REVIEWS

The Role of Health Literacy in Diabetes Knowledge, Self-Care, and Glycemic Control: a Meta-analysis

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BACKGROUND: Empirical evidence on how health literacy affects diabetes outcomes is inconsistent. The purpose of this meta-analysis was to quantitatively summarize the findings on the associations between health literacy and diabetes knowledge, self-care activities, and glycemic control as disease-related outcomes, with specific focus on the type of health literacy assessment.

DATA SOURCES: Nine databases (MEDLINE, CINAHL, Communication and Mass Media Complete, PsychInfo, PsychArticles, Psychology and Behavioral Sciences Collection, ERIC, Sociology, Embase) were searched for peer-reviewed original research articles published until 31 March 2018.

METHODS: Studies with type 1 and/or type 2 diabetes patients aged 18 or older, providing a calculable baseline effect size for functional health literacy and diabetes knowledge, self-care activities, or HbA1C were included.

RESULTS: The meta-analysis includes 61 studies with a total of 18,905 patients. The majority were conducted in the USA, on type 2 diabetes patients, and used the S-TOFHLA as a performance-based or the BHLS as a perception-based measure of functional health literacy. Meta-analytic results show that all three outcomes are related to health literacy. Diabetes knowledge was best predicted by performance-based health literacy measures, self-care by self-report measures, and glycemic control equally by both types of health literacy assessment.

DISCUSSION: Health literacy plays a substantial role in diabetes knowledge. Findings for the role of health literacy in self-care and glycemic control remain heterogeneous, partly due to the type of health literacy assessment (performance- vs. perception-based). This has implications for the use of health literacy measures in clinical settings and original research. This meta-analysis was limited to functional health literacy and, due to the paucity of studies, did not investigate the role of other dimensions including communicative and critical health literacy.

KEY WORDS: health literacy; diabetes; knowledge; self-care; glycemic control; meta-analysis.

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INTRODUCTION

Diabetes is a common chronic condition, which can lead to "long-term damage, dysfunction, and failure of different organs, especially the eyes, kidneys, nerves, heart, and blood vessels".[1] In 2015, the disease had a worldwide prevalence of 8.8% and is expected to grow to 10.4% by 2040,[2] causing a substantial increment in self-care cost.[3] Diabetes requires patients to actively self-manage the disease in their everyday lives. For this reason, the ability to effectively use health information and healthcare services is of great importance. As such, good self-management is closely related to health literacy, defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions".[4] These functional skills have been studied in the context of chronic diseases since the term *health literacy* first appeared in 1974,[5] and their relations to health outcomes, use of healthcare services, and costs have been repeatedly documented.[6] Concerning diabetes, a large body of empirical research assessing the relation between health literacy and diabetes-related knowledge, management, and outcomes has been summarized in numerous systematic and narrative reviews with heterogeneous results (e.g.,[5–9]) For example, Caruso and colleagues,[10] in their systematic review of six systematic reviews, concluded that, while the link between health literacy and diabetes knowledge is well-established, inconsistent findings exist for the relationships between health literacy and diabetes-related outcomes. To the best of our knowledge, only one meta-analysis on eight studies[11] investigated the role of health literacy in diabetes outcomes, focusing on health-literacy–sensitive interventions. Again, the heterogeneity levels in the final effect size were very high. A possible explanation is the variety of definitions and measurements of health literacy.[12, 13] In clinical settings, health literacy has been traditionally assessed with word recognition tests like the Rapid Estimate of Adult Literacy in Medicine (REALM[12]) or combined health literacy and numeracy tests like the Short Test of Functional Health Literacy (S-TOFHLA[13]). These tests measure patients' *performance*, i.e., basic comprehension, reading, and numeracy skills. Despite the introduction of shorter versions, they require time and clinical staff to assist in the administration. To overcome these

shortcomings, brief screening tools have been developed and validated including the Brief Health Literacy Screening questions (BHLS[14]). These self-report tools measure patients' *perception* of their (in-)abilities to function in healthcare settings covering comprehension, navigation, and writing skills. Furthermore, disease-specific literacy (e.g., Literacy Assessment for Diabetes (LAD)[15]) and numeracy tests (e.g., Diabetes Numeracy Test (DNT)[16]) have been proposed following the notion that measuring health literacy will be best achieved where content and context are well defined.[12] In a previous review of four studies including both performance-based and self-report health literacy measures, Kiechle and colleagues did not find any differential effects of measurement type on self-reported health outcomes including diabetes management.[17] However, the small number of "fair" rated studies did not allow a quantitative synthesis or more detailed subgroup analyses. That said, the present meta-analysis wants to shed light on the role of health literacy in diabetes-related knowledge, self-care, and glycemic control,[18] taking into account variations in functional health literacy assessments.

METHODS

We conducted this meta-analysis according to the MOOSE guidelines[19] and, in part, the PRISMA guidelines.[20]

Study Sources and Searches

The first two authors searched in nine electronic databases up to 31 March 2018: MEDLINE, CINAHL, Communication and Mass Media Complete, Psychology and Behavioral Sciences Collection, PsychInfo, ERIC and Sociology, Embase, and PsychArticles. The detailed search strategy and keywords are reported in Appendix 1. We carried out an additional hand search by going through the reference list of relevant review articles identified through the database search and scanning the first 100 Google Scholar entries.

Study Selection

After duplicates were removed, the first two authors independently completed a title and abstract screening. We included only studies according to the following criteria: (1) written in English, (2) published in a peer review journal, (3) including only adult patients (≥ 18 years of age) with (4) type 1 or type 2 diabetes, (5) with at least one validated measure of health literacy or numeracy and one measure of diabetes knowledge or glycemic control (HbA1C) or self-care activities, and (6) an outcome which could be converted into an effect size. We excluded studies with children or adolescent populations or gestational diabetics. We further excluded conference abstracts, theses, books, or book sections. In case of longitudinal or intervention studies, we extracted only baseline measures. To obtain a measure of interrater reliability, we calculated the Cohen's kappa statistic for title and abstract screening. If at least one of the two coders decided to retain an article, we included it in the full-text screening. Discrepancies after full-text screening were resolved by consensus.

Data Extraction

For each included study, we extracted information about the article (first author, year of publication, journal title), the study (country where the study was conducted, study design, sample size, type of health literacy measure), and principal outcomes (any data assessing the association between health literacy and diabetes knowledge, self-care, and glycemic control, which could be converted into an effect size). Finally, we collected sample characteristics including proportion of female, age, education level, ethnicity, type of diagnosis (diabetes type 1 or 2), presence of comorbidities, BMI, insulin use, diabetes duration, past diabetes education, social support, and insurance status.

Quality Assessment

Measures of health literacy, diabetes knowledge, and self-care activities require patients' capacity to understand and respond to questions or tasks. Thus, as a form of quality assessment, we checked whether studies explicitly mentioned limited language proficiency, psychological problems, cognitive, vision, or hearing impairment of patients as an exclusion criterion. We used this quality information in subgroup analyses and tested whether there was a difference in the effect size between studies with good and poor quality.

Data Synthesis and Analysis

We conducted the meta-analysis using the "esc"[21] and "meta"[22] packages in R statistical software. We used Fisher's r to z transformation as a measure of effect size, with results converted back to the r correlation coefficient. Since the raw data were heterogeneous, we used different transformation formulas[23, 24] to compute the effect size. The analyses were implemented using the inverse-variance method with a random effects model and Hartung–Knapp–Sidik–Jonkman adjustment,[25] which allows to control for the error rates of the effect size due to heterogeneity. Moreover, we use the restricted maximum-likelihood estimator (REML) to estimate the between-study variance τ^2 and the I^2 statistic[26–28] to describe the heterogeneity of the effect size. Potential publication biases were assessed via Egger's regression test for funnel plot asymmetry using the mixed-effects meta-regression model.[29] To explain possible heterogeneity in the effect sizes, we implemented influence analyses (using the leaving-one-out method), meta-regression, and subgroup analyses. We performed sensitivity analyses of our results to potential moderators by a combination of stratified analyses and meta-regression modeling. This included distinguishing studies according to the type of health literacy or numeracy measure (performance-based or self-report, including a numeracy section or not, being diabetes specific or not). We also considered

different sociodemographic and study-specific characteristics in subgroup analyses. Notably, we performed meta-regression analyses only for outcomes that had a sufficient number of studies, ideally at least ten.[28]

Role of the Funding Source

The authors received no specific funding for this meta-analysis.

RESULTS

The initial database and hand search returned 2970 publications, of which 1491 were duplicates or no peer-reviewed journal articles. After title and abstract screening of 1479 records (Cohen's kappa = 0.923), we assessed 113 full-text articles for eligibility. We excluded 52 articles resulting in a meta-analysis of 61 studies with 58 unique samples. The study selection process and the reasons for exclusion after full-text screening are reported in the PRISMA flowchart (Fig. 1).

Study Characteristics

The present meta-analysis is based on 61 studies[30–90] with 58 unique samples. Overall, the analytical sample amounts to 18,905 patients. Of all studies, 51 used a cross-sectional design. Thirty-nine were conducted in North America (36 in the USA and 3 in Canada), 8 in Asia, 7 in Middle Eastern countries, and 4 in Europe. The sample size per study ranged from 36 to 2564 patients with diabetes type 1 ($n = 1$), type 2 ($n = 35$), type 1 and 2 ($n = 16$), or unspecified diabetes ($n = 9$). Nineteen studies reported on patients' comorbidities including hypertension, retinopathy, or hyperlipidemia. Concerning our measures of interest, 33 studies assessed patients' functional health literacy with a performance-based measure including the S-TOFHLA ($n = 16$) or adapted versions ($n = 2$), TOFHLA ($n = 2$), REALM ($n = 9$) or its revised version ($n = 1$), or other tests ($n = 3$). Another 18 studies used self-report measures such as the BHLS ($n = 9$), FCCHL ($n = 5$), or other partly ad hoc created measures ($n = 4$). Of all health literacy measures, 5 were diabetes-specific tests ($n = 3$) or diabetes-specific self-report scales ($n = 2$). Numeracy was assessed in 11 studies with performance-based measures including the DNT ($n = 7$), the NVS ($n = 3$), or the numeracy section of the WRAT-3R ($n = 1$). HbA1C was measured in 43 out of 61 studies. Twenty-seven studies assessed diabetes self-care activities using the SDSCA or subdimensions of this scale being used in 19 studies. Diabetes-related knowledge was measured in 26 studies either with the DKT ($n = 9$), the SKILLD instrument ($n = 7$), the DKQ ($n = 3$), or other mostly ad hoc created instruments ($n = 7$). Limited language proficiency or cognitive, vision, or hearing impairment of patients as an exclusion criterion was applied in 47 studies. Detailed information about each study and measures including references are reported in Appendices Table 2 and 3.

Health Literacy and Diabetes Knowledge

Higher levels of health literacy were significantly associated with better diabetes knowledge ($n = 20$, $r = 0.308$, $p < 0.001$, $I^2 = 85\%$). No particular study influenced the overall heterogeneity. However, studies using a performance-based test had a significantly ($p = 0.023$) larger effect size ($n = 16$, $r = 0.339$, $p < 0.001$) than studies using self-report measures ($n = 4$, $r = 0.193$, $p = 0.030$) (see Table 1 and Fig. 2). Using health literacy tests with a numeracy section led to a significantly ($p = 0.002$) smaller effect size ($n = 8$, $r = 0.232$, $p = 0.002$) compared to tests without ($n = 8$, $r = 0.437$, $p < 0.001$). Only one study used a diabetes-specific health literacy measure[58]; hence, it could not be compared with other studies using unspecific health literacy measures. Although the meta-analysis on numeracy and diabetes knowledge showed a large positive significant correlation ($n = 6$, $r = 0.486$, $p = 0.001$), the heterogeneity level was very high ($I^2 = 91\%$). Leaving out the study by Huizinga,[49] the original validation study of the DNT in type 1 and 2 diabetic patients, decreased the heterogeneity level to 0%, yet the correlation remained rather unaffected ($r = 0.419$, $p < 0.0001$).

Health Literacy and Diabetes Self-Care

Higher levels of health literacy were not associated with more frequent self-care activities ($n = 11$, $r = 0.052$, $p = 0.117$, $I^2 = 51\%$). Leaving out the study by Inoue [50] decreased the heterogeneity level to 25%; however, the total effect size remained nonsignificant. Subgroup analyses revealed a significant ($p = 0.025$) difference related to the type of test: in studies including self-report health literacy measures, the overall association with self-care activities was significant and positive ($n = 6$, $r = 0.095$, $p = 0.045$), while no such association was found for studies with performance-based tests. Subgroup analyses did not show any differences between the effect sizes of studies using diabetes-specific and nonspecific measures. Only one study used a diabetes-specific health literacy measure and only one a health literacy test without a numeracy section[42]; hence, subgroup comparison could not be conducted. Moreover, there was an insufficient number of studies ($n = 1$)[31] to perform a meta-analysis on numeracy and diabetes self-care. Finally, the meta-analyses on health literacy and single self-care activities (i.e., diet, blood monitoring, exercise, medication adherence, and foot care) did not reveal any significant relationships. However, subgroup analyses for single self-care activities showed that the correlations with exercise and with foot care were significantly positive in studies using self-report measures ($n = 6$, $r = 0.098$, $p < 0.001$, $I^2 = 0\%$ for exercise and $n = 3$, $r = 0.274$, $I^2 = 92\%$, $p = 0.023$ for foot care) (see Table 1).

Health Literacy and Glycemic Control

Higher levels of health literacy were associated with lower levels of HbA1C ($n = 36$, $r = -0.048$, $p = 0.027$, $I^2 = 71\%$).

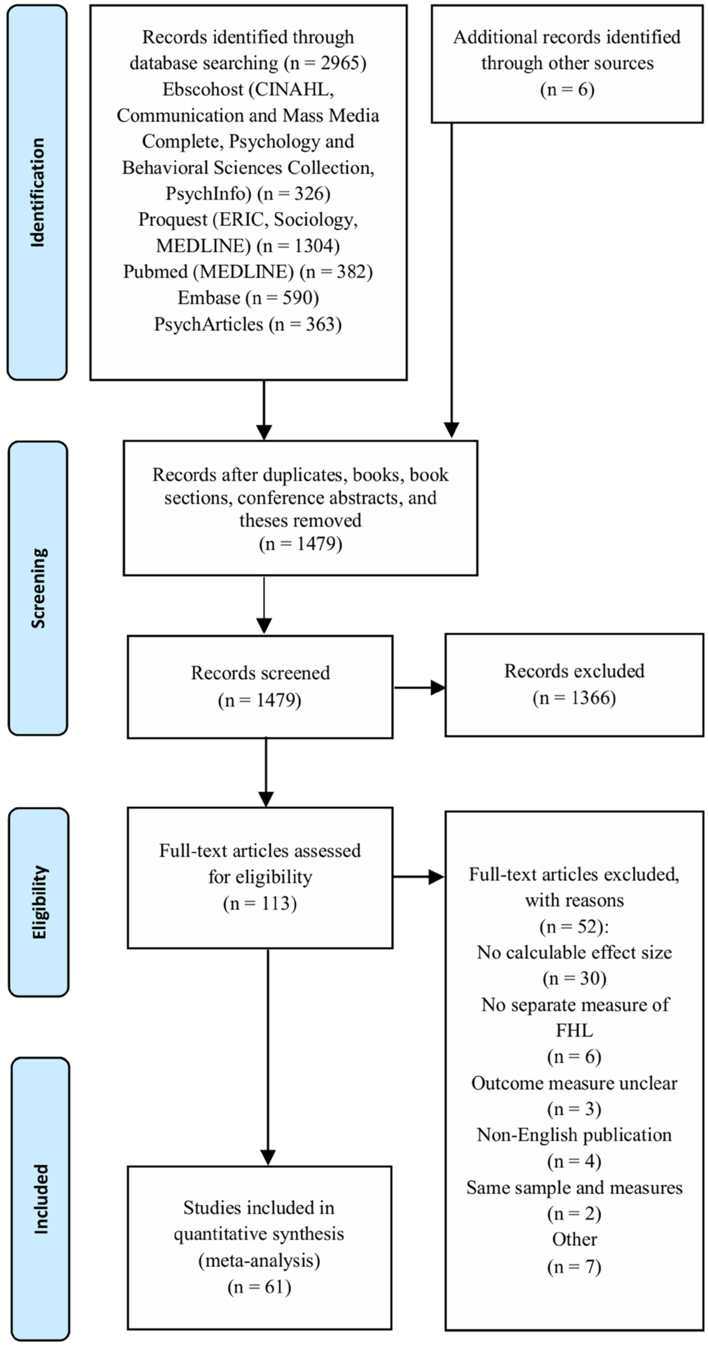

Figure 1 Flowchart of the search strategy.

Leaving out the study by Niknami[67] decreased the I^2 level to 51% ($r = -0.030$, $p = 0.065$). Subgroup analyses revealed that studies with performance-based measures had a significant effect size ($n = 24$, $r = -0.046$, $p = 0.034$, $I^2 = 54\%$), while those using self-report measures, comprised of less than half as many studies, were not significant ($n = 12$, $r = -0.037$, $p = 0.439$, $I^2 = 85\%$). However, the difference between the two types of measurement was not statistically significant ($p = 0.858$) (see Table 1 and Fig. 3). There were no differences in effect sizes related to the type of performance-based health literacy measure, i.e., including a numeracy section or being diabetes-specific. Furthermore, the pooled effect size of the meta-analysis on numeracy and glycemic control was not significant ($n = 8$, $r = -0.018$, $p = 0.653$).

Additional Subgroup Analyses

Considering other potential moderators, primarily related to the study design, we found the following significant subgroup differences: the correlation between health literacy and diabetes knowledge was positive only for studies conducted in North and South America ($n = 15$, $r = 0.351$, $p < 0.001$, $I^2 = 79\%$). Furthermore, health literacy was negatively related to HbA1C in studies conducted only

Table 1 Summary of Meta-analytical Results

Outcomes	*N*	*k*	*r* CI [95%]	*Q*	I^2 (%)	Subgroup difference (*p* value)
HL and diabetes knowledge	4973	20	0.308*** [0.228–0.383]	129.77***	85	–
Performance measures	2555	16	0.339*** [0.247–0.424]	81.35***	82	*0.023*
Self-reported measures	2418	4	0.193** [0.036–0.341]	12.00**	75	
With a numeracy section	1321	8	0.232** [0.123–0.335]	16.91*	59	*0.002*
Without a numeracy section	1234	8	0.437*** [0.349–0.542]	34.45***	80	
Diabetes specific	137	1	0.398*** [0.247–0.530]	na	na	0.261
Not diabetes specific	4836	19	0.303*** [0.220–0.382]	125.88***	86	
NU and diabetes knowledge	1445	6	0.486*** [0.324–0.620]	56.05***	91	–
Diabetes specific	1068	4	0.522* [0.232–0.727]	45.74***	93	0.161
Not diabetes specific	377	2	0.402* [0.200–0.571]	0.11	0	
HL and diabetes self-care	3100	11	0.052 [− 0.015 to 0.119]	20.32*	51	–
Performance measures	744	5	− 0.020 [− 0.122 to 0.082]	3.96	0	*0.025*
Self-reported measures	2356	6	0.095* [0.003–0.185]	10.13	51	
With a numeracy section	644	5	− 0.034 [− 0.160 to 0.093]	3.04	1	0.340
Without a numeracy section	100	1	0.070 [− 0.128 to 0.263]	na	na	
Diabetes specific	1713	3	0.083 [− 0.032 to 0.197]	1.94	0	0.265
Not diabetes specific	1392	8	0.030 [− 0.065 to 0.124]	17.38	60	
NU and diabetes self-care	151	1	0.3100*** [0.158–0.448]	na	na	–
HL and diabetes self-care: diet	1838	11	0.020 [− 0.145 to 0.184]	75.20***	87	
Performance measures	694	5	− 0.104 [− 0.290 to 0.089]	12.04*	67	0.089
Self-reported measures	746	5	0.150 [− 0.215 to 0.478]	39.18***	90	
HL and diabetes self-care: exercise	3552	12	0.024 [− 0.053 to 0.102]	34.03***	68	–
Performance measures	694	5	− 0.053 [− 0.219 to 0.116]	9.51	58	*0.015*
Self-reported measures	2460	6	0.098*** [0.065–0.131]	2.05	0	
HL and diabetes self-care: blood monitoring	1708	10	0.044 [− 0.073 to 0.160]	34.16***	74	–
Performance measures	694	5	− 0.020 [− 0.140 to 0.101]	4.88	18	0.106
Self-reported measures	616	4	0.158 [− 0.163 to 0.449]	22.27***	87	
HL and diabetes self-care: foot care	1621	9	− 0.157 [− 0.310 to 0.004]	93.07***	91	–
Performance measures	694	5	− 0.104 [− 0.266 to 0.064]	7.66	48	*0.023*
Self-reported measures	529	3	0.274 [− 0.380 to 0.745]	25.7***	92	
HL and diabetes self-care: medication adherence	178	3	− 0.078 [− 0.413 to 0.276]	2.38	16	–
HL and glycemic control	12,293	36	− 0.048* [− 0.091 to 0.006]	121.81***	71	–
Performance measures	8443	24	− 0.046* [− 0.088 to − 0.004]	49.88***	54	0.585
Self-reported measures	3850	12	− 0.037 [− 0.138 to 0.065]	71.93***	85	
With a numeracy section	6824	15	− 0.035 [− 0.093 to 0.023]	38.66***	64	0.521
Without a numeracy section	1619	9	− 0.060 [− 0.126 to 0.005]	10.40	23	

(*continued on next page*)

Table 1. (continued)

Outcomes	N	k	r CI [95%]	Q	I^2 (%)	Subgroup difference (p value)
Diabetes specific	2180	4	− 0.013 [− 0.062 to 0.037]	1.55	0	0.172
Not diabetes specific	10,113	32	− 0.051* [− 0.100 to − 0.003]	118.26***	74	
NU and glycemic control	1810	8	− 0.018 [− 0.091 to 0.305]	14.73*	52	–
Diabetes specific	1331	6	− 0.019 [− 0.148 to 0.110]	12.83*	61	0.870
Not diabetes specific	479	2	− 0.005 [− 0.726 to 0.721]	1.76	43	

HL health literacy, NU numeracy
*< 0.1, * < 0.05, ** < 0.01, *** < 0.001, significant p values for group differences are displayed in italics*

with diabetes type 2 patients ($n = 23$, $r = -0.063$, $p = 0.044$, $I^2 = 77\%$) and a higher proportion of low-educated ($n = 30$, $\beta = -0.002$, $p = 0.022$) and uninsured patients ($n = 15$, $\beta = -0.002$, $p = 0.043$) impacted on the final effect. Detailed results on subgroup analyses are available from the first author upon request.

Publication Biases

Egger's tests for funnel plot asymmetry did not reveal any publication bias, except for the meta-analysis on health literacy and diabetes knowledge (Egger's regression test result: $t = 2.744$, $p = 0.013$).

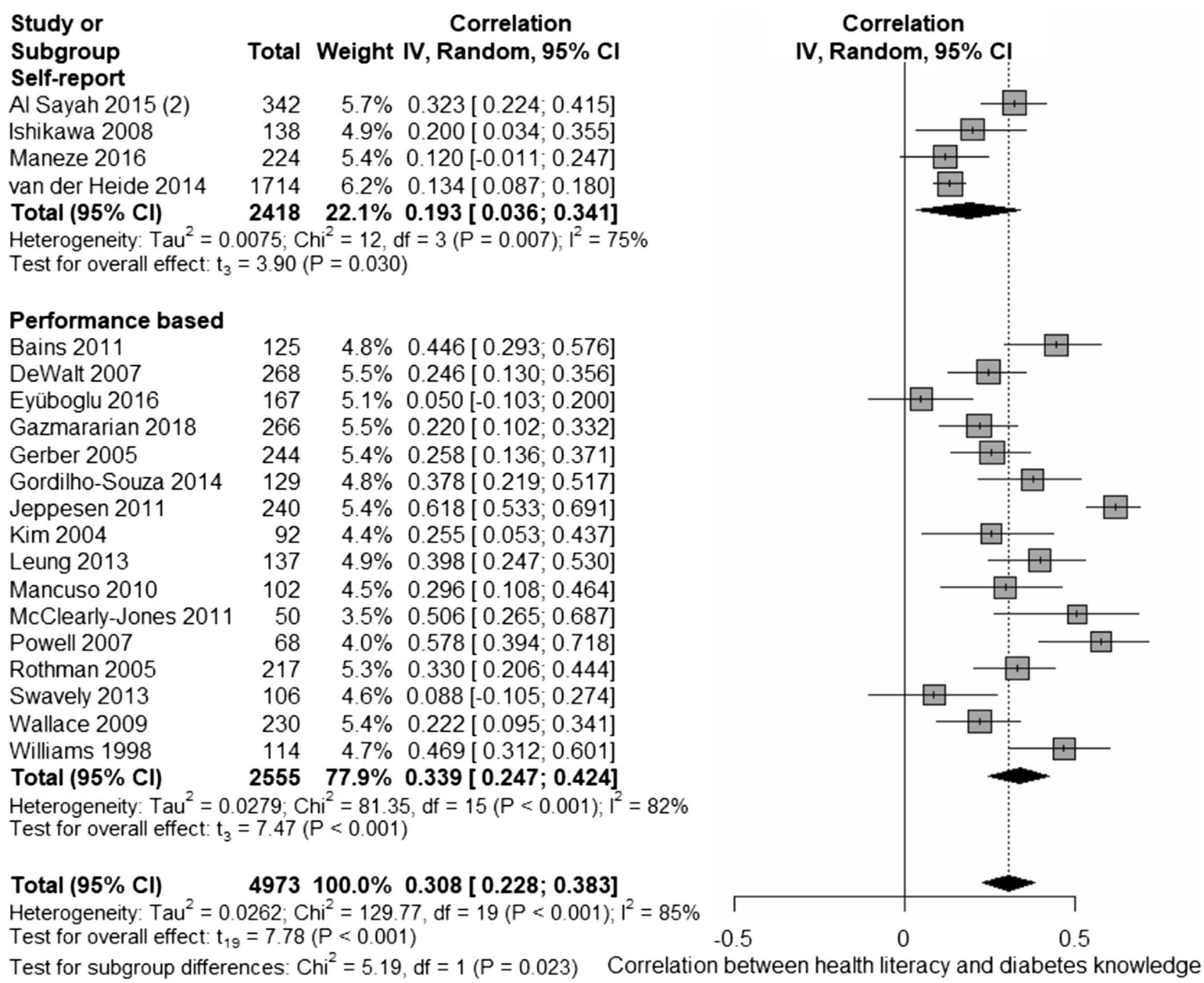

Figure 2 Forest plot of health literacy and diabetes knowledge divided by type of health literacy assessment.

Study or Subgroup	Total	Weight	Correlation IV, Random, 95% CI
Self-report			
Al Sayah 2014	36	1.1%	0.214 [-0.123; 0.507]
Al Sayah 2015	154	2.6%	0.000 [-0.158; 0.158]
Al Sayah 2015 (2)	342	3.3%	0.035 [-0.071; 0.140]
Ishikawa 2008	138	2.5%	0.040 [-0.128; 0.206]
Lai 2013	63	1.6%	-0.030 [-0.276; 0.219]
Lee 2016	295	3.2%	-0.010 [-0.124; 0.104]
Maneze 2016	224	3.0%	0.133 [0.002; 0.259]
Niknami 2018	347	3.4%	-0.400 [-0.485; -0.308]
Radwan 2018	369	3.4%	-0.074 [-0.175; 0.028]
Woodard 2014	183	2.8%	-0.207 [-0.341; -0.064]
Yamashita 2011	1318	4.0%	-0.001 [-0.055; 0.053]
Zuercher 2017	381	3.4%	0.025 [-0.076; 0.125]
Total (95% CI)	**3850**	**34.3%**	**-0.037 [-0.138; 0.065]**
Heterogeneity: Tau^2 = 0.0206; Chi^2 = 71.93, df = 11 (P < 0.001); I^2 = 85%			
Test for overall effect: t_{11} = -0.80 (P = 0.439)			
Performance based			
Bains 2011	125	2.4%	-0.030 [-0.205; 0.146]
Brega 2012	2594	4.2%	-0.070 [-0.108; -0.032]
Chen 2014	467	3.6%	-0.022 [-0.113; 0.068]
Coccaro 2016	100	2.1%	-0.129 [-0.317; 0.069]
DeWalt 2007	268	3.1%	-0.054 [-0.173; 0.066]
Ferguson 2015	278	3.2%	0.019 [-0.099; 0.136]
Gerber 2005	244	3.1%	0.047 [-0.079; 0.172]
Gordilho-Souza 2014	129	2.4%	-0.156 [-0.320; 0.017]
Kim 2004	92	2.0%	0.043 [-0.163; 0.246]
Mancuso 2010	102	2.1%	-0.063 [-0.254; 0.133]
Mayberry 2014	183	2.8%	0.049 [-0.097; 0.192]
Morris 2006	1002	3.9%	0.037 [-0.025; 0.098]
Morris 2013	751	3.8%	0.042 [-0.029; 0.114]
Osborn 2010	383	3.4%	-0.055 [-0.155; 0.045]
Powell 2007	68	1.7%	-0.207 [-0.425; 0.033]
Rothman 2004	217	2.9%	0.007 [-0.126; 0.140]
Saeed 2018	204	2.9%	-0.039 [-0.175; 0.099]
Schillinger 2002	408	3.5%	-0.020 [-0.117; 0.077]
Schillinger 2003	51	1.4%	0.198 [-0.082; 0.449]
Schillinger 2006	395	3.4%	-0.148 [-0.243; -0.050]
Tang 2007	149	2.6%	-0.320 [-0.457; -0.168]
Thabit 2009	51	1.4%	-0.350 [-0.571; -0.082]
White 2013	127	2.4%	-0.077 [-0.248; 0.099]
Williams 1998	55	1.5%	-0.192 [-0.435; 0.077]
Total (95% CI)	**8443**	**65.7%**	**-0.046 [-0.088; -0.004]**
Heterogeneity: Tau^2 = 0.0036; Chi^2 = 49.88, df = 23 (P < 0.001); I^2 = 54%			
Test for overall effect: t_{11} = -2.25 (P = 0.034)			
Total (95% CI)	**12293**	**100.0%**	**-0.048 [-0.091; -0.006]**
Heterogeneity: Tau^2 = 0.0098; Chi^2 = 121.81, df = 35 (P < 0.001); I^2 = 71%			
Test for overall effect: t_{35} = -2.30 (P = 0.027)			
Test for subgroup differences: Chi^2 = 0.03, df = 1 (P = 0.858)			

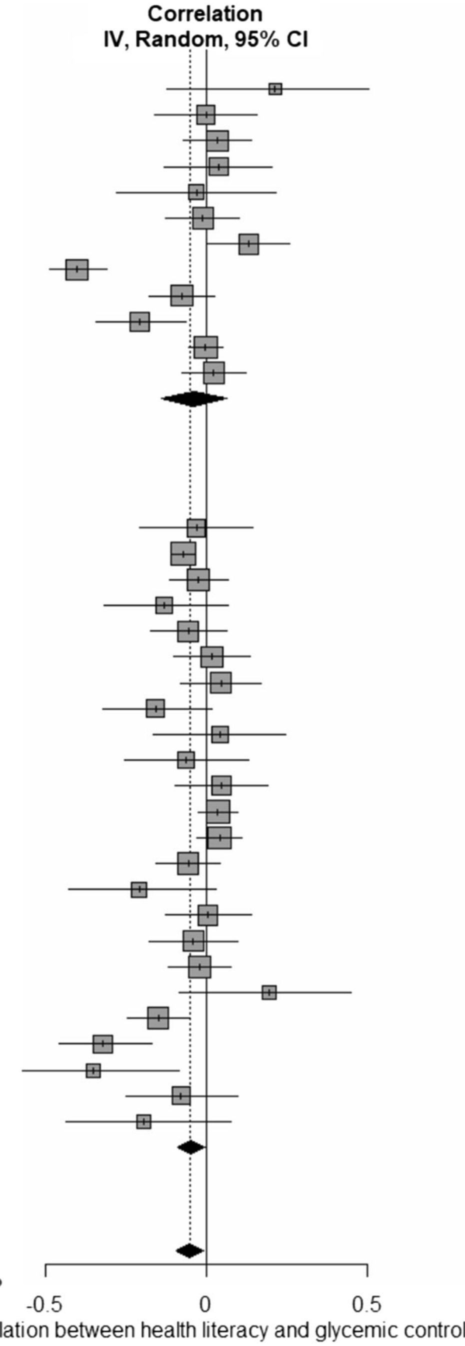

Figure 3 Forest plot of health literacy and glycemic control divided by type of health literacy assessment.

DISCUSSION

Based on 61 studies, our meta-analysis is the first to summarize empirical evidence on the role of health literacy in diabetes-related knowledge, self-care, and glycemic control, taking into account different types of health literacy assessment.

We found that health literacy had a small though significant effect on better glycemic control, as measured using the HbA1C. The effect was even stronger when health literacy was assessed by performance-based measures such as the S-TOFHLA or REALM. Thus, clinicians interested in the assessment of health literacy to better predict glycemic control in their patients should rely on performance-based measures. To date, these are primarily available for functional health literacy and do not capture more advanced skills including navigation, communicative, and critical skills. Another finding from subgroup analyses is that the more patients are in need, because of low education and missing insurance, the stronger is the relationship between health literacy and HbA1C. One possible explanation is that general education and insurance status function as a "buffer," and the lack of those two stresses even more the importance of an adequate level of health literacy to obtain good diabetes outcomes.

In a similar fashion, we found that health literacy was positively related to diabetes knowledge, echoing findings from systematic reviews on the two concepts.[10] Again, the relationship was stronger when performance-based tests were used exclusively or in addition to other measures, as compared to measures based on (self-)perception. This is an important finding as research has previously shown that diabetes knowledge is related with successful self-management and health outcomes.[91, 92]

On the contrary, we found that health literacy had a positive impact on self-care activities only for studies that assessed literacy with perception-based measures. The same result was found in subgroup analyses for two specific self-care activities: exercise and food care, but not for diet and blood monitoring. The fact that all our measures of self-care activities are also self-reports suggests that such measures assess patients' confidence in their capacity to comprehend and use medical materials, rather than their actual ability. Conceptually, confidence or, in other terms, self-efficacy differs from health literacy[93] and has been found to be associated with diabetes care across different health literacy levels.[94] Additionally, self-report data are prone to systematic biases, including patients' difficulties in critical self-assessment and social desirability bias,[95] especially in clinical assessment situations where patients may feel ashamed of their limited health literacy.[96] It could also be that, as both the health literacy and the self-care measures are based on self-perception, the two may be linked by shared biases, i.e., that the reasons why a person misjudges his ability to understand nutrition rules might be the same as the reasons why he misperceives his factual nutrition behavior.

Based on these findings, for clinicians interested in health literacy screenings of patients, the question whether to use performance-based or self-report measures cannot be answered by a simple choice. Much depends on which diabetes outcome(s) they are concerned with. Glycemic control, the most studied outcome, is predicted by both performance-based and self-report health literacy measures, although performance-based measures tend to be the better predictor. Diabetes knowledge is best predicted by performance-based assessments of health literacy and numeracy. Self-care activities, usually reported by patients, are best predicted by self-report health literacy; however, this could be due to the nature of self-care information, which is also self-reported. Thus, one strong point which is evident is the following: if previously self-reported and performance-based measures were considered equally adequate in assessing health literacy, we can now assert that they are not. This point is important when clinicians have to decide which health literacy measure to use.

Given these findings, we call for more research on health literacy in diabetes outcomes. First, we recommend to invest in the development and validation of diabetes-specific performance-based measures of health literacy capturing more advanced skills beyond functional health literacy skills. The paucity of studies using diabetes-specific health literacy and numeracy measures, beyond mere reading and comprehension skills, does not yet allow a quantitative synthesis of the evidence on health literacy in diabetes management. Second, for researchers interested in the evaluation of diabetes interventions, performance-based literacy assessments should be used; they show strong effect sizes with diabetes knowledge and, to a lesser extent, glycemic control, and they overcome potential bias introduced by self-report measures. We also recommend to invest in the assessment of diabetes numeracy to produce more evidence on the relationship with different diabetes outcomes, especially self-care activities. Additionally, more research is needed to better understand the difference between diabetes-specific and general health literacy measures. In particular, considering that usually performance-based measures are not diabetes specific, the development of new disease-specific functional health literacy measures could be a promising route for future studies for improving healthcare.

Our study has some limitations. We did not explore any differences among functional, communicative, and critical health literacy, given the limited number of studies reporting diabetes outcomes for all three dimensions of health literacy. Furthermore, it was not possible to evaluate other important factors, such as depressive symptoms or self-efficacy, due to the paucity of studies including these variables. Moreover, although we could explain a significant portion of study heterogeneity with different types of health literacy assessments, heterogeneity may also be affected by differences in the studies' inclusion criteria and methodologies as well as patients' comorbidities.

In sum, all three diabetes outcomes (knowledge, self-care, glycemic control) are related to health literacy. Knowledge seems more responsive to performance-based, self-care to perception-based, and glycemic control to both measures, with a preference for performance-based tools. In other words, when the outcome is assessed by a "soft" criterion such as self-reported self-care behavior, the relationship appears to be generated more by the perception-based measure of health literacy, while an outcome assessment based on "hard" criteria, e.g., blood sugar level, with reservations also a person's diabetes knowledge, appears to react more strongly to more objective performance-based measures.

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