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Update on Health Literacy and Diabetes

Purpose

Inadequate literacy is common among patients with diabetes and may lead to adverse outcomes. The authors reviewed the relationship between literacy and health outcomes in patients with diabetes and potential interventions to improve outcomes.

Methods

We reviewed 79 articles covering 3 key domains: (1) evaluation of screening tools to identify inadequate literacy and numeracy, (2) the relationships of a range of diabetes-related health outcomes with literacy and numeracy, and (3) interventions to reduce literacy-related differences in health outcomes.

Results

Several screening tools are available to assess patients' print literacy and numeracy skills, some specifically addressing diabetes. Literacy and numeracy are consistently associated with diabetes-related knowledge. Some studies suggest literacy and numeracy are associated with intermediate outcomes, including self-efficacy, communication, and self-care (including adherence), but the relationship between literacy and glycemic control is mixed. Few studies have assessed more distal health outcomes, including diabetes-related complications, health care utilization, safety, or quality of life, but available studies suggest low literacy may be associated with increased risk of complications, including hypoglycemia. Several interventions appear to be effective in improving diabetes-related outcomes regardless of literacy status,

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perspective in practice

but it is unclear if these interventions can reduce literacy-related differences in outcomes.

Conclusions

Low literacy is associated with less diabetes-related knowledge and may be related to other important health outcomes. Further studies are needed to better elucidate pathways by which literacy skills affect health outcomes. Promising interventions are available to improve diabetes outcomes for patients with low literacy; more research is needed to determine their effectiveness outside of research settings.

Diabetes is the seventh leading cause of death in the United States and is one of the most common chronic diseases, affecting 8.3% of the US population.[1] Patients with diabetes are at risk for a range of adverse health outcomes, including heart attacks, strokes, amputations, blindness, and end-stage renal disease. Although longer duration of diabetes, poor control of intermediate risk factors (eg, blood pressure, cholesterol levels, glycemic control), and genetic susceptibility are clearly associated with increased risk of adverse outcomes in patients with diabetes, nonclinical factors such as patients' socioeconomic and psychosocial characteristics play a key role in determining risk.[2–4]

In particular, health literacy, or "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions," has been theorized to be one important, nonclinical factor that may decrease the risk of adverse outcomes in diabetes.[5,6] Inadequate health literacy is common in the United States; according to the National Assessment of Adult Literacy, more than one-third of US adults have basic or below basic health literacy and would have difficulty managing common health-related tasks.[6] Limited health literacy poses a significant economic burden to our society, with national estimates indicating that low health literacy costs the US health care system from $106 to $238 billion each year.[7] Accordingly, health literacy is a national priority; Healthy People 2020 goals have called for significant improvements in health literacy to advance the health of the population.[8]

Conceptually, adequate health literacy in the context of diabetes includes a constellation of skills that are critical to patients for managing their condition and navigating the health care environment. These include cultural and conceptual knowledge, aural and oral literacy (ie, listening and speaking), print literacy (ie, writing and reading), and numeracy (ie, the ability to understand and use numbers). Health literacy skills specific to diabetes include reading labels on pill bottles, following written or verbal directions, and comprehending appointment information, educational brochures, and informed consent documents.[9] Numeracy[10] is fundamental to diabetes self-management in understanding medication dosing, health insurance information, test results, and insulin requirements and in interpreting food labels. To date, however, no single measure of health literacy in diabetes has adequately captured the full range of skills described above.

Although adequate health literacy is important for optimal diabetes self-management, many questions, both practical and theoretical, remain about how to best measure health literacy: whether to measure literacy as a part of routine care, which outcomes are associated with health literacy, the mechanisms by which inadequate health literacy affects diabetes outcomes, and how interventions designed to support patients with limited health literacy might enhance patient outcomes. The purpose of this article is to critically review the existing literature on the association between health literacy and outcomes among patients with diabetes and make recommendations for future research to help move the field forward in the coming years.

Methods

In an effort to bring together the broadest knowledge from a variety of study designs and methodologies, a modified narrative synthesis approach was used.[11] A narrative synthesis is an attempt to systematize the process of analysis when a meta-analysis or a systematic review may not be the most appropriate approach because of the diversity of methodologies used in the studies reviewed. The first step of this process was to search PubMed to identify English-language journal articles using the keywords "diabetes" AND ("health literacy" OR "numeracy") for the period of January 2009 through December 2012. Only articles describing research conducted in the United States were included. Published systematic

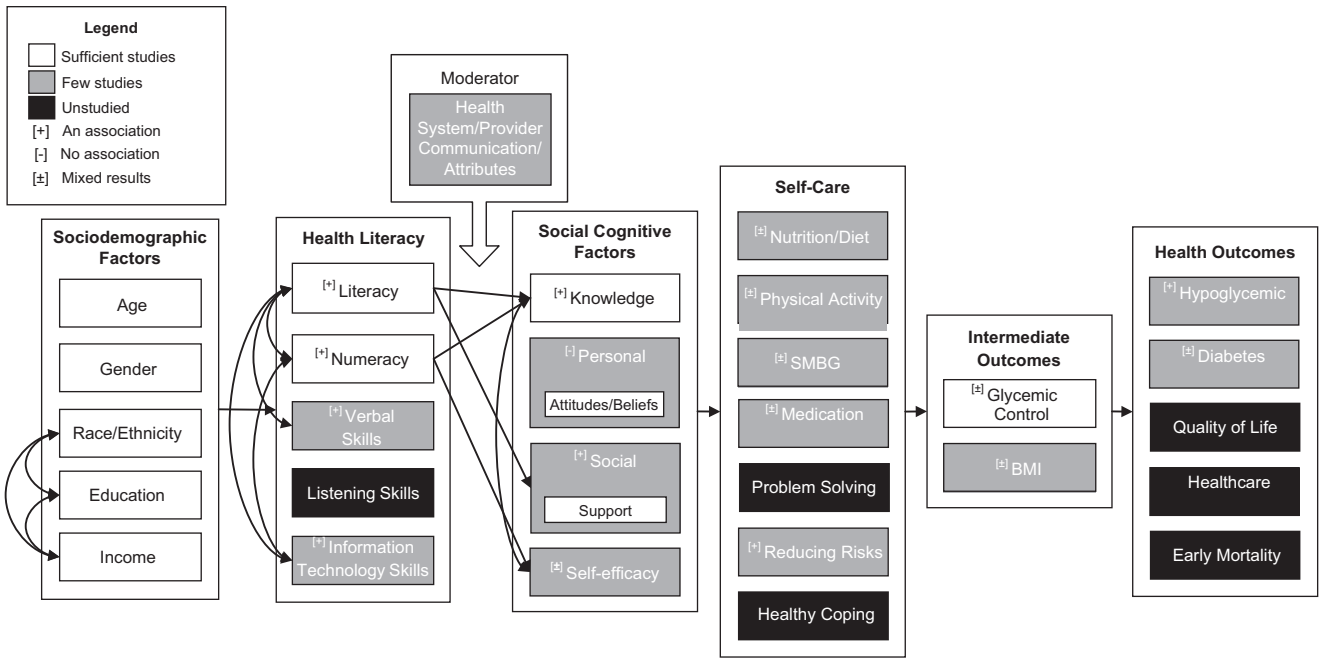

Figure 1. A framework illustrating sociodemographic determinants of health literacy and health literacy's association with diabetes mechanisms and outcomes. SMBG, self-monitoring of blood glucose; BMI, body mass index. Factors are color coded to indicate whether there are sufficient, few, or unstudied associations between health literacy and diabetes mechanisms/outcomes in the health literacy literature to date. [+]Denotes evidence of an association between health literacy and a mechanism/outcome; [-]denotes evidence of no association between health literacy and a mechanism/outcome; [±]denotes mixed evidence of an association between health literacy and a mechanism/outcome.

reviews were relied on to capture findings that appeared in the published literature before 2009.[12,13] Next, studies were selected that addressed 3 key domains: (1) tools to identify inadequate health literacy and numeracy among patients with diabetes, (2) the relationship between health literacy or numeracy and a range of diabetes-related outcomes, and (3) interventions to reduce health literacy–related differences in diabetes-related health outcomes and/or to promote positive outcomes among all patients with diabetes regardless of literacy/numeracy skills. Relevant information was extracted from each of the studies and included in a table. This information was reviewed and synthesized to produce a textual summary of study findings for each of the domains.

To guide this work, a theoretical framework was developed, shown in Figure 1, which is based on the literature. The figure shows several demographic factors that have been shown to be associated with health literacy. Health literacy itself is conceptualized as having several subdomains and is presumed to be associated with several social cognitive constructs, for example, self-efficacy. In turn, these constructs are linked to a number of self-care domains for diabetes. Self-care domains are linked to a range of intermediate and more distal diabetes-related health outcomes, including quality of life. Health system attributes and provider communication skills are theorized to modify the literacy-social cognitive (and self-care) relationships. This framework was used to guide the evaluation of the literature and recommendations for future work.

Results

The literature search returned a total of 79 articles, which were categorized into the 3 domains and summarized below.

Diabetes and Health Literacy Measures

Studies examining the role of health literacy in patients with diabetes used measures of general print literacy and numeracy (eg, Wide Range Achievement Test, National Adult Reading Test), general health literacy/numeracy (eg, Short Test of Functional Health Literacy in Adults

[STOFHLA], Rapid Estimate of Adult Learning in Medicine [REALM], Newest Vital Sign, Brief Health Literacy Screen, Subjective Numeracy Scale), and diabetes-specific measures of print literacy and numeracy (Literacy Assessment for Diabetes and Diabetes Numeracy Test).[14,15] Table 1 summarizes psychometric findings, including the internal consistency reliability, construct validity, and predictive validity of measures used in recent studies.[16-33] In general, these studies have confirmed that measures have excellent internal consistency reliability and convergent validity, with strong associations between health literacy measures and patient characteristics, including educational attainment, income, and other measures of health literacy/numeracy. Many recent studies have focused on developing shorter versions of existing measures or adapting measures for use in new patient populations (eg, Spanish speakers, Americans Indians, adolescents).[17,18,22,25,26,28,30]

Most health literacy/numeracy measures that have been developed for or used with diabetes patients assess a narrow definition of the health literacy constructs, largely focusing on print literacy and computational numerical skills. Existing measures have not accounted for other elements of literacy/numeracy skills, including oral and aural literacy, understanding of and ability to apply information, the role of cultural and conceptual knowledge, and a wide range of numerical abilities, including "gist" numerical knowledge, which is a global, inexact interpretation of numerical information influenced by a person's background and experiences, among other factors.[5,34-36] For example, current measures of health literacy have not adequately addressed how patients interpret oral or multimedia instructions or educational material and apply this information to real-world situations.

Numeracy is of particular importance in patients with diabetes, given that many self-care skills, including medication management, interpretation of glucose meter readings, adjustment of insulin, and dietary assessment, rely on numerical skills.[37] Recent studies have demonstrated that numeracy is important in diabetes and that diabetes-related numeracy can be validly assessed.[14,16,38] Moreover, although current numeracy assessments have focused largely on mathematical skills, many patients make decisions based on their "gist" of numerical information.[34] Thus, a more robust assessment of how different aspects of health literacy and numeracy affect patients' decision making would better elucidate how to address health literacy/numeracy barriers to self-care in future behavioral diabetes interventions.

Recent measurement studies have relied on cross-sectional designs to assess the validity of health literacy measures among patients with diabetes.[17,22,23,25,28] As a result, there is limited evidence of the test-retest reliability of these instruments (ie, measurement stability over time) as well as their predictive validity for future diabetes self-care behaviors and glycemic control. Prospective studies are needed to answer these and other measurement-related questions.

In summary, significant advances have been made in the development and validation of health literacy/numeracy measures in diabetes. Although some research suggests diabetes-specific measures may be of greater value than general measures for this population,[38] more robust studies are needed to fully assess the reliability and validity of both general and diabetes-specific measures. In addition, instruments need to be broadened to include a more comprehensive array of health literacy/numeracy skills, such as oral literacy and gist numerical knowledge. Future scales will also need to be validated and adapted for additional populations, including children with diabetes and their parents and populations that primarily speak languages other than English and Spanish. Finally, the inclusion of health literacy/numeracy measures in prospective studies will allow for more robust evaluation of the psychometric properties and predictive validity of these instruments.

Association Between Health Literacy, Numeracy, and Diabetes Outcomes

Research on the relationship between health literacy and diabetes-related outcomes is presented in Table 2a,[10,18,24,38-54] which includes 20 recent studies that examine the association between health literacy and diabetes-related outcomes, and Table 2b,[10,38,55,56] which includes 5 recent studies that examine the relationship between numeracy and diabetes-related outcomes. Below is a summary of the literature on the association between health literacy, numeracy, and select diabetes outcomes.

Prevalence of diabetes

One older study involving more than 2500 community dwelling elders[57] found that limited health literacy (measured using the REALM) was independently associated with a greater prevalence of diabetes, increasing the odds by 48%.

Table 1

Measures of Health Literacy and Numeracy in Diabetes

Measure	Items	Measurement Description	Sample	Findings		
				Internal Consistency Reliability	Construct Validity	Predictive Validity
General						
Brief Health Literacy Screen (BHLS)[17]	3	Respondents are asked to rate their confidence completing medical forms, state how often they have problems learning, and indicate if they need help completing medical forms	296 English- and Spanish-speaking adults with T2DM[17]	N/A	Each BHLS item and the BHLS summative score were associated with health literacy (STOFHLA)[17]	N/A
Brief Measures of Print Literacy and Numeracy[18]	3 (HL[d]), 4 (HN[e])	3-item HL screener adapted from Chew et al[19] 4-item HN items adapted from Lipkus[20] and STOFHLA[21]	3033 American Indian and Alaska Natives[18]	$\alpha = 0.67$ for HL[d] items[18]	Both HL[d] and HN[e] associated with key demographics (age, education level, income) and diabetes- and other disease-related knowledge[18]	N/A
Newest Vital Sign (NVS)[22]	6	Respondents are asked to read and interpret a nutritional label	205 adults with diabetes[22]	N/A	NVS associated with educational attainment and health literacy (STOFHLA, $r = 0.54$)[22]	N/A
Rapid Estimate of Adult Literacy in Medicine (REALM)[23]	66	Respondents read medical words, and a correct response is given for each correct pronunciation	240 adults with diabetes[23]	N/A	REALM associated with health literacy (SKILLD)[23]	N/A
Rapid Estimate of Adult Literacy in Medicine–revised (REALM-R)[24]	8	Respondents read medical words, and a correct response is given for each correct pronunciation	125 adults with T2DM; 71% African American; 68% less than high school[24]	$\alpha = .95$; item-test correlations, $r = 0.78$-0.91[24]	N/A	REALM-R associated with diabetes knowledge, but not A1C[24]
Rapid Estimate of Adult Literacy in Medicine–short form (REALM-SF)[22]	7	Respondents read medical words, and a correct response is given for each correct pronunciation	243 adults with diabetes[22]	N/A	REALM-SF associated with educational attainment and health literacy (STOFHLA, $r = .48$)[22]	N/A
Single-Item Literacy Screener (SILS)[25]	1	Respondents rate how often they need to have someone help them read instructions, pamphlets, or other written material from their physician or pharmacy[26]	225 adults with diabetes[25]	N/A	SILS was associated with health literacy (STOFHLA)[25]	N/A

(continued)

Table 1

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Measure	Items	Measurement Description	Sample	Findings: Internal Consistency Reliability	Findings: Construct Validity	Findings: Predictive Validity
Short Estimate of Functional Health Literacy in Adults (STOFHLA)[17,22,25,27,28]	41	Respondents read 2 health-related passages and complete 37 Cloze items and 4 numeracy items	180 adolescents with asthma and diabetes[27]	N/A	N/A	STOFHLA associated with intent to use online health resources[27]
			225 adults with diabetes[25]	N/A	Low scores on the STOFHLA associated with black race, lower self-rated reading ability, lower educational attainment, and health literacy (SILS)[25]	N/A
			490 adults with diabetes[22]	N/A	STOFHLA associated with educational attainment and health literacy (NVS [n = 205, r = 0.54] and REALM-SF [n = 240, r = 0.48])[22]	N/A
			296 English- and Spanish-speaking adults with T2DM[17]	N/A	STOFHLA categories associated with health literacy (each BHLS item and the BHLS summative score)[17]	N/A
			144 Latino adults with diabetes[28]	N/A	STOFHLA associated with the DNT-15 Latino[28]	N/A
Diabetes specific						
Diabetes Numeracy Test-15 (DNT-15)[28]	15	Latino version of the original DNT[16,29]; items require respondents to perform addition, subtraction, understand fractions, divide, understand number hierarchy, and perform calculations	144 Latino adults with diabetes[28]	KR-20 = 0.78[28]	DNT-15 Latino associated with educational attainment, general numeracy (WRAT), and health literacy (STOFHLA)[28]	DNT-15 Latino was associated with acculturation but not self-care or A1C[28]
DNT-Adolescent and DNT-14 Adolescent[30]	39 (DNT-A), (DNT-14)	Adolescent versions of the original DNT[16,29]; items require respondents to perform addition, subtraction, understand fractions, divide, understand number hierarchy, and perform calculations related to common diabetes tasks	Sample 1 = 61 adolescents; sample 2 = 72 adolescents[30]	Sample 1: KR-20 = 0.93 Sample 2: KR-20 = 0.83 Combined sample (DNT-14), KR-20 = 0.82[30]	In sample 1, DNT-39 and DNT-14 associated with parent education and adolescent reading skills (WRAT)[30] In sample 2, DNT-14 associated with diabetes problem-solving skills	In sample 1, DNT-39 and DNT-14 associated with insulin pump use In combined sample analysis, DNT-14 associated with A1C[30]

(continued)

Table 1

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Measure	Items	Measurement Description	Sample	Findings		
				Internal Consistency Reliability	Construct Validity	Predictive Validity
Diabetes-specific Health Literacy Index (DHLI)[31]	10	An index of diabetes-specific health literacy was constructed from responses to 10 diabetes self-care regimen items	1318 adults with diabetes[31]	$\alpha = .93$[31]	Compared with patients with the lowest DHLI literacy level, patients with the highest DHLI literacy level were more likely to be younger, be white, have more education, but have modestly less income[31]	DHLI associated with self-graded diabetes self-care but was not associated with the average number of days performing 5 self-management behaviors or A1C[31]
Literacy Assessment for Diabetes (LAD)[33]	60	Respondents read words related to diabetes management and care, and a correct response is given for each correct pronunciation	203 adults	High test-retest reliability; ICC = 0.86	LAD had high concurrent validity with WRAT3 ($r = 0.81$) and REALM ($r = 0.90$)	N/A
Spoken Knowledge in Low Literacy in Diabetes Scale (SKILLD)[23]	10	Further validation of the original SKILLD[32]; respondents answer open-ended questions about behaviors to manage diabetes	240 adults with diabetes[23]	$\alpha = .54$[23] Interrater reliability on 23 interviews; all kappas $P < .001$, Spearman $\rho = 0.79\%$ (95% CI 0.56 to 0.91, $P < .001$)[23]	SKILLD associated with higher education, health literacy (REALM), and diabetes knowledge (DKT)[23]	N/A

Abbreviations: A1C, hemoglobin A1C; BHLS, Brief Health Literacy Screen; CI, confidence interval; DHLI, Diabetes Specific Health Literacy Index; DKT, Diabetes Knowledge Test; DNT-A, Diabetes Numeracy Test–Adolescent; DNT-14, Diabetes Numeracy Test 14; DNT-15, Diabetes Numeracy Test–15; DNT-39, Diabetes Numeracy Test 39; HL, health literacy; HN, health numeracy; LAD, Literacy Assessment for Diabetes; NVS, Newest Vital Sign; REALM, Rapid Estimate of Adult Literacy in Medicine; REALM-R, Rapid Estimate of Adult Literacy in Medicine–Revised; REALM-SF, Rapid Estimate of Adult Literacy in Medicine–Short Form; SILS, Single-Item Literacy Screener; SKILLD, Spoken Knowledge in Low Literacy in Diabetes Scale; STOFHLA, Short Test of Functional Health Literacy in Adults; T2DM, type 2 diabetes mellitus; WRAT, Wide Range Achievement Test.

Table 2a

Recent Studies Examining the Association Between Literacy and Diabetes-Related Outcomes

Author	Associations Examined	Key Findings	Literacy Assessment
Bauer et al, *Journal of General Internal Medicine*, 2013[39]	Literacy, adherence for antidepressants among diabetes population	N = 1366 Limited health literacy associated with poorer adherence (more time without sufficient pill supply: (41% vs 36%, $P < .01$) to newly prescribed antidepressants	3-item screener
Bains and Egede, *Diabetes Technology and Therapeutics*, 2011[24]	Literacy, diabetes knowledge, self-care, and glycemic control	N = 125 Health literacy associated with diabetes knowledge ($\beta = .55$) but not adherence or glycemic control ($\beta = -0.03$)	REALM-R
Brega et al, *Patient Education and Counseling*, 2012[40]	Literacy/numeracy, diabetes knowledge, self-care behavior, and glycemic control in American Indians and Alaska Natives	N = 2594 Literacy was related to diabetes knowledge ($\beta = .695$) and to glycemic control (unadjusted $\beta = -.070$), partly explained by glucose monitoring and by knowledge	Adapted Chew 3-item literacy screener 4 numeracy items adapted from Lipkus et al[20] and STOFHLA
Brega et al, *Ethnicity & Disease*, 2012[18]	Literacy and numeracy with diabetes and cardiovascular knowledge	N = 3033 Literacy and numeracy were associated with 4 types of knowledge: general diabetes, insulin use, blood pressure, and cholesterol	Adapted Chew 3-item literacy screener 4 numeracy items adapted from Lipkus[20] and STOFHLA
Cavanaugh et al, *Annals of Internal Medicine*, 2008[38]	Literacy and glycemic control	N = 398 Literacy not associated with A1C in adjusted analysis	REALM
Coffman et al, *Journal of Cultural Diversity*, 2012[41]	Literacy and diabetes symptoms in Latinos	N = 144 46.5% low literacy; health literacy not associated with diabetes knowledge in multivariate analysis	STOFHLA (Spanish)
Glasgow et al, *Journal of Medical Internet Research*, 2011[42]	Literacy and use of diabetes self-care Web site	N = 270 Health literacy not related to Web site use (data not shown)	STOFHLA
Karter et al, *Diabetes Care*, 2010[43]	Literacy and insulin initiation adherence	N = 169 Nonadherent patients more likely to report inadequate health literacy: 51% vs 30%	Single question (trouble learning about condition because of difficulty understanding written information)
Mancuso, *Nursing and Health Sciences*, 2010[44]	Literacy, trust, and glycemic control	N = 102 Literacy not related glycemic control ($r = -0.063$; $\beta = -.070$) or to trust ($r = 0.063$) but is related to diabetes knowledge ($r = 0.296$)	STOFHLA
Mayberry et al, *Diabetes Technology and Therapeutics*, 2011[45]	Literacy and use of Web portals for diabetes	N = 61 Participants with limited health literacy or numeracy were no less likely to access Web portals, but lower health literacy was associated with less frequent use of a computer to research diabetes medications or treatments	3-item screener
Mbaezue et al, *Journal of the National Medical Association*, 2010[46]	Literacy and self-monitoring of blood glucose	N = 189 Literacy not related to daily blood glucose testing but was related to keeping a record of blood glucose levels (77.3% vs 88.6%)	STOFHLA
McCleary-Jones, *ABNF Journal*, 2011[47]	Literacy and diabetes knowledge	N = 50 Literacy associated with diabetes knowledge in bivariate analysis	REALM

(continued)

Table 2a

(continued)

Author	Associations Examined	Key Findings	Literacy Assessment
Morris et al, *BMC Family Practice*, 2006[48]	Literacy, glycemic control, and diabetes complications	N = 1002 Literacy not related to glycemic control or diabetes-related complications	STOFHLA
Osborn et al, *Diabetes Technology and Therapeutics*, 2010[49]	Health literacy, self-care, and glycemic control	N = 130 Literacy not directly related to self-care or glycemic control, but literacy related to these outcomes somewhat through social support	REALM-R
Osborn et al, *Journal of Health Communication*, 2010[10]	Literacy, self-efficacy, medication adherence, and glycemic control in diabetes	N = 383 Literacy associated with adherence ($r = 0.12$) Literacy associated with self-efficacy, but literacy was not associated with glycemic control directly ($r = –0.02$), only indirectly though self-efficacy	REALM
Sarkar et al, *Patient Education Counseling*, 2008[50]	Literacy and patients' reported preferences for diabetes self-management support and perceived need for better communication to improve diabetes control	N = 796 Limited literacy was significantly associated with greater interest in telephone self-management support (OR, 1.74; 1.19-2.54) 52% with limited literacy vs 31% with adequate literacy reported that better communication with provider would improve their diabetes control	Chew 3-item screener
Sarkar 2010 J Health Comm[51]	Literacy and use of electronic patient portal	N=14,102 Patients with limited literacy had higher odds of never signing on to the patient portal (OR, 1.7; 1.4-1.9) compared with those with adequate literacy	Chew 3-item screener
Sarkar et al, *Journal of General Internal Medicine*, 2010[52]	Literacy and risk of hypoglycemia in patients with type 2 diabetes	Low literacy associated with increased risk of hypoglycemia (adjusted OR, 1.3-1.4, for each screening question)	3-item screener (modified)
Vassy et al, *Medical Decision Making*, 2012[53]	Literacy and motivation to implement lifestyle change after genetic testing	Patients with high literacy (but not those with low literacy) were less highly motivated to make lifestyle change after receiving low-risk results	
Wallace et al, *Nursing Research*, 2010[54]	Literacy and patient-rating of self-management support	Higher self-management support noted in patients with higher literacy	

Abbreviations: A1C, hemoglobin A1C; OR, odds ratio; REALM, Rapid Estimate in Adult Literacy in Medicine; REALM-R, Rapid Assessment of Adult Literacy in Medicine–Revised; STOFHLA, Short Test of Functional Health Literacy in Adults.

Table 2b

Numeracy and Diabetes Outcomes

Author	Associations Examined	Key Findings	Numeracy Assessment
Cavanaugh et al, *Annals of Internal Medicine*, 2008[38]	Association between diabetes-related numeracy and self-management skills and glycemic control	N = 398 adults with diabetes DNT associated with self-management skills (misinterpreting glucometer readings, miscalculating carb load, and medication dose) and glycemic control; DNT was also associated with health literacy and general numeracy skills	Diabetes Numeracy Test (DNT)
Huizinga et al, *Obesity*, 2008[29]	Association between diabetes-related numeracy, health literacy, and BMI	N =160 English-speaking, adult primary care patients; numeracy was associated with BMI after adjusting for health literacy; health literacy was not associated with BMI	WRAT-3
Marden et al, *Diabetic Medicine*, 2012[55]	Association between diabetes-related numeracy, health literacy, and glycemic control	N = 112 adults with type 1 diabetes; numeracy was associated with A1C, but health literacy was not associated with A1C	Skills for Life Initial Assessment
Osborn et al, *Diabetes Care*, 2009[56]	Evaluated whether diabetes-related numeracy, health literacy, and general numeracy mediated association between race and glycemic control	N = 383 adults with type 2 diabetes; diabetes-related numeracy largely explained differences in A1C level between African American and white patients; health literacy was not associated with A1C and did not explain differences in control between African Americans and whites	Diabetes-related numeracy (DNT), general numeracy (WRAT-3), literacy (REALM)
Osborn et al, *Journal of Health Communication*, 2010[10]	Evaluated whether self-efficacy explains the association between diabetes-related numeracy and health literacy and glycemic control	N = 383 adults with diabetes; literacy and numeracy were bivariately associated with self-efficacy; however, only numeracy was independently associated with self-efficacy; self-efficacy in turn was associated with A1C control; numeracy and literacy were not associated with A1C after adjustment for confounders; study suggests an indirect effect of numeracy → self-efficacy → A1C	Diabetes-related numeracy (DNT), general numeracy (WRAT-3R), literacy (REALM), 8-item Perceived Diabetes Self-management Scale (PDSMS)

Abbreviations: A1C, hemoglobin A1C; BMI, body mass index; DNT, Diabetes Numeracy Test; PDSMS, Perceived Diabetes Self-management Scale; REALM, Rapid Assessment of Adult Literacy in Medicine; WRAT-3, Wide Range Achievement Test 3; WRAT-3R, Wide Range Achievement Test 3–Revised.

Knowledge

A number of studies have explored the relationship between health literacy and diabetes-related knowledge.[18,24,40,44,47,58-62] They have consistently found higher health literacy to be associated with greater diabetes-specific knowledge. One recent study[41] did not find an association between health literacy and knowledge, perhaps because of overadjustment for related variables.

Comprehension/communication

Several studies have explored the relationship between health literacy and domains of patient-clinician communication.[42,45,50,51,63,64] One older study, involving more than 400 public hospital patients with type 2 diabetes, found that patients with limited health literacy, measured with the STOFHLA, were more likely to report worse provider communication in the domains of general clarity,

explanation of condition, and explanation of processes of care.[63] These results suggest that limited health literacy may be a marker for oral communication problems, particularly in the technical, explanatory domains of clinician–patient dialogue. A substudy that used direct observation methods also determined that diabetes patients with limited health literacy had low rates of comprehension of medical terminology used in their visits.[64]

A large national study involving more than 800 patients from 4 public hospitals found that patients with limited health literacy (measured using the 3-item literacy measure developed by Chew et al[19]) were more likely than those with adequate health literacy to report both that their diabetes would be better controlled if they had better communication with their health care provider and that they desired self-management support.[50]

One study found patients with lower health literacy to be less likely to use online patient portals for communicating with health systems, even though they had computer access and had registered with the portal[51]; other studies found no consistent association between health literacy and engagement with patient portals and health information technology.[42,45] One additional study linked limited health literacy with preferential use of phone support over health information technology.[50] These studies differed greatly, however, in terms of the study samples and research methodologies used. It is likely that the 2 studies with inconsistent findings were limited by a small sample size (N = 59)[45] and a small percentage of study participants with limited literacy skills (5.9%).[42] In contrast, the study by Sarkar and colleagues[51] among 14 102 patients (62% with some limitation in literacy skills) found significant differences in patient portal use by literacy skills, even after controlling for relevant covariates.

Trust and participation in decision making

A study in a public university clinic setting found no associations between health literacy, measured with the REALM, and patients' reports of trust or facilitation of patient involvement, although this study did find that patients with lower health literacy reported less desire to participate in decision making.[61]

Self-efficacy

Some early studies failed to find a relationship between health literacy and diabetes self-efficacy, although in one study, the relationship approached significance (P = .08).[61,65] However, a recent study showed a positive association between health literacy and self-efficacy.[10] This study used a different measure of diabetes-related self-efficacy than previous studies, included patients with type 1 diabetes, and had a larger sample size than the study by Dewalt et al, which may partially explain the variation in findings.[10]

Self-care

Some recent studies have shown an association between health literacy and self-care behavior.[38,40,53,66] In contrast, other recent studies failed to detect a health literacy–self-care linkage.[40,46,66] These studies varied greatly in terms of study sample demographics, methodologies, and analyses conducted, limiting the ability to synthesize findings across studies. Similarly, a broad range of self-care behaviors was examined (diet, exercise, foot care, blood glucose testing, etc), with some showing a significant association with literacy and/or numeracy skills and others not reaching significance.

Medication adherence

Several studies have evaluated the relationship between health literacy and adherence to medications. Two studies evaluated early stages of adherence: Karter and colleagues[43] found a linkage between health literacy and whether patients initiated newly prescribed insulin. Bauer et al[39] reported that, among diabetes patients with newly prescribed antidepressants, limited health literacy was associated with larger gaps in pill supply and inadequate use of antidepressant therapy.

The studies regarding adherence to ongoing medications (also called secondary adherence) were less conclusive. Bains and Egede[24] found that patients with low health literacy, defined as a grade 6 reading level or lower according to the REALM-R,[67] did not exhibit any differences in medication adherence in comparison to patients with adequate literacy skills. However, Osborn et al[68] reported that low health literacy, as measured by the REALM, partially explained observed racial differences in diabetes medication adherence between African American and white adults.

Glycemic control

Several older studies examined the relationship between health literacy and the most diabetes-specific intermediate outcome, hemoglobin A1C. The aforementioned study in a

public hospital setting involving 408 diverse, low-income patients[9] found that limited health literacy, as measured by the STOFHLA in English and Spanish, was independently associated with a 2-fold greater odds of very poor glycemic control (>9.5%). A smaller study from an academic clinic in the US South found that patients with limited health literacy, measured with the REALM, had greater than a 1% higher absolute difference in A1C compared with those with greater than high school literacy.[58]

In contrast, 2 studies from university clinic settings found no association between health literacy and A1C.[61,62] In addition, a large study conducted in a community-based sample from Vermont found no relationship between health literacy and glycemic control; of note, the sample had excellent glycemic control overall (median A1C = 6.9%), 97% of participants were white, and fewer than 20% had less than adequate health literacy on the STOFHLA.[48]

The relationship between literacy and glycemic control continues to be mixed in recent studies.[38,40,44,55,56] Using a measure of health literacy that incorporated print literacy and numeracy, Brega and colleagues[40] found a positive relationship among American Indians and Alaska Natives. However, other investigators did not find such relationships in other populations.[38,44] Recent studies have found a linkage between the numeracy component of health literacy and glycemic control.[38,55] Numeracy skills also seemed to explain much of the racial disparity in glycemic control in the latter study.[56]

Diabetes complications

Three studies examined whether limited health literacy is associated with diabetes complications. The aforementioned study involved 408 diverse, low-income patients from a hospital setting[9] and found that limited health literacy was associated with 2-fold greater odds of patients reporting micro- and macrovascular complications of diabetes, such as retinopathy and cerebrovascular disease. Another study found that patients with diabetes and limited health literacy (measured using the STOFHLA) had 50% greater odds of having coexisting heart failure.[69] In contrast, Morris and colleagues[48] did not find statistically significant relationships between health literacy and several diabetes-related complications, including retinopathy, nephropathy, gastroparesis, and cardiovascular disease. In some cases (eg, retinopathy, gastroparesis), the point estimates suggested a relationship (odds ratios near 2.0), but the small numbers of patients with low health literacy reduced the power to detect statistically significant results.[48]

Health care utilization/costs/safety/mortality

We are unaware of any studies that have examined the relationship between health literacy and diabetes-related health care utilization or costs. In the only study regarding safety, limited health literacy was associated with a higher risk of hypoglycemia in insulin-treated patients with diabetes.[52] Finally, no studies have examined the relationship between health literacy and mortality among patients with diabetes specifically.

Association Between Health Literacy and Diabetes: Future Research Directions

This review identified a relatively extensive body of literature examining the relationship between health literacy and a range of diabetes-related health outcomes. These studies have generally identified positive relationships between health literacy and diabetes-related knowledge.[18,24,40,44,47,58-62] They have reached mixed conclusions as to whether low health literacy is associated with having less self-efficacy[10,61,65]; similarly, the relationship between low health literacy and suboptimal self-care behavior and glycemic control is mixed* and appears to vary by the clinical context and the makeup of the patient population. Numeracy has been associated with glycemic control in a small number of studies[38,56,65] but not others.[40] Few studies have examined more distal diabetes health outcomes, including complications, utilization, or quality of life, although 2 studies had findings demonstrating higher rates of complications[9,69] and 1 study identified limited health literacy as a patient safety risk.[51]

Recent studies have also better examined the pathways that may link health literacy and diabetes-related outcomes using exploratory and confirmatory causal techniques, such as structural equation modeling and marginal structural models.[10,18,40,49,66] Although this work has yet to fully elucidate the mechanisms linking health literacy to diabetes outcomes, studies have highlighted the important role that specific constructs may play in mediating the relationship between health literacy and diabetes outcomes. For instance, Brega et al[40] showed

*References 9, 38, 40, 44, 46, 48, 53, 55, 56, 58, 61, 62, 70.

that the relationship between health literacy and glycemic control was mediated by diabetes knowledge. Osborn and colleagues[10] found that the numeracy–glycemic control relationship was mediated by self-efficacy.

One important and unresolved methodological issue in health literacy research (and a potential source of variation in results across studies) is the optimal strategy for adjusting for potential confounders. Ideally, studies will adjust for variables that are truly confounders, to avoid distorting the estimate of the effect of health literacy on the health outcome. However, it is important to recognize that adjustment for related variables, such as education, that can be part of the causal pathway between low health literacy and adverse health outcomes may lead to overadjustment and produce false-negative results (ie, may suggest no relationship when a true relationship actually exists).[71] The ordering of these causal pathways (eg, education before health literacy vs health literacy before education) strongly depends on how one conceptualizes health literacy (eg, whether it reflects innate cognitive aptitude vs learned functioning). Given the complexities of these causal webs, when planning the analytic strategy, it is recommended that researchers explicitly define the concept of health literacy and formalize the many potential causal linkages via techniques such as directed acyclic graphs (a diagram illustrating connectivity in conjunction with causality),[72] with special attention and sensitivity analyses to evaluate the closely linked socioeconomic factors that may mediate, confound, or modify the health literacy–health effect.

Looking to the future of research regarding associations between health literacy and diabetes-related outcomes, several priority areas can be identified. Foremost, additional, large longitudinal cohort studies are needed that measure health literacy, other key predictive constructs such as provider communication skills, and a range of diabetes-related outcomes, including clinical events, safety, and quality of life. Ideally, such studies would incorporate not only measures of reading ability but also those that examine quantitative skills (numeracy) and even domains such as the ability to communicate verbally (oral and aural literacy) and through writing (including e-mail and text messages). Because of the considerable potential measurement burden in studies of associations between health literacy and diabetes outcomes, more studies (both longitudinal and cross-sectional) are also needed to examine how measures of these different health literacy domains relate to one another. It is currently unknown whether health literacy skills cluster together within individuals; it is also unknown if there are different thresholds at which literacy skills result in better or worse diabetes outcomes. It is also important to understand whether contextual factors, such as the type of health care delivery and financing system, may also influence outcomes and whether limited health literacy is more strongly associated with health outcomes among certain ethnic minority subgroups.

Recent studies identified in this review have included a wider range of populations, including Latinos, Asian, Pacific Islanders, and American Indians/Alaska Natives.[40,41] It is important that future studies also examine diverse populations, particularly those with high risks of diabetes and diabetes-related complications. For those for whom English is a second language, measuring health literacy in both their primary and secondary languages and examining how these different measures affect health literacy outcomes associations would also be helpful and could help target potential interventions for testing and implementation.

Exploring the real-world implications of extant research findings is an important next step. Many of the studies on health literacy and numeracy have been conducted in the context of research. However, important work is needed to explore whether and how to practically assess health literacy and numeracy in usual care settings and how these measures would be implemented to guide approaches to care delivery.

Interventions to Improve Diabetes Outcomes

Table 3[73-85] summarizes 13 papers describing 11 unique interventions, including 6 randomized controlled trials and 5 studies that implemented pre-post designs to improve outcomes in diabetes. Studies typically involved 1 of 4 types of intervention: (1) patient education, (2) self-management support, (3) disease management, and (4) feedback of health literacy screening results to providers. Outcomes examined include diabetes knowledge, self-efficacy, self-care behavior, and glycemic control.

Education-based strategies

Five studies have targeted patient education as a means of improving diabetes outcomes.[73,75,77-79] Using a computerized diabetes education program, Kandula and colleagues[77,78] demonstrated significant improvement in

Table 3

Diabetes-Related Interventions Designed to Address Health Literacy

Source	Study Design (N)	Intervention/Population	Health Literacy Measure	Outcomes	Key Findings
Cavanaugh et al, *Diabetes Care*, 2009[73]	RCT (198)	Compared treatment group (providers educated on HL, numeracy, and communication. Patients educated using Diabetes Literacy and Numeracy Education Toolkit) with control group (enhanced diabetes care program). Participants were adult, English-speaking patients with type 1 or 2 diabetes and A1C ≥7.0% who were referred for participation in the enhanced diabetes care program of 1 of 2 academic medical centers.	REALM (<ninth grade vs higher) Diabetes Numeracy Test (DNT)	Self-efficacy Self-care Satisfaction A1C	Adjusted analyses: Compared with controls, the treatment group showed significantly greater improvement in A1C from baseline to 3 months (P = .03) but not baseline to 6 months. There were no significant group differences in change in self-efficacy, self-care, or satisfaction from baseline to 6 months. Analyses were not stratified by patient HL level.
DeWalt et al, *Patient Education and Counseling*, 2009[74]	Pre-post (250)	Examined whether Living With Diabetes Guide—designed to facilitate problem solving and goal setting—helped patients achieve behavioral goals. Participants were adult, English- or Spanish-speaking patients with a diagnosis of type 2 diabetes.	STOFHLA (inadequate/marginal vs adequate)	Goal setting Problem solving Achievement of behavior goals Satisfaction	Most participants established goals related to diet and/or nutrition; 93% achieved ≥1 goal, 73% achieved ≥2 goals, and 33% reported achieving their goals at each of 3 follow-up visits. Some participants exhibited problem-solving behavior, and most were satisfied with the guide. No differences in behavior change were found by HL level or language spoken.
Gerber et al, *Diabetes Care*, 2005[75]	RCT (244)	Examined use and effect of Living Well With Diabetes intervention, delivered via touch-screen computers in clinic waiting rooms. Controls received computerized diabetes quizzes plus usual care. Participants were adult patients with self-reported type 1 or type 2 diabetes in 5 public outpatient clinics in Chicago, Illinois. Patients who never used study computer or who had incomplete data were excluded from analyses.	STOFHLA (inadequate/marginal vs adequate)	Knowledge Self-efficacy Perceived susceptibility to complications Use of recommended medical care Study computer use A1C BMI BP	Participants with lower HL showed lower knowledge at baseline compared with those with higher HL (P < .05). Intervention had no significant effect on A1C, BMI, BP, self-efficacy, knowledge, or use of medical care (P's > .10). Intervention group experienced significantly greater increase in perceived susceptibility to diabetes complications compared with control group (P = .009). A significant increase in perceived susceptibility was seen in the lower HL group (P = .016) but not the higher HL group (P > .10). Exploratory analyses of low-literate participants with poor glycemic control showed greater improvement in A1C in the intervention compared with the control group (P < .05); a similar intervention effect was not seen among high-literate participants with poor glycemic control. Mean duration of study computer use was greater in the intervention group (P = .001). Within the intervention group, computer use was greater for participants with higher HL (minutes of use, P = .006; times used, P = .002).

(continued)

Table 3

(continued)

Source	Study Design (N)	Intervention/Population	Health Literacy Measure	Outcomes	Key Findings
Glasgow et al, *Patient Education and Counseling*, 2012[76]	RCT (463)	Examined impact of computer-assisted self-management (CASM) and CASM plus human support (CASM+) versus enhanced usual care. Participants were overweight patients with type 2 diabetes and at least 1 other risk factor for heart disease. Patients were aged 25 to 75 y, had access to a telephone and the Internet, and were able to read and write in Spanish or English.	3 Chew items Subjective Numeracy Scale	Self-efficacy Problem-solving Supportive resources Eating behaviors Fat intake Caloric expenditure Medication adherence Health status Distress BMI A1C Lipids Mean arterial pressure 10-y coronary heart disease risk	Combined intervention arms showed significantly greater improvement at 12 mo than the control condition on eating habits, fat intake, physical activity, and distress (*P*'s < .05). Groups did not differ at 12 mo on medication adherence, clinical outcomes, self-efficacy, problem solving, supportive resources, or health status. The CASM and CASM+ groups did not differ on behavioral outcomes. Patient HL level did not moderate intervention effects.
Kandula et al, *Patient Education and Counseling*, 2009[77]	Pre-post (190)	Examined knowledge before and after participants were exposed to Multimedia Diabetes Education Program (MDEP). Participants were English-speaking patients aged 35 to 75 y from 1 of 2 primary care clinics. Some patients had type 2 diabetes, whereas others did not have diabetes.	STOFHLA (inadequate, marginal, adequate)	Knowledge	MDEP resulted in improved knowledge in each of 3 HL groups: adequate, marginal, and inadequate ($P < .001$). Controlling for pretest score, age, gender, diabetes status, and race/ethnicity, people with inadequate HL learned less than did those with adequate HL ($\beta = -2.3$, $P < .01$). When education was included as a covariate, the association of HL with knowledge gain became nonsignificant (-0.91).

(continued)

Table 3

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Source	Study Design (N)	Intervention/Population	Health Literacy Measure	Outcomes	Key Findings
Kandula et al, *Journal of Health Communication*, 2011[78]	Pre-post Experiment 1 (113) Experiment 2 (58)	Experiment 1 examined knowledge before and after exposure to MDEP. Experiment 2 examined knowledge before and after participants received MDEP plus teach-back. Participants were adults aged 35 to 75 y either with or without type 2 diabetes.	STOFHLA (inadequate/ marginal vs adequate)	Knowledge	Experiment 1 Unadjusted analyses: MDEP resulted in immediate improvement in knowledge ($P < .001$). Knowledge declined significantly over the following 2 wk ($P < .001$) but remained significantly higher than baseline ($P < .001$). This pattern held true for those with adequate and marginal/inadequate (M/I) HL. Although those with adequate HL scored better at each time point than did those with M/I HL (Ps $< .001$), pre-post knowledge gain and knowledge decline from posttest to 2-wk follow-up did not differ by HL level. Experiment 2 Unadjusted analyses: Knowledge improved significantly from pre- to posttest ($P < .001$) and posttest to post–teach-back ($P < .001$), significantly declining from post–teach-back to 2-wk follow-up ($P < .001$). Knowledge at 2 wk remained significantly higher than pretest ($P < .001$). This pattern held true in both HL groups. Those with adequate HL scored significantly better than did those with M/I HL at each time point ($P < .01$). Those with M/I HL showed greater decline from post–teach-back to 2-wk follow-up than did those with adequate HL ($P < .001$). Overall knowledge gain did not differ by HL group. Combined samples: Controlling for age, education, gender, diabetes, and baseline knowledge, teach-back did not result in improved knowledge ($\beta = -.5$). There was no difference between the HL groups in knowledge retention once education was controlled.
Kim et al, *Diabetes Care*, 2004[79]	Pre-post (92)	Examined impact of university-based diabetes education classes. Participants were English-speaking adults with type 1 or type 2 diabetes already enrolled in class.	STOFHLA[e] (inadequate/ marginal vs adequate)	Knowledge Self-care A1C	Patients with limited HL had significantly lower levels of knowledge at baseline and 3-mo follow-up than did participants with higher HL (Ps $\leq .01$). Participants showed significant improvement in knowledge and self-care. Patients with adequate HL showed a significant increase in exercise, whereas those with limited HL showed a significant improvement in diet, SMBG, and foot care. A1C also significantly improved (effect sizes of 0.53 and 0.49 for those with adequate and limited HL, respectively). HL groups did not differ on A1C at 3 mo.

(continued)

Table 3

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Source	Study Design (N)	Intervention/Population	Health Literacy Measure	Outcomes	Key Findings
Rothman et al, *Journal of the American Medical Association*, 2004[80]	RCT (217)	Examined impact of an intensive diabetes management program. Control received single educational visit with clinical pharmacist and usual care. Participants were English-speaking adults with type 2 diabetes and poor glycemic control (A1C ≥ 8.0%).	REALM (low HL [≤sixth grade] vs higher HL)	A1C SBP	Compared with controls, intervention participants experienced significantly greater improvement in A1C from baseline to 12 mo ($P = .001$) and were more likely to attain their goal A1C of ≤7.0% ($P = .05$). When stratified by HL group, only participants with low HL showed significant improvement in A1C ($P < .001$) and were more likely to attain goal A1C levels ($P = .02$). Intervention participants showed significant improvement in SBP over time, in comparison with controls ($P = .006$). The intervention effect did not differ by HL group.
Rothman et al, *Diabetes Educator*, 2004[81]	Pre-post (159)	Examined impact of a pharmacist-delivered diabetes management program designed for patients with limited literacy. Participants were adult patients with a diagnosis of type 2 diabetes and poor glycemic control (A1C ≥ 8.0%).	REALM (low HL [≤sixth grade] vs higher HL)	A1C	Both participants with lower and higher levels of HL showed significant improvement in A1C between baseline and 6-mo follow up. Controlling for patient characteristics, baseline A1C, and time between baseline and follow-up A1C values, health literacy was not a significant predictor of improvement in A1C.
Schillinger et al, *Health Education and Behavior*, 2008[82]	RCT (224)	Examined participation in 2 self-management support (SMS) interventions as part of the Improving Diabetes Efforts Across Language and Literacy (IDEALL) project: (1) weekly automated telephone disease management with nurse follow-up when clinically warranted (ATDM) and (2) monthly group visits facilitated by physician and health educator (GMV). Participants were adult patients with diagnoses of type 2 diabetes and A1C ≥8.0% and who spoke English, Spanish, or Cantonese.	STOFHLA (limited [inadequate/marginal] vs adequate)	Intervention reach: Participation Represent-ativeness Engagement	Most clinics recruited agreed to participate (67%). Most clinicians from those clinics (84%) referred at least 1 patient to 1 of the SMS interventions. Enrolled patients were similar to eligible patients from participating clinics on age, sex, and A1C but differed with regard to language, race/ethnicity, and insurance coverage. ADTM: Most patients (93.8%) responded to at least 1 call, with no difference by literacy level. Ever users responded to 56.6% of calls. Among English speakers, patients with lower HL were more likely to develop action plans as a result of nurse follow-up calls ($P = .03$). GMV: 69.6% of participants attended at least 1 session. Ever users attended 53.1% of sessions. Participants with limited HL attended fewer visits and were less likely to participate fully (P's $< .05$).

(continued)

Table 3

(continued)

Source	Study Design (N)	Intervention/Population	Health Literacy Measure	Outcomes	Key Findings
Schillinger et al, *Diabetes Care*, 2009[83]	RCT (339)	The Improving Diabetes Efforts Across Language and Literacy (IDEALL) project compared 2 SMS interventions to usual care: (1) weekly automated telephone self-management support with nurse follow-up when clinically warranted (ATSM), (2) GMV. Participants were adult patients with type 2 diabetes and poor glycemic control (ie, A1C ≥8.0%) who had been seen in the Community Health Network of San Francisco in the past year. Patients spoke English, Spanish, or Cantonese.	STOFHLA (limited [inadequate/marginal] vs adequate)	Patient experience with chronic illness care Self-efficacy Self-care Engagement Quality of life Functional status A1C DBP SBP BMI	Compared with usual care, ATSM and GMV participants showed improvements in patient experience of chronic illness care (effect sizes = 0.51 and 0.53, respectively, *P*s < .001), self-efficacy (effect sizes = 0.41 and 0.38, respectively, *P*s < .01), and self-care (effect sizes = 0.62 and 0.30, respectively, *P*s < .05). Improvement in self-care was significantly greater in the ATSM than the GMV arm (effect size = 0.34, *P* = .02). ATSM participants reported significantly fewer days restricted to bed than did usual care (*P* = .05) and GMV participants (*P* = .004) and reported less restricted activity than usual care participants (*P* = .03). The ATSM group showed significant improvement in mental health quality of life compared with the GVM group (effect size 0.31, *P* < .03). Clinical outcomes did not show significant improvement. Analyses were not stratified by HL level.
Seligman et al, *Journal of General Internal Medicine*, 2005[84]	RCT (63 physicians, 182 patients)	Examined the impact of notifying primary care physicians of patient HL status. Intervention physicians were notified that patient had limited HL. Control providers were not. Participants were English- or Spanish-speaking patients >30 y of age with type 2 diabetes, limited HL, and an existing treatment relationship with a provider in the general internal medicine or family practice clinics at the participating academic hospital.	STOFHLA (limited [inadequate/marginal] vs adequate)	Perceived usefulness of HL screening Use of recommended communication strategies by provider Provider satisfaction with visit Provider perceived effectiveness Patient self-efficacy A1C	Intervention physicians were more likely than control physicians to use 3 or more recommended communication strategies (*P* = .04). Intervention physicians were less likely to feel satisfied with the visit (*P* = .01). Patient self-efficacy did not differ by treatment arm at follow-up. Nearly all patients thought HL screening was useful. Providers thought it was useful for 64% of visits and discussed results with only 2% of patients. No changes in A1C were seen in either treatment arm.
Wallace et al, *Patient Education and Counseling*, 2009[85]	Pre-post (250)	Examined impact of Living With Diabetes Guide, which was designed to facilitate problem solving and goal setting. Participants were adult, English- or Spanish-speaking patients with type 2 diabetes from 1 of 3 academic internal medicine practices.	STOFHLA (limited [inadequate/marginal] vs adequate)	Knowledge Self-efficacy Motivation Self-care Distress	Participants showed significant improvement in knowledge, self-efficacy, activation, distress, and self-care behavior from baseline to study completion (*P* < .001). Results did not differ by literacy level, although some outcomes differed by participant language. Diabetes distress declined significantly more for Spanish than English speakers (*P* = .03). Self-efficacy (*P* < .001) and self-care improved more in the English- than Spanish-speaking participants (*P* = .05).

Abbreviations: A1C, hemoglobin A1C; ATDM, automated telephone diabetes management; ATSM, automated telephone self-management; BMI, body mass index; BP, blood pressure; CASM, Computer Assisted Diabetes Management; CASM+, Computer Assisted Diabetes Management plus Human Support; DBP, diastolic blood pressure; DNT, Diabetes Numeracy Test; GMV, group medical visit; HL, health literacy; IDEALL, Improving Diabetes Efforts Across Language and Literacy; MDEP, Multimedia Diabetes Education Program; M/I, marginal/inadequate; RCT, randomized controlled trial; REALM, Rapid Assessment of Adult Literacy in Medicine; SBP, systolic blood pressure; SMBG, self-monitoring of blood glucose; SMS, self-management support; STOFHLA, Short Test of Functional Health Literacy in Adults.

diabetes knowledge among participants with adequate and limited health literacy. The addition of the teach-back method to the educational program did not enhance diabetes knowledge. Those with adequate health literacy improved more than those with limited health literacy.

As part of a randomized controlled trial, Gerber et al.[75] also implemented a computerized educational intervention. Investigators found no improvement in knowledge, self-efficacy, use of recommended medical services, or clinical outcomes, although intervention participants with limited health literacy did experience a significant increase in perceived susceptibility to diabetes complications. Exploratory analyses of patients with poor glycemic control showed a statistically significant impact of the intervention on A1C for participants with lower literacy skills but not for participants with higher health literacy skills.

Using a pre-post design, Kim et al.[79] examined whether health literacy status modified the impact of diabetes education classes on self-care and risk factor control. Participants with adequate and limited health literacy showed significant pre-post improvement in knowledge, self-care, and A1C. Improvements in A1C were similar for those with adequate and limited health literacy.

As part of a randomized controlled trial, Cavanaugh et al.[73] compared an enhanced, health literacy–sensitive 3-month educational program versus a standard disease management program. Intervention patients showed a greater improvement in A1C at 3 months that was statistically significant. However, these differences did not persist at 6 months. In addition, there was no difference in effect between those with adequate versus limited health literacy.

Self-management support

Five studies have described interventions designed to improve diabetes self-management, and the effect size was contrasted in those with versus without health literacy limitations.[74,76,82,83,85] The effect of patient education combined with one-on-one counseling to encourage patient goal setting and action planning[74,85] showed improvement in knowledge, self-efficacy, activation, distress, and self-care, but the benefits did not differ by health literacy.[85]

Similarly, 2 randomized controlled trials found that employing technology to enhance diabetes self-management was effective in improving eating habits, fat intake, physical activity, and distress but showed no difference by patient health literacy levels.[76,82,83] Schillinger et al[82,83] tested 2 self-management support interventions: (1) automated telephone self-management (ATSM) and (2) group medical visits (GMVs) compared with usual care. Both interventions showed improvements in patient experience of chronic illness care, self-efficacy, and self-care but not for clinical outcomes. Compared with the GMV group, the ATSM condition showed greater improvement in self-care, days restricted to bed, and mental health quality of life,[83] in addition to being associated with higher levels of patient engagement, especially among low-literate patients.[82]

Hill-Briggs et al[86] found that an intensive diabetes self-management training adapted for patients with low health literacy led to significantly greater change in A1C (–0.72%) than a condensed program, but whether this program had differential effects by literacy status was not assessed.

Disease management

Two studies conducted by Rothman et al tested an intensive diabetes disease management intervention led by clinical pharmacists.[80,81] In a randomized controlled trial, intervention participants received one-on-one education, evidence-based management of blood pressure and glucose-lowering medications, and assistance from a diabetes care coordinator to address patient barriers.[80] At 12 months, intervention participants showed clinically and statistically significant greater improvement in measures of glycemic control and systolic blood pressure compared with usual care controls. Significant improvement in glycemic control was seen only for participants with limited health literacy. In a similar study, conducted using a pre-post design, both participants with limited and adequate health literacy showed significant improvement in A1C.[81]

Feedback of health literacy screening

One randomized controlled trial examined the impact of notifying doctors of their diabetes patients' health literacy limitations.[84] When notified that a patient had limited health literacy skills, physicians were significantly more likely to use 3 or more recommended communication strategies. However, providers notified of their patients' health literacy status felt less satisfied with visits and, for 36% of visits, did not think the notification was valuable. Those in the screening notification group did not have better glycemic control than those in the control group.

Table 4

Current or Recently Completed Interventions Addressing Health Literacy in Patients With Diabetes

ClinicalTrials.Gov Identifier	Title	Description (From Study)
NCT01876485	Point-of-care Health Literacy and Activation Information to Improve Diabetes Care	This hybrid effectiveness/implementation trial will be conducted in 2 phases over 4 y. In phase 1, the process of implementing a collaborative, diabetes goal-setting intervention (Empowering Patients in Chronic Care [EPIC]) personalized to self-reported patient activation and functional health literacy levels into routine primary care practices will be evaluated. In phase 2, a randomized, clinical trial to compare the effectiveness of EPIC to enhanced usual care will be conducted.
NCT00973830	The Missouri Health Literacy and Diabetes Communication Initiative	To evaluate the efficacy of the American College of Physicians Foundation Diabetes Guide (Living With Diabetes: An Everyday Guide for You and Your Family) to improve diabetes self-management.
NCT01344668	The Public Private Partnership Addressing Literacy-Numeracy to Improve Diabetes Care (PRIDE)	This cluster randomized trial will evaluate the effectiveness of addressing health literacy and numeracy to improve diabetes care in state health department safety net clinics.
NCT00848315	Diabetes Management in Low-Income Hispanic Patients	The overall goal of this randomized clinical trial is to test the efficacy of a culturally- and literacy-tailored cognitive-behavioral intervention designed to enhance adherence to diabetes self-management behaviors and improve glycemic control among low-income Hispanic individuals with type 2 diabetes mellitus.
NCT00964587	Cardiovascular Disease Education and Problem-Solving Training in People With Type 2 Diabetes (DECIDE)	The purpose of this study is to determine if patient education and problem-solving training, delivered in self-study, group, and individual intervention modalities, will produce substantial improvements in cardiovascular disease (CVD) risk profile via improved self-management in urban African Americans with type 2 diabetes and a high CVD risk profile.

Of note, there are currently a fair number of intervention studies that have been recently completed or that are currently being completed that evaluate the role of health literacy–focused interventions for patients with diabetes. Several of these studies are highlighted in Table 4. Many of these studies have developed health literacy–sensitive interventions that attempt to provide accommodations for patients with lower health literacy and assess health literacy at enrollment to try to ascertain the role of health literacy as an effect modifier or mediator of the intervention. The results of these studies will provide important additional information about the value of measuring and intervening on health literacy among patients with diabetes.

Conclusions

This review has identified many new studies relevant to understanding the role of health literacy in diabetes. The growing body of research in this field, however,

continues to provide mixed results, making it challenging to summarize, with confidence, our current understanding of how health literacy and diabetes outcomes are related, how best to detect limited health literacy skills, and what interventions to employ to reduce literacy-related health inequities.

In terms of measurement, several effective ways exist to identify limited health literacy and numeracy skills. However, there is no single best measure; available tools require tradeoffs between accuracy and feasibility. The research on associations between health literacy or numeracy and a range of outcomes in patients with diabetes is extensive. For the most part, studies have found strong associations between health literacy or numeracy and diabetes-related knowledge.[18,24,40,44,47,49,58-62] However, the relationships with other intermediate outcomes, including communication, self-efficacy, adherence, and glycemic control, have been mixed. Some studies have found associations between limited health literacy and adverse outcomes or markers for adverse outcomes,[†] whereas others have not.[24,42,45,61,62,65] In some cases, absence of a statistically significant relationship may be attributed to small sample sizes/low power. In other cases, it may reflect overadjustment for potential confounders, particularly educational status, which may be colinear with health literacy.

Few studies have rigorously examined more distal outcomes among patients with diabetes, including diabetes-related complications or health-related quality of life, and those that have done so have had variable conclusions.[9,48,69] Again, limited power and overadjustment may explain some of these discrepancies. Of note, the finding by Sarkar and colleagues[52] that patients with low health literacy have an increased risk of hypoglycemia does suggest that providers should be cognizant of patients' health literacy levels when starting medications, particularly insulin, that have increased risk of hypoglycemia.

In terms of interventions, a range of interventions seems effective in improving diabetes outcomes, including ones focusing primarily on patient education, self-care training, or reorganization of the care process (disease management). However, whether such interventions can reduce health literacy–related disparities in intermediate and clinical outcomes remains unclear. Some studies[80] suggest interventions may work better in patients with limited health literacy, whereas others have found no difference or even more improvement for those with adequate health literacy. Further research is required to understand how to best reduce health literacy–related differences in health outcomes, including interventions to ensure adequate health literacy through initial or remedial education, in addition to interventions to improve overall quality of care. Further, more research is needed to investigate the most effective strategies for enhancing both acquisition and retention of diabetes knowledge, as well as to examine different media and strategies for delivering interventions to patients.

Whether or not to screen for limited health literacy in patients with diabetes is a challenging question. On the basis of the trial conducted by Seligman and colleagues,[84] it does not appear that screening and feedback alone improves outcomes. However, that trial was relatively small and did not have sufficient power to examine rare but important outcomes such as differences in serious hypoglycemia. A larger trial that combines screening with a health literacy–sensitive intervention may be required to determine whether screening is warranted. On the other hand, some have suggested that screening is not a good use of resources and that, instead, providers should implement universal precautions and assume that every patient is at risk.[87-89] Whether such an approach is preferable will require further testing, as there is not current sufficient evidence to decide whether universal screening or universal precautions should be the preferred approach.

There are limitations to this review that should be noted. First, only English-language articles describing research conducted in the United States were included, and systematic reviews were relied on for studies published before 2009. It is therefore possible that some relevant studies may have been excluded from the synthesis. Second, a comprehensive, systematic review was not conducted of the selected literature. Instead, a narrative synthesis approach was used to broadly summarize findings from 3 key domains. This was necessary given the diverse methodologies used across studies. Despite these limitations, this review is a notable addition to the literature as it summarizes findings on (1) tools to identify inadequate health literacy and numeracy among patients with diabetes, (2) the relationship between health literacy or numeracy and a range of diabetes-related outcomes, and (3) interventions to reduce health

[†]References 9, 10, 39, 43, 50, 51, 58, 63, 64.

literacy–related differences in diabetes outcomes and promote positive health outcomes among patients with diabetes regardless of literacy/numeracy skills. Prior reviews have not addressed all 3 of these domains, have not been focused solely on diabetes, or have not included the most recently published research.[12-14,90]

Implications for Educators

Diabetes educators should recognize that inadequate literacy is common and that diabetes care can be even more challenging for patients when they have limited print and numerical literacy skills. Clinicians and educators should ensure they provide easy-to-understand information and reduce unnecessary complexity when developing care plans with patients. Checking understanding by using "teach-back" can reduce the chance of misunderstanding and potentially prevent adverse effects.[91]

References

1. Centers for Disease Control and Prevention. *National Diabetes Fact Sheet*. Atlanta, GA: US Department of Health and Human Services; 2011. http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf. Accessed April 23, 2014.
2. Murea M, Ma L, Freedman BI. Genetic and environmental factors associated with type 2 diabetes and diabetic vascular complications. *Rev Diabetic Stud RDS*. 2012;9(1):6-22.
3. Peyrot M, McMurry JF Jr, Kruger DF. A biopsychosocial model of glycemic control in diabetes: stress, coping and regimen adherence. *J Health Soc Behav*. 1999;40(2):141-158.
4. Haas L, Maryniuk M, Beck J, et al. National standards for diabetes self-management education and support. *Diabetes Care*. 2013;36(suppl 1):S100-S108.
5. *Health Literacy: A Prescription to End Confusion*. Washington, DC: National Academies Press; 2004.
6. Kutner MA; United States Department of Education, National Center for Education Statistics. *The Health Literacy of America's Adults: Results From the 2003 National Assessment of Adult Literacy*. NCES (Series). Washington, DC: US Department of Education, National Center for Education Statistics; 2006. http://nces.ed.gov/pubs2006/2006483.pdf. Accessed April 23, 2014.
7. Vernon JA, Trujillo A, Rosenbaum S, DeBuono B. Low health literacy: implications for national health policy. 2007. http://publichealth.gwu.edu/departments/healthpolicy/CHPR/downloads/LowHealthLiteracyReport10_4_07.pdf. Accessed April 23, 2014.
8. US Department of Health and Human Services. HealthyPeople.gov: health communication and health information techology. 2013. http://healthypeople.gov/2020/topicsobjectives2020/objectiveslist.aspx?topicId=18. Published Accessed April 23, 2014.
9. Schillinger D, Grumbach K, Piette J, et al. Association of health literacy with diabetes outcomes. *JAMA*. 2002;288(4):475-482.
10. Osborn CY, Cavanaugh K, Wallston KA, Rothman RL. Self-efficacy links health literacy and numeracy to glycemic control. *J Health Commun*. 2010;15(suppl 2):146-158.
11. Popay J, Roberts H, Sowden A, et al. *Guidance on the conduct of narrative synthesis in systematic reviews. 14th Cochrane Colloquium*; October 2006; Dublin, Ireland.
12. Sheridan SL, Halpern DJ, Viera AJ, Berkman ND, Donahue KE, Crotty K. Interventions for individuals with low health literacy: a systematic review. *J Health Commun*. 2011;16(suppl 3):30-54.
13. Al Sayah F, Majumdar SR, Williams B, Robertson S, Johnson JA. Health literacy and health outcomes in diabetes: a systematic review. *J Gen Intern Med*. 2013;28(3):444-452.
14. Al Sayah F, Williams B, Johnson JA. Measuring health literacy in individuals with diabetes: a systematic review and evaluation of available measures. *Health Educ Behav*. 2013;40(1):42-55.
15. Sanders LM, Federico S, Klass P, Abrams MA, Dreyer B. Literacy and child health: a systematic review. *Arch Pediatr Adolesc Med*. 2009;163(2):131-140.
16. Huizinga MM, Elasy TA, Wallston KA, et al. Development and validation of the Diabetes Numeracy Test (DNT). *BMC Health Serv Res*. 2008;8:96.
17. Sarkar U, Schillinger D, Lopez A, Sudore R. Validation of self-reported health literacy questions among diverse English and Spanish-speaking populations. *J Gen Intern Med*. 2011;26(3):265-271.
18. Brega AG, Jiang L, Beals J, et al. Special diabetes program for Indians: reliability and validity of brief measures of print literacy and numeracy. *Ethn Dis*. 2012;22(2):207-214.
19. Chew LD, Bradley KA, Boyko EJ. Brief questions to identify patients with inadequate health literacy. *Fam Med*. 2004;36(8):588-594.
20. Lipkus IM, Samsa G, Rimer BK. General performance on a numeracy scale among highly educated samples. *Med Decis Making*. 2001;21(1):37-44.
21. Baker DW, Williams MV, Parker RM, Gazmararian JA, Nurss J. Development of a brief test to measure functional health literacy. *Patient Educ Couns*. 1999;38(1):33-42.
22. Kirk JK, Grzywacz JG, Arcury TA, et al. Performance of health literacy tests among older adults with diabetes. *J Gen Intern Med*. 2012;27(5):534-540.
23. Jeppesen KM, Hull BP, Raines M, Miser WF. A validation study of the spoken knowledge in low literacy in diabetes scale (SKILLD). *J Gen Intern Med*. 2012;27(2):207-212.
24. 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(3):335-341.
25. Jeppesen KM, Coyle JD, Miser WF. Screening questions to predict limited health literacy: a cross-sectional study of patients with diabetes mellitus. *Ann Fam Med*. 2009;7(1):24-31.
26. Wallace LS, Rogers ES, Roskos SE, Holiday DB, Weiss BD. Brief report: screening items to identify patients with limited health literacy skills. *J Gen Intern Med*. 2006;21(8):874-877.
27. Chisolm DJ, Hardin DS, McCoy KS, Johnson LD, McAlearney AS, Gardner W. Health literacy and willingness to use online health information by teens with asthma and diabetes. *Telemed J E Health*. 2011;17(9):676-682.
28. White RO III, Osborn CY, Gebretsadik T, Kripalani S, Rothman RL. Development and validation of a Spanish diabetes-specific

numeracy measure: DNT-15 Latino. *Diabetes Technol Ther*. 2011;13(9):893-898.
29. Huizinga MM, Beech BM, Cavanaugh KL, Elasy TA, Rothman RL. Low numeracy skills are associated with higher BMI. *Obesity*. 2008;16(8):1966-1968.
30. Mulvaney SA, Lilley JS, Cavanaugh KL, Pittel EJ, Rothman RL. Validation of the diabetes numeracy test with adolescents with type 1 diabetes. *J Health Commun*. 2013;18(7):795-804.
31. Yamashita T, Kart CS. Is diabetes-specific health literacy associated with diabetes-related outcomes in older adults? *J Diabetes*. 2011;3(2):138-146.
32. Rothman RL, Malone R, Bryant B, et al. The Spoken Knowledge in Low Literacy in Diabetes scale: a diabetes knowledge scale for vulnerable patients. *Diabetes Educ*. 2005;31(2):215-224.
33. Nath CR, Sylvester ST, Yasek V, Gunel E. Development and validation of a literacy assessment tool for persons with diabetes. *Diabetes Educ*. 2001;27(6):857-864.
34. Reyna VF, Nelson WL, Han PK, Dieckmann NF. How numeracy influences risk comprehension and medical decision making. *Psychol Bull*. 2009;135(6):943-973.
35. Reyna VF. A theory of medical decision making and health: fuzzy trace theory. *Med Decis Making*. 2008;28(6):850-865.
36. Reyna VF, Adam MB. Fuzzy-trace theory, risk communication, and product labeling in sexually transmitted diseases. *Risk Anal*. 2003;23(2):325-342.
37. Rothman RL, Montori VM, Cherrington A, Pignone MP. Perspective: the role of numeracy in health care. *J Health Commun*. 2008;13(6):583-595.
38. Cavanaugh K, Huizinga MM, Wallston KA, et al. Association of numeracy and diabetes control. *Ann Intern Med*. 2008;148(10):737-746.
39. Bauer AM, Schillinger D, Parker MM, et al. Health literacy and antidepressant medication adherence among adults with diabetes: the Diabetes Study of Northern California (DISTANCE). *J Gen Intern Med*. 2013;28(9):1181-1187.
40. Brega AG, Ang A, Vega W, et al. Mechanisms underlying the relationship between health literacy and glycemic control in American Indians and Alaska Natives. *Patient Educ Couns*. 2012;88(1):61-68.
41. Coffman MJ, Norton CK, Beene L. Diabetes symptoms, health literacy, and health care use in adult Latinos with diabetes risk factors. *J Cult Divers*. 2012;19(1):4-9.
42. Glasgow RE, Christiansen SM, Kurz D, et al. Engagement in a diabetes self-management Website: usage patterns and generalizability of program use. *J Med Internet Res*. 2011;13(1):e9.
43. Karter AJ, Subramanian U, Saha C, et al. Barriers to insulin initiation: the translating research into action for diabetes insulin starts project. *Diabetes Care*. 2010;33(4):733-735.
44. Mancuso JM. Impact of health literacy and patient trust on glycemic control in an urban USA population. *Nurs Health Sci*. 2010;12(1):94-104.
45. Mayberry LS, Kripalani S, Rothman RL, Osborn CY. Bridging the digital divide in diabetes: family support and implications for health literacy. *Diabetes Technol Ther*. 2011;13(10):1005-1012.
46. Mbaezue N, Mayberry R, Gazmararian J, Quarshie A, Ivonye C, Heisler M. The impact of health literacy on self-monitoring of blood glucose in patients with diabetes receiving care in an inner-city hospital. *J Natl Med Assoc*. 2010;102(1):5-9.
47. McCleary-Jones V. Health literacy and its association with diabetes knowledge, self-efficacy and disease self-management among African Americans with diabetes mellitus. *ABNF J*. 2011;22(2):25-32.
48. Morris NS, MacLean CD, Littenberg B. Literacy and health outcomes: a cross-sectional study in 1002 adults with diabetes. *BMC Fam Pract*. 2006;7:49.
49. Osborn CY, Bains SS, Egede LE. Health literacy, diabetes self-care, and glycemic control in adults with type 2 diabetes. *Diabetes Technol Ther*. 2010;12(11):913-919.
50. Sarkar U, Piette JD, Gonzales R, et al. Preferences for self-management support: findings from a survey of diabetes patients in safety-net health systems. *Patient Educ Couns*. 2008;70(1):102-110.
51. Sarkar U, Karter AJ, Liu JY, et al. The literacy divide: health literacy and the use of an internet-based patient portal in an integrated health system-results from the diabetes study of northern California (DISTANCE). *J Health Commun*. 2010;15(suppl 2):183-196.
52. Sarkar U, Karter AJ, Liu JY, Moffet HH, Adler NE, Schillinger D. Hypoglycemia is more common among type 2 diabetes patients with limited health literacy: the Diabetes Study of Northern California (DISTANCE). *J Gen Intern Med*. 2010;25(9):962-968.
53. Vassy JL, O'Brien KE, Waxler JL, et al. Impact of literacy and numeracy on motivation for behavior change after diabetes genetic risk testing. *Med Decis Making*. 2012;32(4):606-615.
54. Wallace AS, Carlson JR, Malone RM, Joyner J, Dewalt DA. The influence of literacy on patient-reported experiences of diabetes self-management support. *Nurs Res*. 2010;59(5):356-363.
55. Marden S, Thomas PW, Sheppard ZA, Knott J, Lueddeke J, Kerr D. Poor numeracy skills are associated with glycaemic control in Type 1 diabetes. *Diabet Med*. May 2012;29(5):662-669.
56. 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(9):1614-1619.
57. Sudore RL, Mehta KM, Simonsick EM, et al. Limited literacy in older people and disparities in health and healthcare access. *J Am Geriatr Soc*. 2006;54(5):770-776.
58. Powell CK, Hill EG, Clancy DE. The relationship between health literacy and diabetes knowledge and readiness to take health actions. *Diabetes Educ*. 2007;33(1):144-151.
59. Gazmararian JA, Williams MV, Peel J, Baker DW. Health literacy and knowledge of chronic disease. *Patient Educ Couns*. 2003;51(3):267-275.
60. 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(2):166-172.
61. DeWalt DA, Boone RS, Pignone MP. Literacy and its relationship with self-efficacy, trust, and participation in medical decision making. *Am J Health Behav*. 2007;31(suppl 1):S27-S35.
62. Gerber BS, Pagcatipunan M, Smith EV Jr, et al. The assessment of diabetes knowledge and self-efficacy in a diverse population using Rasch measurement. *J Appl Meas*. 2006;7(1):55-73.
63. Schillinger D, Bindman A, Wang F, Stewart A, Piette J. Functional health literacy and the quality of physician-patient communication among diabetes patients. *Patient Educ Couns*. 2004;52(3):315-323.
64. Castro CM, Wilson C, Wang F, Schillinger D. Babel babble: physicians' use of unclarified medical jargon with patients. *Am J Health Behav*. 2007;31(suppl 1):S85-S95.

65. Sarkar U, Fisher L, Schillinger D. Is self-efficacy associated with diabetes self-management across race/ethnicity and health literacy? *Diabetes Care*. 2006;29(4):823-829.
66. White RO, DeWalt DA, Malone RM, Osborn CY, Pignone MP, Rothman RL. Leveling the field: addressing health disparities through diabetes disease management. *Am J Manag Care*. 2010;16(1):42-48.
67. Bass PF III, Wilson JF, Griffith CH. A shortened instrument for literacy screening. *J Gen Intern Med*. 2003;18(12):1036-1038.
68. 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.
69. Laramee AS, Morris N, Littenberg B. Relationship of literacy and heart failure in adults with diabetes. *BMC Health Serv Res*. 2007;7:98.
70. White RO, Wolff K, Cavanaugh KL, Rothman R. Addressing health literacy and numeracy to improve diabetes education and care. *Diabetes Spectr*. 2010;23(4):238-243.
71. DeWalt DA, Pignone MP. Reading is fundamental: the relationship between literacy and health. *Arch Intern Med*. 2005;165(17):1943-1944.
72. Howards PP, Schisterman EF, Poole C, Kaufman JS, Weinberg CR. "Toward a clearer definition of confounding" revisited with directed acyclic graphs. *Am J Epidemiol*. 2012;176(6):506-511.
73. Cavanaugh K, Wallston KA, Gebretsadik T, et al. Addressing literacy and numeracy to improve diabetes care: two randomized controlled trials. *Diabetes Care*. 2009;32(12):2149-2155.
74. DeWalt DA, Davis TC, Wallace AS, et al. Goal setting in diabetes self-management: taking the baby steps to success. *Patient Educ Couns*. 2009;77(2):218-223.
75. Gerber BS, Brodsky IG, Lawless KA, et al. Implementation and evaluation of a low-literacy diabetes education computer multimedia application. *Diabetes Care*. 2005;28(7):1574-1580.
76. Glasgow RE, Kurz D, King D, et al. Twelve-month outcomes of an Internet-based diabetes self-management support program. *Patient Educ Couns*. 2012;87(1):81-92.
77. Kandula NR, Nsiah-Kumi PA, Makoul G, et al. The relationship between health literacy and knowledge improvement after a multimedia type 2 diabetes education program. *Patient Educ Couns*. 2009;75(3):321-327.
78. Kandula NR, Malli T, Zei CP, Larsen E, Baker DW. Literacy and retention of information after a multimedia diabetes education program and teach-back. *J Health Commun*. 2011;16 (suppl 3):89-102.
79. Kim S, Love F, Quistberg DA, Shea JA. Association of health literacy with self-management behavior in patients with diabetes. *Diabetes Care*. 2004;27(12):2980-2982.
80. Rothman RL, DeWalt DA, Malone R, et al. Influence of patient literacy on the effectiveness of a primary care-based diabetes disease management program. *JAMA*. 2004;292(14):1711-1716.
81. Rothman R, Malone R, Bryant B, Horlen C, DeWalt D, Pignone M. The relationship between literacy and glycemic control in a diabetes disease-management program. *Diabetes Educ*. 2004;30(2):263-273.
82. Schillinger D, Hammer H, Wang F, et al. Seeing in 3-D: examining the reach of diabetes self-management support strategies in a public health care system. *Health Educ Behav*. 2008;35(5):664-682.
83. Schillinger D, Handley M, Wang F, Hammer H. Effects of self-management support on structure, process, and outcomes among vulnerable patients with diabetes: a three-arm practical clinical trial. *Diabetes Care*. 2009;32(4):559-566.
84. Seligman HK, Wang FF, Palacios JL, et al. Physician notification of their diabetes patients' limited health literacy: a randomized, controlled trial. *J Gen Intern Med*. 2005;20(11):1001-1007.
85. Wallace AS, Seligman HK, Davis TC, et al. Literacy-appropriate educational materials and brief counseling improve diabetes self-management. *Patient Educ Couns*. 2009;75(3):328-333.
86. Hill-Briggs F, Lazo M, Peyrot M, et al. Effect of problem-solving-based diabetes self-management training on diabetes control in a low income patient sample. *J Gen Intern Med*. 2011;26(9):972-978.
87. Paasche-Orlow MK, Wolf MS. Evidence does not support clinical screening of literacy. *J Gen Intern Med*. 2008;23(1):100-102.
88. Paasche-Orlow MK, Schillinger D, Greene SM, Wagner EH. How health care systems can begin to address the challenge of limited literacy. *J Gen Intern Med*. 2006;21(8):884-887.
89. US Department of Health and Human Services. National action plan to improve health literacy. http://www.health.gov/communication/hlactionplan/pdf/Health_Literacy_Action_Plan.pdf. 2010. Accessed April 23, 2014.
90. Berkman ND, Sheridan SL, Donahue KE, Halpern DJ, Crotty K. Low health literacy and health outcomes: an updated systematic review. *Ann Intern Med*. 2011;155(2):97-107.
91. National Quality Forum. *Safe Practices for Better Healthcare—2009 Update: A Consensus Report*. 2009. http://www.qualityforum.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=17795. Accessed April 23, 2014.