpatient billing codes for hypertension in the past year. Moreover, the patients with low health literacy were at least as engaged in seeking regular health care, as reflected by a greater number of clinic visits compared to those with adequate health literacy. These factors may mitigate some effects of low health literacy, although the sensitivity analysis that adjusted for the number of clinic visits did not affect the results. In addition, other unmeasured confounders may have influenced the results, such as the possibility that patients with low health literacy received more counseling from their primary care physician or had greater medication adherence, resulting in lower blood pressure. It will be important to measure such factors in future studies.

Another possible explanation for our results is that health literacy is but one of many variables in a complex pathway leading to chronic disease outcomes (Osborn, Paasche-Orlow, Bailey, & Wolf, 2011; Paasche-Orlow & Wolf, 2007). Some studies demonstrate a link between low health literacy and worse chronic disease outcomes, but a recent review found that evidence for most conditions is of low quality or insufficient due to the small number of studies or patients, poorly designed studies, or inconsistent results (Berkman et al., 2011).

This study confirms previous research findings that higher educational attainment is associated with lower blood pressure (Kaplan & Keil, 1993). As shown by Pandit and colleagues (2009), this relationship exists independently of health literacy. Our study confirms and extends this finding by using the BHLS assessment by clinic staff. Our study also confirms that, in our population of patients with hypertension, no interaction exists between education and health literacy on blood pressure; literacy affects blood pressure at all levels of education. However, contrary to Pandit and colleagues (2009), we demonstrated lower blood pressures in encounters with lower health literacy. Health literacy has been hypothesized to mediate the relationship between education and hypertension outcomes by affecting access to health care, provider–patient interactions and patient self-care (Paasche-Orlow & Wolf, 2007; Osborn, Paasche-Orlow, Bailey, & Wolf, 2011). Our study demonstrates that assessments of a patient’s health literacy in addition to educational attainment are each significantly associated with blood pressure. Our study also showed that educational attainment and health literacy had opposite relationships with blood pressure. Health literacy and education do not always correlate (Kutner et al., 2006), and this may be due to literacy also acting as a marker for other psychosocial factors such as cognitive abilities (Yen & Moss, 1999) or community resources (Wallerstein, 1992). This study is hypothesis-generating for further research to determine the mechanisms of how health literacy may affect hypertension.

This study has several limitations. It was an observational study and, although we included several confounders in our model, unmeasured confounders such as the duration of hypertension, the number and use of antihypertensives, and adherence to antihypertensive medications may have accounted for some of the findings. Future studies should seek to account for these potential confounders.

Another limitation is that, oftentimes, staff did not administer the BHLS and education questions. Staff cited time pressures as the principal barrier. The multiple imputation procedure was able to recover missing information using other covariate data. Though this could introduce bias, sensitivity analysis using only encounters with complete data did not find any substantive differences in the outcomes. Also, health literacy assessment may elicit feelings of shame in some patients with inadequate literacy (von Wagner, Steptoe, Wolf, & Wardle, 2009), and this could have resulted in responder bias or refusal. But clinic staff reported patient comfort with the BHLS items. Patient refusal to answer questions was low, but this was not tracked systematically. Last, our study findings are
generalizable to patients with hypertension seen in academic practices. This population may be different than patients seen in non-academic private practices or among patients seen in practices such as federally qualified health centers or health departments.

Among the strengths of our study is the large sample size, which provided power to discern the small but significant associations of health literacy and educational attainment on BP. Difference in blood pressure, even by a very small amount, is considered an important determinant of cardiovascular outcomes including strokes, myocardial infarctions, heart failure, and renal disease (Chobanian et al., 2003; Law & Wald, 2002; Lewington et al., 2002). The parent HEALS study also follows on the Institute of Medicine recommendation to incorporate patient health literacy level into the electronic medical record (Nielsen-Bohlman, Panzer, & Kindig, 2004). The three-question brief health literacy screen was less time-consuming and more practical for a clinical setting than other measures of health literacy.

This study demonstrates that lower health literacy and higher educational attainment, when routinely assessed by clinic staff, are independent predictors of lower blood pressure in a primary care population of hypertension patients. Though the literacy relationship is contrary to our hypothesis, this finding demonstrates that even in the face of limited health literacy, patients can have lower blood pressure. In addition, education and health literacy are each independently associated with blood pressure. More research is needed that assesses these effects while accounting for medication adherence and antihypertensive treatment. Similarly, the study of implementation strategies of routine screening of health literacy in the clinic setting is also warranted.

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Appendix

Appendix Table 1. Encounter-level patient characteristics among encounters with complete data

|                      | Encounters with BHLS ≤9 (n = 2,077) | Encounters with BHLS >9 (n = 11,698) | All encounters (N = 13,775) |
|----------------------|-------------------------------------|-------------------------------------|-----------------------------|
| Unique patients, n   | 710                                 | 4,633                               | 5,343                       |
| Age, median (IQR), years | 74 (64–83)                            | 65 (55–74)                           | 66 (56–75)                 |
| Male gender, n (%)   | 867 (41.7)                           | 4,601 (39.3)                        | 5,468 (39.7)               |
| Race (%)             |                                     |                                     |                             |
| White                | 1,480 (71.3)                         | 9,114 (77.9)                        | 10,594 (76.9)             |
| Black                | 541 (26.1)                           | 2,474 (21.2)                        | 3,015 (21.9)              |
| Asian                | 51 (2.5)                             | 89 (0.8)                            | 140 (1.0)                 |
| Other                | 5 (0.2)                              | 21 (0.2)                            | 26 (0.2)                  |
| Education, n (%)     |                                     |                                     |                             |
| <HS or equivalent    | 608 (29.3)                           | 709 (6.1)                           | 1,317 (9.6)               |
| HS or equivalent only| 900 (43.3)                           | 3,667 (31.4)                        | 4,567 (33.2)              |
| >HS or equivalent to <4 years after HS | 269 (13.0)                           | 2,904 (24.8)                        | 3,173 (23.0)             |
| 4 to <6 years after HS | 224 (10.8)                           | 2,603 (22.3)                        | 2,827 (20.5)             |
| ≥6 years after HS    | 76 (3.7)                             | 1,815 (15.5)                        | 1,891 (13.7)             |

Note. BHLS = Brief Health Literacy Screen, HS = high school, IQR = interquartile range, mmHg = millimeters mercury.

Appendix Table 2. Encounter-level primary BP outcomes among encounters with complete data (N = 13,775)

|                      | Encounters with BHLS ≤9 (n = 2,077) | Encounters with BHLS >9 (n = 11,698) | p |
|----------------------|-------------------------------------|-------------------------------------|---|
| Systolic BP, median (IQR), mmHg | 130 (119–124)            | 130 (120–142)            | .349 |
| Diastolic BP, median (IQR), mmHg | 70 (64–79)                    | 74 (67–82)                    | <.001 |
| BP controlled, n (%)* | 1,174 (56.6)                    | 6,587 (56.3)                    | .855 |

Note. BHLS = Brief Health Literacy Screen, BP = blood pressure, IQR = interquartile range, mmHg = millimeters mercury, HS = high school.

*BP <140/90 mmHg or <130/80 mmHg among patients with diabetes.
### Appendix Table 3. Adjusted relationship between BHLS sum and BP among encounters with complete data ($N=13,775$)

|                        | SBP, mmHg (95% CI) | DBP, mmHg (95% CI) | BP control, odds ratio (95% CI) |
|------------------------|--------------------|--------------------|---------------------------------|
| Intercept, mmHg or odds ratio | 128.7 (127.9,129.4)* | 73.12 (72.7,73.5)* | 0.89 (0.82, 0.97)†             |
| BHLS sum (per 3-point change) | 0.67 (0.35, 0.98)* | 0.27 (0.09, 0.46)† | 0.95 (0.92, 0.98)†             |
| Age, years (per 10-year change) | 1.00 (0.77, 1.22)* | −2.80 (−2.94, −2.66)* | 1.05 (1.02, 1.07)*             |
| Male gender | −2.81 (−3.40, −2.21)* | 0.91 (0.56, 1.27)* | 1.39 (1.30, 1.50)*             |
| Race (versus White) |                        |                    |                                 |
| Black                  | 3.15 (2.40, 3.89)* | 2.45 (1.99, 2.91)* | 0.86 (0.79, 0.94)*             |
| Asian                  | 0.75 (−2.03, 3.52) | 0.37 (−1.28, 2.03) | 1.17 (0.83, 1.64)              |
| Other                  | 1.21 (−1.77, 4.18) | 1.96 (0.10, 3.83)‡ | 1.06 (0.67, 1.67)              |
| Education, years (versus high school level only) |                        |                    |                                 |
| <HS or equivalent      | 0.93 (−0.29, 2.15) | 0.14 (−0.56, 0.84) | 1.04 (0.92, 1.19)              |
| >HS or equivalent to ≤4 years after HS | −0.84 (−1.63, −0.05)† | 0.03 (−0.45, 0.52) | 1.06 (0.97, 1.17)              |
| 4 to <6 years after HS | −1.60 (−2.40, −0.79)* | 0.50 (0.00, 0.99)† | 1.04 (0.94, 1.14)              |
| >6 years after HS      | −2.24 (−3.16, −1.31)* | 0.56 (0.01, 1.11)† | 1.10 (0.98, 1.23)              |
| Location (versus Clinic A) |                        |                    |                                 |
| Clinic B               | 7.96 (7.08, 8.83)* | 3.58 (3.01, 4.15)* | 0.56 (0.50, 0.62)*             |
| Clinic C               | 4.40 (3.74, 5.06)* | −0.94 (−1.33, −0.55)* | 0.94 (0.87, 1.01)              |

The BHLS sum and age were mean-centered before fitting these models at 12 and 65, respectively. The intercepts for the systolic BP and diastolic BP models represent the expected or mean value for the population of people who have a BHLS score equal to 12, are 65 years old, White, female, have a high school or equivalent education only, and were seen at Clinic A.

BHLS = Brief Health Literacy Screen, BP = blood pressure, HS = high school, mmHg = millimeters mercury.

* $p \leq .001$, † $p \leq .01$, ‡ $p \leq .05$. 