The association of health literacy with illness perceptions, medication beliefs, and medication adherence among individuals with type 2 diabetes

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ABSTRACT

Background: Beliefs in medications and illness perceptions is associated with medication adherence among individuals with diabetes and several adherence interventions focus on patients' beliefs in medicines and illnesses. Though health literacy is important in medication adherence, the relationship between health literacy and medication adherence remains inconclusive; thus raising the question as to whether health literacy has an amplifying or reducing effect on the relationship between beliefs and adherence.

Objective: The study examined (1) the association between health literacy, beliefs in medicines, illness perceptions, and medication adherence in individuals with type 2 diabetes and (2) the moderating effects of health literacy (including numeracy and document literacy) on the relationship between illness perceptions, beliefs in medicines, and medication adherence.

Methods: Adults ≥20 years taking oral diabetes medicines at two family medicine clinics, completed a cross-sectional survey. Participants were assessed on beliefs in medicines, illness perceptions, health literacy, self-efficacy, and medication adherence. Multiple linear regressions examined the effect of health literacy, beliefs and self-efficacy, and the moderator effect of health literacy in the relationship between beliefs and adherence.

Results: Of the 174 participants, more than half were women (57.5%) and white (67.8%). There was a significant positive association between self-efficacy and adherence (β = 0.486, p < .001), and a negative association between threatening illness perceptions and adherence (β = −0.292, p < .001). Health literacy had a significant moderator effect on the relationship between adherence and concerns beliefs (β = −0.156, p = .014) and threatening illness perceptions (β = 0.196, p = .002). The concern beliefs - adherence association was only significant at marginal and adequate literacy levels. When health literacy was separated into numeracy and document literacy, only numeracy moderated the illness perceptions - adherence relationship (β = 0.149, p = .038).

Conclusions: Health literacy, especially numeracy, needs to be initially addressed before diabetes adherence interventions that address individual concerns about medicines and threatening illness perceptions can work.

1. Introduction

Diabetes is a complex and demanding chronic disease that requires extensive self-care, education, and management.[1] One of the seven essential self-management behaviors needed to achieve glycemic control for individuals with diabetes is being adherent to medications.[2] Individuals with diabetes need adequate self-management abilities and require advanced health literacy skills, which may be influenced by their personal health beliefs.

Health literacy, defined as the capacity to obtain, communicate, process, and understand basic health information, is an important factor that influences self-management behaviors and individual

outcomes in chronic diseases including diabetes.[3] In addition to understanding, evaluating, and using written text, individuals with chronic diseases need numeracy skills as it is likely to impact their ability to seek and process health information during disease self-management; hence influencing their adherence and health outcomes.[4–6] Individuals with diabetes who have limited health literacy or numeracy are more likely to have poor ability to recognize their symptoms,[7] lower self-efficacy,[8] poor ability to adhere to treatment recommendations,[8] worse glycemic control,[9] and have difficulties performing numeracy-related tasks such as adjusting insulin for carbohydrate content.[10] Though both health literacy and medication adherence are important in diabetes management, there are inconclusive results

regarding whether health literacy has a direct relationship with medication adherence.[11–14] Ostini and Kairuz, 2014 suggested a relationship where individuals with low health literacy are more often non-adherent, individuals with moderate health literacy are most adherent; and individuals with high health literacy are somewhat non-adherent.[12]

Behavioral models such as the self-regulatory model emphasize the role of individual beliefs in disease self-management including medication adherence.[6] Previous literature shows that negative concern beliefs about medicines (e.g. worries about the side effects or dependence effects of medicines) and negative illness perceptions (e.g. belief that diabetes is not a chronic disease) are associated with poor medication adherence.[15–17] According to the self-regulatory model, individual illness perceptions activate behavioral actions such as medication adherence. The self-regulatory model identifies five domains of illness perceptions as identity (individuals' identification of symptoms), timeline (beliefs about the chronicity of diabetes), cause (personal ideas about the etiology of the illness), consequences (beliefs about expected outcome of illness on health), and control (beliefs and expectations that the illness is controllable). In addition, emotional representations (fear or anxiety activated by diabetes or its symptoms) may also negatively influence adherence.[18–20] Horne and colleagues incorporated beliefs in medicines by extending the self-regulatory model.[21]

Knowing that beliefs in medications and illness perceptions have a strong relationship with medication adherence in individuals with diabetes,[16,22] and the relationship between health literacy and medication adherence is inconclusive; the question remains as to whether the relationship between beliefs and adherence remains the same at all levels of health literacy. Does simply addressing individual beliefs lead to improved medication adherence among individuals with diabetes even when their health literacy is limited? Therefore, the current study hypothesized that health literacy may amplify or reduce the effect of the relationship between beliefs and adherence in patients with diabetes (Fig. 1). Additionally, if health literacy has a moderator effect between beliefs and adherence, understanding which specific belief is critical will aid in the delivery of tailored educational-behavioral medication counseling. Only one study among individuals with chronic obstructive pulmonary disease has examined the association of health literacy, beliefs in medicines, and illness perceptions with medication adherence.[6] This study showed an association of low health literacy with concerns about medicines and components of the illness perceptions domains.

Thus, the objectives of this study were to:

1. Examine the association between health literacy, beliefs in medicines, illness perceptions, and medication adherence in individuals with type 2 diabetes.
2. Examine the moderating effects of health literacy (including numeracy and document literacy) on the relationship between illness perceptions, beliefs in medicines, and medication adherence.

2. Methods

Using a convenience sampling approach, adults who were at least 20 years and older, diagnosed with type 2 diabetes, currently taking at least one prescribed oral diabetes medications daily, and able to speak English participated in the study. Individuals who were too ill to participate, younger than 20 years old, unable to speak English, and currently not taking at least one prescribed oral diabetes medications were excluded. The study research assistant retrieved a list of eligible individuals from the electronic health record database of two family medicine clinics in a Midwestern State in the United States. Using a descriptive cross-sectional study design, we administered a face-to-face questionnaire to participants at two family medicine clinics. The research assistant reviewed the participant log to verify the eligibility of the individual, administered the informed consent form, and completed the 20–30 min' survey with the individual. Data collection occurred from March 2016 to August 2016. Participants were compensated with $25 cash, upon completion of the survey. The Health Sciences Institutional Review Board at the primary investigators' University approved the study.

2.1. Measurement

Medication adherence was evaluated using the 8-item Morisky Medication Adherence Scale (MMAS-8), a valid and reliable measure that has been widely used in individuals with diabetes.[23,24] The total score of MMAS-8 ranged from 0 to 8, with a higher score indicating better medication adherence.[25] Health literacy was measured using the 6-item Newest Vital Sign (NVS).[26,27] This validated measure, which also includes the numeracy domain, has been extensively used across studies including individuals with type 2 diabetes.[28,29] The six items in the NVS was scored "0" for incorrect and "1" for correct yielding a total score ranging from 0 to 6.[30] Scores less than 2 represented low health literacy, 2 to 3 indicated moderate health literacy, and more than 3 suggested adequate health literacy. Beliefs in medications were measured using the Beliefs in Medicines Questionnaire (BMQ). The BMQ has the necessity beliefs and concern beliefs sub-scales measured on five-point Likert-type scales with strongly disagree to strongly agree as the response options for each sub-scale.[31] Higher scores mean stronger concern beliefs or necessity beliefs about the medicine. Illness perceptions were measured using the validated 8-item Brief-Illness Perceptions Questionnaire (B-IPQ) that includes survey items assessing individual illness perceptions along the cognitive domains of the self-regulatory model as well as emotional responses to having diabetes.[32] Each item was assessed on a scale of 0–10 and were added together to compute the overall illness perceptions score. Higher scores represent more threatening illness perceptions. Self-efficacy for medication use was measured using the 13-item Self-efficacy for Appropriate Medication Use Scale (SEAMS), a reliable and valid measure that is appropriate for use regardless of individual literacy skills.[33] The total score ranged from 13 to 39 with higher scores indicating more confidence in adhering to medication use.[33]

Individual sociodemographic information collected in the survey included age, gender, race, the highest education level, health insurance, and the annual household income. The clinical characteristics included self-report health status, the number of medications used, the number of chronic illnesses, frequency of daily diabetes medication use, duration of diagnosis of diabetes mellitus, and whether the individual used insulin for diabetes control.

2.2. Data analysis

Descriptive statistics including frequencies, percentages, means and standard deviations, examined individual sociodemographic and clinical characteristics. Using chi-square tests, we examined the differences in individual factors (categorical variables) by health literacy levels
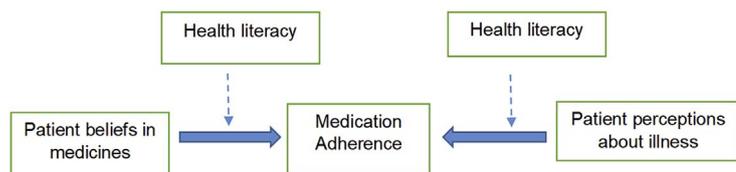

Fig. 1. Conceptual model showing the relationship between medication adherence, patient beliefs, illness perceptions, and health literacy. Note: The solid arrow direction shows that patient beliefs in medicines and patient perceptions about illness are associated with adherence. However, our study hypothesis is that health literacy may amplify or reduce the effect of the relationship between these patient beliefs and adherence in patients with diabetes and is shown using the dotted arrow.

Table 1
Predictor variables for the different regression models.

Model	Dependent Variable	Independent variables	Objective of the regression analysis	Significant finding(s)
Model 1	Medication Adherence	• Necessity beliefs • Concern beliefs • Illness perceptions • Health literacy	Determine the association between beliefs, health literacy and medication adherence	Health literacy does not have a direct relationship with medication adherence. Illness perceptions are negatively associated with medication adherence
Model 2	Medication Adherence	• Necessity beliefs • Concern beliefs • Illness perceptions • Health literacy • Interaction term between necessity beliefs and health literacy • Interaction term between concern beliefs and health literacy • Interaction term between illness perceptions and health literacy	Determine the moderator effect of health literacy in the association between beliefs and medication adherence	Health literacy had a significant moderator effect on the relationship between adherence and concerns beliefs and adherence and illness perceptions
Model 3	Medication Adherence	• Necessity beliefs • Concern beliefs • Illness perceptions • Document literacy, domain of health literacy • Numeracy, domain of literacy	Determine which domain of health literacy is associated with medication adherence	Both document literacy and numeracy did not have a direct relationship with medication adherence. Illness perceptions are negatively associated with medication adherence
Model 4	Medication Adherence	• Necessity beliefs • Concern beliefs • Illness perceptions • Document literacy, domain of health literacy • Numeracy, domain of health literacy • Interaction term between necessity beliefs and numeracy • Interaction term between concern beliefs and numeracy • Interaction term between illness perceptions and numeracy • Interaction term between necessity beliefs and document literacy • Interaction term between concern beliefs and document literacy • Interaction term between illness perceptions and document literacy	Determine which domain of health literacy has the moderator effect in the association between beliefs and medication adherence	When health literacy was separated into numeracy and document literacy, it was numeracy that moderated the illness perceptions - adherence relationship

(i.e., low, moderate, and adequate health literacy). One-way ANOVA was used to examine the mean differences in the main predictor variables (i.e. illness perceptions, necessity beliefs, and concern beliefs) by health literacy levels (low, moderate, and adequate). Self-report measures of medication adherence are usually skewed in the direction of better adherence and may require transformation of raw data for parametric analysis. Hence, we examined the distribution of the data including skewness and kurtosis. We also checked for correlations between the two health literacy domains (numeracy and document literacy), and investigated if there was multicollinearity in the regression models.

To examine the association of health literacy and individual beliefs on medication adherence and the moderator effect of health literacy on the relationship between individual beliefs and diabetes medication adherence, several linear regression models were used. For some regression models, health literacy was divided into two components - document literacy (2 items from the NVS) and numeracy (4 items from the NVS) to account for the expected influence of numeracy on diabetes medication adherence. The regression models were developed to determine (1) the association between beliefs in medicines, illness perceptions, and health literacy with medication adherence; 2) the moderator effect of health literacy in the relationship between patient beliefs (in medicines and illness) with medication adherence; 3) the

domain of health literacy (document literacy versus numeracy) that had an association with medication adherence, and 4) the domain of health literacy that had the moderator effect in the relationship between patient beliefs and medication adherence.

Medication adherence was the dependent variable in all models and the models were controlled for self-efficacy, age, sex, race, education, number of medications, and number of illness. Table 1 explains in detail the independent variables used in all the regression models and the objective of each analysis. To further explore the moderator effect of health literacy by varying levels of health literacy (low, moderate, and adequate), several graphs were plotted with medication adherence versus the interaction term of health literacy and concern beliefs, and medication adherence versus the interaction term of health literacy and illness perceptions. All analyses were performed using SPSS statistical software v. 23.

3. Results

A total of 199 individuals were approached, and 174 agreed to participate in and complete the survey. Hence, there were 174 respondents. Participants' mean age was 58.7 (SD = 12.8); 57.5% were women; 67.8% Non-Hispanic white and 24.7% African American, and 62.1% with at least a college or technical degree. Of the 174

Table 2
Participants' demographic information (n = 174).

Variables	n (%)	Mean ± standard deviation (SD)
Age		58.7 (12.8)
Gender		
Women	100 (57.5)	
Men	74 (42.5)	
Race		
White	118 (67.8)	
Black	43 (24.7)	
Hispanic	8 (4.6)	
Asian	4 (2.3)	
American Indian	1 (0.6)	
Education		
Completed 8th grade or less	4 (2.3)	
Some high school	15 (8.6)	
High school graduate	47 (27.0)	
Some college or technical school	67 (38.5)	
College graduate	24 (13.8)	
Graduate degree	17 (9.8)	
Annual household income		
Less than 20,000	74 (42.5)	
Equal or more than 20,000	100 (57.5)	
Number of medications		7.8 (3.9)
Number of illness		3.9 (1.8)
Frequency of medication use		
Once daily	17 (9.8)	
Twice daily	81 (46.6)	
Three times daily	56 (32.2)	
More than three times daily	20 (11.5)	
Insulin use		
Yes	64 (36.8)	
No	110 (63.2)	
Health status[a]		
Poor	12 (6.9)	
Fair	61 (35.1)	
Good	79 (45.4)	
Very good	21 (12.1)	
Excellent	1 (0.6)	
Duration of diabetes diagnosed (years)		9.6 (7.1)
Health literacy		3.7 (2.0)
Health literacy - Numeracy		2.3 (1.5)
Health literacy – Document literacy		1.5 (0.8)
Self-efficacy on medication use[b]		33.2 (6.0)
Self-reported medication adherence[c]		5.9 (1.9)
The beliefs about medication		
Necessity beliefs		18.9 (4.3)
Concern beliefs		13.2 (4.4)
Illness perceptions		37.1 (11.1)

[a] Heath literacy was measured with the Newest Vital Sign (NVS).
[b] The score of the self-efficacy on medication use ranges from 13 to 39.
[c] Self-report medication adherence was measured with the 8-item Morisky Medication Adherence Scale.

Table 3
Multiple linear regression analysis to determine the moderator effect of health literacy on the relationship between beliefs in medicine, illness perceptions, self-efficacy and medication adherence (n = 174).

	Unstandardized regression coefficients	Standardized regression coefficients	T-values	Significance (p-values)
Model 1				
Demographic factors				
Age	0.003	0.023	0.346	0.730
Men	0.220	0.058	0.981	0.328
Non-white[a]	−2.323	−0.058	−0.810	0.419
Education[b]	−0.003	−0.001	−0.012	0.991
Diabetes- and health-related factors				
Number of medications	0.008	0.016	0.183	0.855
Number of illness	0.148	0.145	1.724	0.087
Health Literacy	0.002	0.002	0.026	0.980
Self-efficacy	0.152	0.486	7.502	**< 0.001**
Necessity beliefs	0.003	0.007	0.109	0.913
Concern beliefs	−0.022	−0.051	−0.806	0.421
Illness perceptions	−0.049	−0.292	−3.943	**< 0.001**
Model 2				
Demographic factors				
Age	0.003	0.019	0.290	0.772
Men	0.324	0.086	1.464	0.145
Non-white[a]	−0.201	−0.050	−0.720	0.473
Education[b]	0.013	0.004	0.054	0.957
Diabetes- and health-related factors				
Number of medications	−0.009	−0.019	−0.217	0.828
Number of illness	0.176	0.172	2.905	**0.038**
Health Literacy	0.000	0.000	−0.006	0.995
Self-efficacy	0.149	0.477	7.408	**< 0.001**
Necessity beliefs	−0.011	−0.024	−0.382	0.703
Concern beliefs	−0.035	−0.081	−1.255	0.211
Illness perceptions	−0.046	−0.275	−3.819	**< 0.001**
Necessity beliefs and Health literacy[c]	−0.012	−0.058	−0.942	0.348
Concern beliefs and Health literacy[c]	−0.031	−0.156	−2.478	**0.014**
Illness perceptions and Health literacy[c]	0.016	0.196	3.133	**0.002**

R^2 = 0.465, p < .001.
R^2 = 0.504, p < .001.
Bolded means significant at p < .05.
[a] Compared with white.
[b] Compared with those with a degree less than or equal to high school graduate.
[c] Interaction term between the two variables.

participants, 40.8% reported low medication adherence (a score of < 6), 22.4% had medium medication adherence (score of 6 to < 8), and 24.1% had high medication adherence (a score of 8). Regarding health literacy, 59.8% had adequate health literacy, 22.4% had moderate health literacy, and 17.8% had low health literacy. For beliefs in medicines, participants had mean necessity beliefs (18.9 ± 4.3) and mean concern beliefs (13.2 ± 4.4). The mean illness perceptions score was 37.1 ± 11.1. Table 2 describes the data in detail.

Participants with adequate health literacy were more likely to have a high school degree or higher (p < .001), were more likely to have an annual income of equal or more than $20,000 (p < .001), and were more likely to be white (p < .001). Participants with moderate health literacy were more likely to report concerns about their medications compared to participants with adequate health literacy (p = .028). Participants with adequate health literacy had the highest adherence

score (6.1) and those with moderate health literacy had the lowest adherence score (5.1) (p = .016).

The mean score of self-report medication adherence was 5.9 (SD = 1.9), which was normally distributed with acceptable skewness (−0.61) and kurtosis (−0.56). The two health literacy domains had a medium correlation (correlation coefficient: 0.41). However, there was no multicollinearity in the regression model since all variance inflation factor (VIF) values were less than 10.

While examining the association of health literacy and individual beliefs on medication adherence, there was a significant negative association between illness perceptions and adherence and a positive association between self-efficacy and adherence (Table 3). Health literacy did not have a direct relationship with medication adherence, thus supporting the moderator effect analysis. Health literacy had a significant moderator effect on the relationship between adherence and
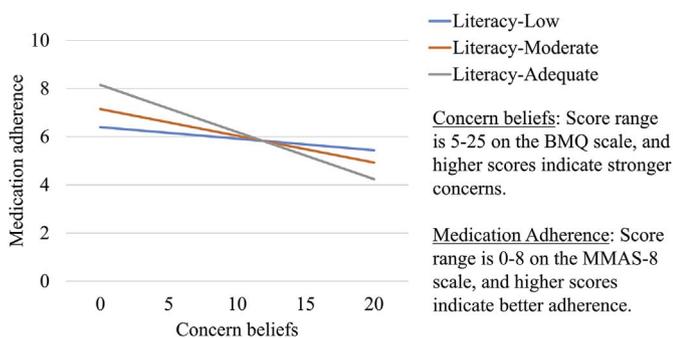
Fig. 2. The trends in the change in concern beliefs in medicines and medication adherence at varying levels of health literacy.
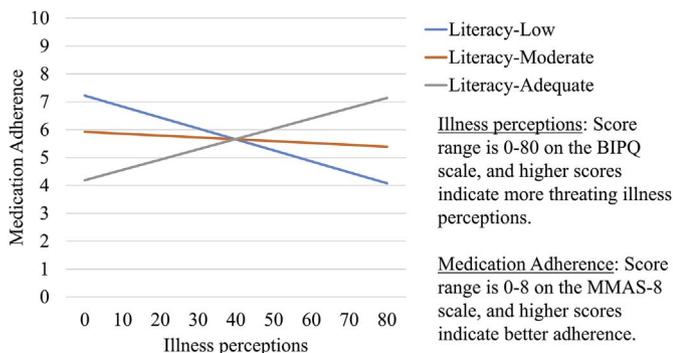

Fig. 3. The trends in the change in illness perceptions and medication adherence at varying levels of health literacy.

concerns beliefs ($\beta = -0.156$, $p = .014$) and illness perceptions ($\beta = 0.196$, $p = .002$) (Table 3). When the moderator effect was examined based on the levels of health literacy, there was a significant negative association between concern beliefs and adherence at moderate and adequate health literacy levels, but at low literacy levels, there was no association between concern beliefs and medication adherence (Fig. 2.). For illness perceptions, there was a significant negative association between threatening illness perceptions and medication adherence across all health literacy levels. However, for individuals with low and moderate health literacy, an increase in their threatening illness perceptions resulted in a sharp decline in their medication adherence. The medication adherence of individuals with adequate health literacy were less likely to decrease with increased threatening illness perceptions. (Fig. 3.). When health literacy was separated into numeracy and document literacy, it was numeracy that moderated the illness perceptions - adherence relationship ($\beta = 0.149$, $p = .038$) (Table 4).

4. Discussion

The aims of the study were to examine the association of health literacy and individual beliefs in medication adherence and to determine if health literacy has a moderator effect on the relationship between beliefs and medication adherence in individuals with type 2 diabetes. This study showed that 1) the strength of the association between medication adherence and concern beliefs in medicines among individuals with type 2 diabetes was dependent on levels of health literacy, 2) numeracy literacy moderated the association between illness perceptions and adherence, and 3) individuals with moderate health literacy had more concerns about their medicines compared to individuals with adequate health literacy.

As expected, the associations between concern beliefs and adherence were significant and negative. However, interestingly, this association was only significant among individuals with moderate and adequate health literacy. For individuals with low health literacy there was no association between concern beliefs and adherence, further confirming our hypothesis that health literacy may amplify or reduce the effect of the relationship between beliefs and adherence. It is possible that adherence interventions that address individual concerns about medicines will not work for individuals with low health literacy because these individuals may not have the capacity to understand and use health information to recognize the concerns about their medicines. These results suggest that healthcare providers may need to first address health literacy issues among individuals with diabetes who have low health literacy before adherence interventions that modify or change negative concern beliefs about medicines can be designed. This could include an initial assessment of patient's health literacy level during patient intake at the clinic, similar to taking vital signs within a clinical practice, by possibly using brief and concise health literacy instruments such as the NVS. Subsequently, with the health literacy information included within the medical record of a patient, any medication counseling, patient education, or clinic-based intervention can be tailored according to the health literacy needs of the patient, further informing a tailored approach to communication and counseling regarding treatment.

The other significant result from this study was the lesser influence on medication adherence by illness perceptions for individuals with adequate health literacy compared to individuals with low and moderate health literacy. For individuals with low and moderate health literacy, an increase in threatening illness perceptions was associated with a corresponding decrease in medication adherence, which was similar to the previous study.[6] However, for individuals with adequate health literacy, this association was not very profound. In other words, the ability to obtain, process, and understand health information by those with adequate health literacy may be acting as a 'protective' effect on their adherence. Thus, the study results suggest a focus on addressing concern beliefs in adherence interventions for individuals with adequate health literacy, rather than illness perceptions.

Though numeracy is a key component to consider for adherence interventions for individuals with type 2 diabetes, the current study showed that numeracy as a component of health literacy does not have a direct relationship with diabetes medication adherence, but rather acts as a moderator between illness perceptions and medication adherence. As shown in literature, for individuals with diabetes, reading skill or document literacy, while necessary, may not sufficiently capture the day-to-day complexities of diabetes care.[10] Accurate interpretation and application of quantitative information is likely required for successful diabetes medication use, as well as dietary and glucose monitoring management.[8] Given the often-recommended and required individual self-adjustment of diabetes therapy, which relies heavily on numeracy skills, numeracy is an important individual-level factor to consider while developing diabetes self-management interventions. Thus, interventions focusing on illness perceptions should first consider the individual's numeracy skills. In the clinical setting, diabetes interventions focusing on illness perceptions could consider the individual's numeracy skills by first assessing how well the patient understands the numbers related to their blood sugars, carbohydrate intake, medication dosing, etc. Understanding the patient's numeracy skills will then allow for a more tailored approach to using simple and plain language to

Table 4
Multiple regression analysis to determine the moderator effect of numeracy and document literacy on the relationship between beliefs in medicine, illness perceptions, self-efficacy and medication adherence (n = 174).

	Unstandardized regression coefficients	Standardized regression coefficients	T-values	Significance (p-values)
Model 3				
Demographic factors				
Age	0.003	0.019	0.286	0.776
Men	0.176	0.047	0.785	0.434
Non-white[a]	−0.204	−0.051	−0.715	0.476
Education[b]	−0.028	−0.007	−0.109	0.913
Diabetes- and health-related factors				
Number of medications	0.007	0.015	0.168	0.867
Number of illness	0.169	0.165	1.958	0.052
Health Literacy				
Numeracy	0.107	0.087	1.178	0.241
Document literacy	−0.218	−0.099	−1.489	0.138
Self-efficacy	0.150	0.478	7.386	**< 0.001**
Necessity beliefs	$-3.892e^{-5}$	0.00	−0.001	0.999
Concern beliefs	−0.019	−0.043	−0.682	0.496
Illness perceptions	−0.049	−0.288	−3.919	**< 0.001**
Model 4				
Demographic factors				
Age	0.003	0.019	0.278	0.781
Men	0.274	0.073	1.223	0.223
Non-white[a]	−0.200	−0.050	−0.705	0.482
Education[b]	−0.021	−0.005	0.083	0.934
Diabetes- and health-related factors				
Number of medications	−0.004	−0.008	−0.085	0.932
Number of illness	0.195	0.190	2.283	**0.024**
Health Literacy				
Numeracy	0.109	0.089	1.188	0.237
Document literacy	−0.234	−0.106	−1.576	0.117
Self-efficacy	0.147	0.471	7.270	**< 0.001**
Necessity beliefs	−0.018	−0.042	−0.647	0.519
Concern beliefs	−0.032	−0.075	−1.141	0.256
Illness perceptions	−0.045	−0.268	−3.700	**< 0.001**
Necessity beliefs and Numeracy[c]	−0.022	−0.083	−1.248	0.214
Concern beliefs and Numeracy[c]	−0.037	−0.138	−1.924	0.056
Illness perceptions and Numeracy[c]	0.016	0.149	2.094	**0.038**
Necessity beliefs and document literacy[c]	0.016	0.031	0.472	0.638
Concern beliefs and document literacy[c]	−0.015	−0.031	−0.411	0.682
Illness perceptions and document literacy[c]	0.009	0.047	0.627	0.531

$R^2 = 0.474$, p < .001.
$R^2 = 0.515$, p < .001.
Bolded means significant at p < .05.
  [a] Compared with white.
  [b] Compared with those with a degree less than or equal to high school graduate.
  [c] Interaction term between the two variables.

communicate their treatment during counseling.

When individual adherence by health literacy levels were examined, individuals with adequate health literacy had the highest adherence while those with moderate health literacy had the lowest adherence. This is in contrast to the conclusion by Ostini and Kairuz, 2014, where they suggested that individuals with low health literacy are more often non-adherent, mostly unintentionally; individuals with moderate health literacy are the most adherent; and individuals with adequate health literacy are somewhat non-adherent, possibly due to intentional non-adherence.[12] It is possible that these differences occurred because of the use of the NVS in this current study which weighed heavily towards numeracy compared to other available health literacy measures. Future research will need to further examine the possibility of these relationships, especially for individuals with moderate health literacy, and examine if the reasons for adherence differ between individuals with low, moderate, and adequate health literacy.

This study is not without limitations. The study used a convenience sample recruited from two clinics in the Midwest that limits the generalizability of the study. A self-report measure was used to measure medication adherence; hence, there might be overestimation of medication adherence. However, studies show reliability of self-report adherence measures.[34–37] The study did not use any objective measures of

adherence such as the proportion of days covered, as this information was not available. The NVS which weighs heavily towards numeracy, was used compared to other available health literacy measures with less focus on numeracy. Clinical markers were not controlled for in the final data analysis.

5. Conclusions

Health literacy, an important individual psychosocial factor, and especially numeracy, needs to be initially addressed before diabetes adherence interventions that address individual concerns about medicines and threatening illness perceptions can work. Interventions focusing on individual beliefs that initially measure and rectify health literacy issues may yield better outcomes.

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Conflicts of interest

All authors have no relevant conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.sapharm.2017.12.005.

References

1. White RO, Wolff K, Cavanaugh KL, Rothman R. Addressing health literacy and numeracy to improve diabetes education and care. *Diabetes Spectr.* 2010;23:238–243.
2. Tomky D, Cypress M, Dang D, Maryniuk M, Peyrot M, Mensing C. Aade position statement. *Diabetes Educat.* 2008;34:445–449.
3. Kindig DA, Panzer AM, Nielsen-Bohlman L. *Health Literacy: A Prescription to End Confusion.* National Academies Press; 2004.
4. Centers for Disease Control and Prevention. Understanding literacy and numeracy. Available at: https://www.cdc.gov/healthliteracy/learn/understandingliteracy.html; December 2016, Accessed date: 27 February 2017.
5. Rothman RL, Housam R, Weiss H, et al. Patient understanding of food labels: the role of literacy and numeracy. *Am J Prev Med.* 2006;31:391–398.
6. Kale MS, Federman AD, Krauskopf K, et al. The association of health literacy with illness and medication beliefs among patients with chronic obstructive pulmonary disease. *PLos One.* 2015;10:e0123937.
7. Williams MV, Baker DW, Parker RM, Nurss JR. Relationship of functional health literacy to patients' knowledge of their chronic disease. A study of patients with hypertension and diabetes. *Arch Intern Med.* 1998;158:166–172.
8. Cavanaugh K, Huizinga MM, Wallston KA, et al. Association of numeracy and diabetes control. *Ann Intern Med.* 2008;148:737–746.
9. Schillinger D, Grumbach K, Piette J, et al. Association of health literacy with diabetes outcomes. *J Am Med Assoc.* 2002;288:475–482.
10. Osborn CY, Cavanaugh K, Wallston KA, White RO, Rothman RL. Diabetes numeracy: an overlooked factor in understanding racial disparities in glycemic control. *Diabetes Care.* 2009;32:1614–1619.
11. Bains SS, Egede LE. Associations between health literacy, diabetes knowledge, self-care behaviors, and glycemic control in a low income population with type 2 diabetes. *Diabetes Technol Ther.* 2011;13:335–341.
12. Ostini R, Kairuz T. Investigating the association between health literacy and non-adherence. *Int J Clin Pharm.* 2014;36:36–44.
13. Geboers B, Brainard JS, Loke YK, et al. The association of health literacy with adherence in older adults, and its role in interventions: a systematic meta-review. *BMC Publ Health.* 2015;15:903.
14. Zhang NJ, Terry A, McHorney CA. Impact of health literacy on medication adherence a systematic review and meta-analysis. *Ann Pharmacother.* 2014;48:741–751.
15. Sjolander M, Eriksson M, Glader EL. The association between patients' beliefs about medicines and adherence to drug treatment after stroke: a cross-sectional questionnaire survey. *BMJ Open.* 2013;3:e003551.
16. Shiyanbola OO, Nelson J. Illness perceptions, beliefs in medicine and medication non-adherence among South Dakota minority women with diabetes: a pilot study. *S D Med.* 2011;64:365–368.
17. Unni EJ, Shiyanbola O, Farris KB. Medication adherence: a complex behavior of medication and illness beliefs. *Aging Health.* 2013;9:377–387.
18. Kucukarslan SN. A review of published studies of patients' illness perceptions and medication adherence: lessons learned and future directions. *Res Soc Adm Pharm.* 2012;8:371–382.
19. Leventhal H, Phillips LA, Burns E. The Common-Sense Model of Self-Regulation (CSM): a dynamic framework for understanding illness self-management. *J Behav Med.* 2016;39:935–946.
20. Leventhal H, Brissette I, Leventhal EA. *The Common-sense of Self-regulation of Health and Illness.* Psychology Press; 2003.
21. Horne R. Patients' beliefs about treatment: the hidden determinant of treatment outcome? *J Psychosom Res.* 1999;47:491–495.
22. Mann DM, Ponieman D, Leventhal H, Halm EA. Predictors of adherence to diabetes medications: the role of disease and medication beliefs. *J Behav Med.* 2009;32:278–284.
23. Krousel-Wood M, Islam T, Webber LS, Re RN, Morisky DE, Muntner P. New medication adherence scale versus pharmacy fill rates in seniors with hypertension. *Am J Manag Care.* 2009;15:59–66.
24. Clifford S, Perez-Nieves M, Skalicky AM, Reaney M, Coyne KS. A systematic literature review of methodologies used to assess medication adherence in patients with diabetes. *Curr Med Res Opin.* 2014;30:1071–1085.
25. Morisky DE, Ang A, Krousel-Wood M, Ward HJ. Predictive validity of a medication adherence measure in an outpatient setting. *J Clin Hypertens.* 2008;10:348–354.
26. Weiss BD, Mays MZ, Martz W, et al. Quick assessment of literacy in primary care: the newest vital sign. *Ann Fam Med.* 2005;3:514–522.
27. Haun JN, Valerio MA, McCormack LA, Sorensen K, Paasche-Orlow MK. Health literacy measurement: an inventory and descriptive summary of 51 instruments. *J Health Commun.* 2014;19(Suppl 2):302–333.
28. Shigaki C, Kruse RL, Mehr D, et al. Motivation and diabetes self-management. *Chron Illn.* 2010;6:202–214.
29. Kirk JK, Grzywacz JG, Arcury TA, et al. Performance of health literacy tests among older adults with diabetes. *J Gen Intern Med.* 2012;27:534–540.
30. Osborn CY, Cavanaugh K, Wallston KA, et al. Health literacy explains racial disparities in diabetes medication adherence. *J Health Commun.* 2011;16(Suppl 3):268–278.
31. Horne R, Weinman J, Hankins M. The beliefs about medicines questionnaire: the development and evaluation of a new method for assessing the cognitive representation of medication. *Psychol Health.* 1999;14:1–24.
32. Broadbent E, Petrie KJ, Main J, Weinman J. The brief illness perception questionnaire. *J Psychosom Res.* 2006;60:631–637.
33. Risser J, Jacobson TA, Kripalani S. Development and psychometric evaluation of the Self-efficacy for Appropriate Medication Use Scale (SEAMS) in low-literacy patients with chronic disease. *J Nurs Meas.* 2007;15:203–219.
34. Morisky DE, Green LW, Levine DM. Concurrent and predictive validity of a self-reported measure of medication adherence. *Med Care.* 1986;24:67–74.
35. Bolarinwa OA. Principles and methods of validity and reliability testing of questionnaires used in social and health science researches. *Niger Postgrad Med J.* 2015;22:195–201.
36. Krass I, Schieback P, Dhippayom T. Adherence to diabetes medication: a systematic review. *Diabet Med.* 2015;32:725–737.
37. Morisky DE, DiMatteo MR. Improving the measurement of self-reported medication nonadherence: response to authors. *J Clin Epidemiol.* 2011;64:255–257 discussion 258–263.