Title

A systematic review of the prevalence and associations of limited health literacy in chronic kidney disease

Authors

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Abstract

Background and objectives: The self-management and decision-making skills required to manage chronic kidney disease (CKD) successfully may be diminished in those with low health literacy. A 2012 review identified five papers reporting the prevalence of limited health literacy in CKD, largely from US dialysis populations. The literature has expanded considerably since.

Design, setting and participants: Systematic review, pooled prevalence analysis, meta-regression, exploration of heterogeneity in studies of patients with CKD (all stages).

Results: From 433 studies, 15 new studies met the inclusion criteria and were analyzed together with five studies from the 2012 review. These included 13 cross-sectional surveys, five cohort studies (using baseline data) and two using baseline clinical trial data. Most (19/20) were from the USA. In total, 12,324 patients were studied (3,529 non-dialysis CKD; 5,289 dialysis; 2,560 transplant; 946 with unspecified CKD), median 198.5 (IQR: 128.5 to 260) per study. Median prevalence of limited health literacy within studies was 23% (IQR: 16% to 33%), pooled prevalence 25% (95% CI: 20 to 30%) with significant between-study heterogeneity (I² =97%). Pooled prevalence of limited health literacy was 25% (95% CI: 16 to 33%; I²: 97%) among non-dialysis CKD patients, 27% (95% CI: 19 to 35%; I²: 96%) among dialysis patients and 14% (95% CI: 7 to 21%; I²: 97%) among transplant patients. A higher proportion of non-white participants was associated with increased limited health literacy prevalence (p=0.044) but participant age was not (p=0.4). Within studies, non-white ethnicity and low socioeconomic status were consistently and independently associated with limited health literacy. Studies were of low or moderate quality. Within-study participant selection criteria had potential to introduce bias.

Conclusions: Limited health literacy is common in CKD, especially among individuals with low socioeconomic status and non-white ethnicity. This has implications for the design of self-management and decision making initiatives to promote equity of care and improve quality. Lower prevalence among transplant patients may reflect selection of patients with higher health literacy for transplantation, either because of less comorbidity in this group or as a direct effect of health literacy on access to transplantation.
**Introduction**

Chronic kidney disease (CKD) affects 12% of US adults and is associated with significant morbidity and mortality, predominantly through increased cardiovascular risk (1). CKD progression further increases cardiovascular risk (2) and the risk of requiring renal replacement therapy (RRT) (3). CKD management aims to reduce these risks, and prepare people with advanced CKD for dialysis, transplantation or conservative care (4). Increasingly, CKD management involves shared decision-making and self-care activities, which are actively promoted in healthcare policy (5, 6). However, these activities require patients to learn, understand, appraise and apply knowledge of a complex disease process and its treatment. As CKD progresses, the burden of self-management activities increases, while patients’ capacity (7, 8) to perform these activities may reduce because of disease-related reduction in function (9). Further, CKD is associated with low socioeconomic status (SES) (10), so people with CKD may lack the social resources needed for successful CKD management (8). Effective self-management may therefore depend on individual skills in managing health such as health literacy (11).

Health literacy is a personal attribute that ‘entails people’s knowledge, motivation and competences to access, understand, appraise and apply health information’ (12). As a potentially modifiable factor influencing individual health, it is the focus of an expanding field of research. Multiple tools have been developed to measure health literacy or to screen for low or ‘limited’ health literacy (13). In general populations, limited health literacy is associated with poorer health (14), less efficient use of healthcare services (15), and higher mortality (16). However, investigation of limited health literacy in CKD has been relatively limited: a 2012 systematic review identified four studies of hemodialysis patients, one study of transplant patients, and one including patients with early CKD (17). Only 1,405 patients were studied in total. Limited health literacy was associated with lower SES (18-21), and increased comorbidity (20). One study showed increased mortality among dialysis patients with limited health literacy (22). The review identified a need for studies measuring health literacy among patients with CKD stages 1-4 and for studies from outside the USA.

Since this review, investigation of limited health literacy as a barrier to effective clinician-patient communication has been identified as a research priority in CKD (23). Health literacy measures specific to CKD have been developed and validated (24, 25). A Cochrane review of health literacy-focused interventions in CKD is underway (26). We
recognized that health literacy research in CKD had increased significantly. This study aimed to re-explore the prevalence and socio-demographic associations of limited health literacy among patients with CKD, compare patients with non-dialysis CKD, on dialysis and with a kidney transplant and identify causes of heterogeneity in reported results.

**Materials and Methods**

The review protocol was registered with the international prospective register of systematic reviews.
(http://www.crd.york.ac.uk/PROSPERO; registration number D42016036742).

English-language references from between December 2010 and July 2016 were identified from Medline, Embase, Ovidfulltext (including Psycharticles), Health Management Information Consortium, CINAHL and Psychinfo. The search strategy (see supplementary material) was developed from the 2012 review, from a Cochrane systematic review protocol for health literacy interventions in CKD (26) and from review articles of health literacy measurement tools (24, 27-32). In addition to database searches, reference lists from articles included in this review and from other review articles were hand-searched.

Two reviewers (DT and SF) independently assessed journal articles for inclusion by three criteria:

1. At least 50 adults over 18 with CKD were included (aiming to identify studies with a predominantly quantitative rather than qualitative focus)
2. The study used a validated measure to quantitatively describe health literacy
3. The study reported the prevalence of limited health literacy, or data from which this could be derived.

Full texts of journal articles were reviewed if the first criterion and either of the other two were met. Authors were contacted if required to establish if a study should be included, or to request additional data. Articles which met the inclusion criteria were analyzed along with the five articles included in the 2012 review. In a sensitivity analysis, searches were widened to include unpublished studies available as abstracts from nephrology and health literacy conferences (see Supplementary Material).
Study quality was scored independently by DT and SF, guided by a review of tools for assessing the quality of observational studies (33). Studies were assigned scores for sample size, setting, recruitment methods, and potential for unrecognized confounding of results. Scores were combined to indicate study quality and used to inform grading of studies as ‘low’, ‘moderate’ or ‘high’ quality. However, this scoring acted as a guide only and grading of studies was decided by discussion between the two reviewers.

For each study, the prevalence of limited health literacy, number of unique participants, study methods and demographics of participants were recorded. Meta-analysis was performed with subgroup analysis by CKD treatment stage (Non-dialysis CKD; Dialysis; Transplant) and by health literacy measure. Results were presented as Forest plots, with 95% confidence intervals for each prevalence value and for the pooled prevalence of limited health literacy. I² statistics were calculated to measure the degree of heterogeneity between studies and subgroups. A random-effects model was used because we expected to find significant heterogeneity in the prevalence of limited health literacy based on the results of the 2012 review (9). Univariate meta-regression was performed for continuous variables, which included the proportion of patients with non-white ethnicity and the age of participants (mean or median). If data on treatment stage, age or ethnicity were unavailable, studies were excluded from each analysis.

For studies where more than one validated health literacy measure was used, scores from STOFHLA (Short Test of Functional Health Literacy in Adults) are presented here because of its use as a reference measure to validate health literacy screening tools (24, 25, 34). Analyses were then repeated using scores from other measures to establish if this altered the overall results. Socio-demographic characteristics significantly associated with limited health literacy were summarized, with covariates included in multivariate models, to identify independent associations. Statistical significance within studies was defined by individual study methods. A p-value of <0.05 was selected a priori to define statistical significance for meta-analysis and meta-regression. Analyses were performed using the user-written commands ‘metaprop’ and ‘metareg’ in Stata 12 (StataCorp LP, USA).

**Results**

Figure 1 shows the study selection process, which identified 433 unique studies, 15 of which met the inclusion criteria (24, 25, 35-47), with full agreement between the two reviewers. Table 1 summarises the 15 new studies in
addition to five studies included in the 2012 review (19-22, 48). All 20 studies are included in the following
description and analysis.

Of 20 studies, 13 were cross-sectional surveys, five used baseline data from cohort studies and two used baseline
data from clinical trials. One study presented UK data (45), all others reported from the USA. Study quality was
graded as ‘low’ for 15 studies and ‘moderate’ for five studies (19, 22, 43-45).

In total, 12,324 patients were studied, including 1,327 patients included in the 2012 review. This included 3,529
patients with non-dialysis CKD from seven studies, 5,289 dialysis patients from ten studies, and 2,560 transplant
patients from five studies. Five studies included patients from multiple treatment stages. The prevalence of limited
health literacy by treatment stage was not available for 946 patients from two studies (41, 42), even after
communication with authors. Studies included a median of 198.5 patients (IQR: 128.5 to 260).

One study included live kidney donors (37), and one included recipients of solid organ transplants of different types
(42) in addition to patients with CKD; subgroup information was available from published data. One study (41)
measured health literacy in 46,000 emergency department attendees, including 851 with CKD (41). The authors
provided data on this subgroup by personal communication.

Table 2 summarises the health literacy measures and definitions of limited health literacy used.

One study included all emergency department attendees (41) and one aimed to approach all eligible patients UK-
wide (45). Two studies surveyed patients from clinical trials whose primary objective was unrelated to health literacy
(20, 35). All others recruited from clinical environments without efforts to obtain a sample representative of a target
CKD population. Two studies surveyed CKD patients at transplant assessment clinics (38, 42), while one excluded
patients listed for transplant (20). Three studies reported offering a monetary gift to participants (46-48). At least 11
studies excluded patients with cognitive impairment. One study included patients deemed suitable for an
educational intervention (22). Six studies specified an upper limit for age, ranging from 74 to 80 years (21, 24, 36, 43-
45).

Ethnicity data were unavailable for one study (total 95 patients) (42), and age data for two studies (total 322
patients) (25, 42). From the remaining data, the median proportion of participants of non-white ethnicity was 48%
(IQR: 23 to 64%) and mean or median age ranged from 47 to 72 years. In some US studies, the majority of study participants had Black ethnicity (21, 24, 40). One study excluded patients with Hispanic ethnicity (43). Twelve studies included only English speakers. Three studies included Spanish speakers, and used health literacy measures translated into Spanish (25, 40, 44).

The median prevalence of limited health literacy by study was 23% (IQR: 16 to 33%). The overall pooled prevalence of limited health literacy was 25% (95% CI: 20 to 30%). A high degree of heterogeneity was present between studies ($I^2 = 97.4\%$).

Figure 2 shows a Forest plot of the prevalence of limited health literacy in all 20 studies with subgroup analysis by health literacy measure. Studies using the Newest Vital Sign (NVS) and Single-Item Literacy Screener (SILS) reported significantly different prevalence values, but only one study used each measure (39, 45). These prevalence values contributed to the significant overall heterogeneity in limited health literacy prevalence between studies using different measures ($p<0.001$). However, when studies using REALM (Rapid Estimate of Adult Literacy in Medicine), STOFHLA and B HLS (Brief Health Literacy Screen) were compared alone, no significant between-group heterogeneity was detected ($p=0.8$).

Figure 3 shows sub-group analysis by CKD treatment stage, excluding two studies where subgroup information was unavailable (41, 42). The pooled prevalence of limited health literacy was 25% (95% CI: 16 to 33%) among patients with non-dialysis CKD, 27% (95% CI: 19 to 35%) among dialysis patients, and 14% (95% CI: 7 to 21%) among transplant patients. Overall, there was significant between-group heterogeneity ($p=0.03$), although this appears to be related to the lower prevalence of limited health literacy in transplant patients: when patients with non-dialysis CKD and dialysis patients were compared separately, no significant between-group heterogeneity was present ($p=0.8$).

Univariate meta-regression analysis showed a significant association between the proportion of non-white participants in a study and the prevalence of limited health literacy ($\beta: 0.35$; 95% CI: 0.001 to 0.69; $p=0.044$). This equates to a 3.5% increase in the prevalence of limited health literacy for every 10% increase in the proportion of non-white participants. Average age of study participants was not significantly associated with the prevalence of limited health literacy ($\beta: 1.05$; 95% CI: -0.5 to 2.6; $p=0.4$).
Two studies used multiple health literacy measures, reporting three limited health literacy prevalence values each (24, 25). In the above analyses, results defined by STOFHLA were used for both studies. Repeated analyses using each of nine possible combinations of limited health literacy prevalence values did not lead to a change in the significance of the above results, except for meta-regression by proportion of non-white participants. In four of nine combinations, this association was no longer statistically significant. A further sensitivity analysis included 11 conference abstracts in addition to the 20 published papers included here. Analysis of results from all 31 studies showed a pooled prevalence of limited health literacy of 25%, and no change in the pattern of results as presented above. However, when abstracts were included, the significance of the association between proportion of non-white participants and limited health literacy prevalence increased (p=0.005).

Table 3 summarizes significant associations with limited health literacy and covariates included in multivariate models. A large variety of variables was tested. In ten studies which undertook multivariate analysis, the only demographic factors consistently and independently associated with limited health literacy were ethnicity (20, 22, 35), and markers of lower SES including income (19, 21, 35) and lower educational level (19-22, 37, 45). Independent associations were also reported between limited health literacy and older age (21), male gender (22), lower English fluency (45), individual comorbidities (39, 43) and higher comorbidity score (45).

In patients with non-dialysis CKD, two studies reported independent associations between limited health literacy and lower eGFR (39, 43). Limited health literacy was associated with deceased-donor transplantation (compared to live-donor) and transplantation after dialysis start (compared to pre-emptive) (45). One study reported an independent association between limited health literacy and mortality (22).

Discussion

This systematic review of literature published until mid-2016 demonstrates the significant expansion of health literacy research in CKD. Fifteen studies published since 2012 were identified, and 12,324 patients have now been studied, compared to 1,405 in the 2012 review by Fraser et al (17). Geographical variation of studies remains limited: only one was from outside the USA. The pooled prevalence of limited health literacy in the present analysis was 25%, similar to 23% in the 2012 review. The six new studies of patients with non-dialysis CKD and four new studies of
transplant patients allowed meta-analysis by patient group, confirming the reduced prevalence of limited health literacy among transplant patients, which has been reported in individual studies (45). Four new studies used the BHLS, and comparison with studies using REALM and STOFHLA showed no significant difference in limited health literacy prevalence, increasing the confidence with which results can be compared between studies of CKD patients using these health literacy measures.

The lower prevalence of limited health literacy among kidney transplant patients has several possible explanations. Firstly, limited health literacy may directly impede effective clinician-patient communication, reducing the likelihood of clinically-suitable patients understanding the benefits of transplantation and pursuing it as a treatment option. Because of associations with low SES, limited health literacy has been implicated as a possible mediating factor in reducing access to transplantation. However, mechanisms by which low SES associates with reduced access to transplantation (49) are complex (and in the USA, include reduced access to immunosuppressant drugs (50). The associations of both limited health literacy (45) and SES (51) with increased comorbidity add further complexity: patients with limited health literacy and low SES may in fact be less suitable for transplantation for clinical reasons. These complex associations warrant further investigation.

A higher proportion of individuals with non-white ethnicity was significantly correlated with a higher prevalence of limited health literacy. As 19 out of 20 studies were from the USA, non-white ethnicity represents patients with Black American or Hispanic ethnicity. Non-white ethnicity in the USA has established, complex associations with low SES (52) and poorer health outcomes (53), so this may represent confounding by SES and comorbidity. Although all three studies that reported independent associations between ethnicity and limited health literacy adjusted for SES (20, 22, 35), only one adjusted for comorbidity (as presence or absence of diabetes) (22). Age of study participants did not appear to influence the prevalence of limited health literacy.

Even after adjustment for treatment stage, health literacy measure, age or ethnicity, there was significant residual heterogeneity in the prevalence of limited health literacy between studies. Study methodology had potential to contribute to this heterogeneity. Sample size was mostly small (median 189). The majority of studies recruited patients by convenience in clinical environments, which may result in participation bias. Studies which included only patients who had been referred for transplantation (or excluded those who had been referred) are likely to produce biased estimates of limited health literacy prevalence (20, 47, 48). Patients with cognitive impairment or language
difficulties may demonstrate a reduction in understanding and be falsely classified as having limited health literacy. Many studies excluded those with cognitive impairment for this reason, but some did not, and no associations between cognitive impairment and health literacy were tested. The approach to patients whose first language is not English could also bias results. Some studies excluded non-English-speakers, who would be more likely to have limited health literacy because of its association with non-white ethnicity and lower SES. Others used translated versions of health literacy measures to allow inclusion of non-English speakers. However, non-English versions of health literacy measures have not been validated extensively, and comparison of results between English and non-English versions is problematic because of inherent differences between English-speaking and non-English-speaking populations (54). Other studies used English health literacy measures for all participants, which could result in patients being falsely classified as having low health literacy because of poor understanding related to language.

The different health literacy measures used vary in their method of assessment and in the skills which are assessed. This limits comparability of results between studies. REALM and STOFHLA are direct assessments of pronunciation and reading comprehension, whereas the screening tools BHLS and SILS focus on patient’s perception of their level of understanding. It is reassuring that the BHLS produced similar prevalence estimates to REALM and STOFHLA in our meta-analysis, although health literacy screening tools have been shown in validation studies of CKD and other populations to lack sensitivity and specificity in detecting limited health literacy defined by REALM or STOFHLA (24, 25, 34, 55). Screening tools benefit from short administration times, so are more practical for use in large-scale cohort studies or for screening in clinical practice. The NVS (56) is the only measure used here that assesses poor numeracy: a common characteristic of patients with CKD (57) and other chronic diseases (58) which may impair patients’ ability to dose medications, follow dietary advice and keep appointments (59).

Systematic reviews of health literacy prevalence in other populations report similar findings. A 2005 review of US studies reported a pooled prevalence of 26% ‘low’ health literacy, associated with lower educational level, Black ethnicity and older age (60). A review of health literacy in patients with musculoskeletal diseases found between 7% and 42% low health literacy, associated with lower SES (61).

This review benefits from a comprehensive search strategy using updated search terms. Eligibility criteria were clearly defined. We sought and received valuable communication from many authors, enhancing the quality of the review. A sensitivity analysis, which included data from conference abstracts, identified no major differences in
results. There are several limitations. Firstly, studies were of low or moderate quality because of small sample size, single center samples and non-representative sampling methods. Second, studies using newer measures that measure multiple aspects of health literacy on separate scales (13), but do not define limited health literacy could not be included. Third, most studies used cross-sectional data and the association of limited health literacy with increased mortality (22) could result in survivorship bias and an underestimate of limited health literacy prevalence in cross-sectional studies. Fourth, meta-regression to account for age and ethnicity differences between studies was especially limited by missing data, and multivariate meta-regression was not possible. However, a positive association was still shown between non-white ethnicity and limited health literacy prevalence, despite this lack of power. Fifth, ages of study participants were available as mean or median, limiting the reliability of meta-regression analysis by age. Lastly, one study showed a lower prevalence of limited health literacy among those listed for transplantation compared to incident dialysis patients (45), but this association could not be investigated here because of the absence of consistent data on wait-listing status.

Clinicians should recognize that a quarter or more of CKD patients have reduced health literacy skills. Standard shared decision-making and self-management initiatives may not be suitable (11, 62). Further, those with limited health literacy have an increased burden of disease and treatment due to comorbidity, and may lack social resources required to manage disease because of low SES (7, 8). In the face of these challenges, health literacy-sensitive communication methods, educational tools and decision-aids may be key to improving clinical outcomes and may have a role in reducing inequity in access to transplantation.

The expansion of health literacy research in CKD since the last review is welcome, but further work is required to use this knowledge to promote improved clinical outcomes. All health literacy research will be facilitated by evidence-based consensus on the optimal tools to measure health literacy. Prospective studies are required to examine the impact of limited health literacy on healthcare service use, CKD management and RRT modality choice (including non-dialysis care). Interactions between health literacy and other patient attributes such as capacity (8) and patient activation (63) warrant investigation. Knowledge of the mechanisms by which limited health literacy could impair navigation of the CKD care pathway will inform enhanced communication methods, and modified approaches to shared decision-making and self-management. By improving patients’ understanding, these initiatives would aim to reduce inequity of care and improve the health of the CKD population.
References


34. Chew LD, Bradley KA, Boyko EJ: Brief Questions to Identify Patients With Inadequate Health Literacy. 588-594, 2004


## Disclosures

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<td>Dominic M Taylor</td>
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<td>Simon Fraser</td>
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<td>Clare Bradley</td>
<td>CB received consulting fees (relating to diabetes, unrelated to this work) for one advisory board meeting and some consultancy fees, 2014-2016. She is the majority shareholder in Health Psychology Research Ltd. Her other research (not including this work) is funded by four grants from GSK/ViiV. She receives royalties for the use of her patient-reported outcome measures, none of which are referenced in this manuscript (and none of which relate to health literacy).</td>
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<tr>
<td>Heather Draper</td>
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<table>
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<th>Median age (years) (mean)</th>
<th>Male (%)</th>
<th>CKD stage</th>
<th>Aim</th>
<th>Design</th>
<th>Setting &amp; recruitment method</th>
<th>Participants</th>
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<th>Health literacy measure</th>
<th>Outcome variables tested</th>
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<td>Adeseun (35)</td>
<td>2012</td>
<td>USA</td>
<td>72</td>
<td>[52] 68</td>
<td>Incident Dialysis (HD or PD)</td>
<td>Examine relationship between health literacy and cardiovascular disease risk factors</td>
<td>Cohort (baseline data)</td>
<td>Adults from transplant evaluation clinics taking part in the Dialysis Heart and Bone Study.</td>
<td>100% with limited health literacy were Black, compared to 50% of those with adequate health literacy</td>
<td>Previous coronary revascularization, cardiac devices or weight &gt;350lbs</td>
<td>STOFHLA</td>
<td>BP, lipid profile, waist-to-hip ratio, BMI, Tobacco use</td>
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<td>Boulware (36)</td>
<td>2013</td>
<td>USA</td>
<td>130</td>
<td>60 40</td>
<td>Non-dialysis CKD 3-5</td>
<td>Compare the effectiveness of educational interventions on pre-emptive living donor kidney transplantation</td>
<td>Cohort (baseline data)</td>
<td>Nephrology clinics</td>
<td>46% White 47% Black &lt;1% Hispanic</td>
<td>&lt;18, &gt;70, Non-English speaking, previous transplant, cancer heart failure, severe liver disease, PVD, HIV, unstable coronary artery disease.</td>
<td>REALM</td>
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<td>Brice (25)</td>
<td>2014</td>
<td>USA</td>
<td>227</td>
<td>-</td>
<td>Prevalent HD</td>
<td>Validate TILS and SILS against STOFHLA</td>
<td>Cross-sectional</td>
<td>Adults from 7 HD centers</td>
<td>English (96%) and Spanish speakers (4%)</td>
<td>&lt;18, Unable to speak English or Spanish. 'Mental impairment' defined by dialysis staff. Poor vision.</td>
<td>STOFHLA, TILS and SILS (English or Spanish)</td>
<td>-</td>
<td>45 (STOFHLA 22 [SILS])</td>
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<td>Cavanaugh 1 *(22)</td>
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<td>USA</td>
<td>480</td>
<td>62 56</td>
<td>Incident HD</td>
<td>Measure the prevalence and associations of limited health literacy and risk of all-cause mortality</td>
<td>Cohort</td>
<td>Adults 'eligible for a patient education program' from 77 Dialysis units. Health literacy measured if low literacy was suspected by case manager.</td>
<td>52% White 50% Diabetic</td>
<td>&lt;18; Non-permanent dialysis patients, Known cognitive impairment, Non-English speakers, Nursing-home residents.</td>
<td>REALM</td>
<td>Mortality</td>
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<td>Prevalent HD</td>
<td>Validate BHLS against REALM and STOFHLA</td>
<td>Cross-sectional</td>
<td>Adults from 4 dialysis units</td>
<td>73% Black.</td>
<td>&lt;18. &gt;80. Dialysis initiation &lt;1 month. Non-English speakers. Cognitive impairment</td>
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<td>23 (BHLS 27 [REALM] 8 [STOFHLA])</td>
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<td>255</td>
<td>[48] 64</td>
<td>Incident Transplant</td>
<td>Compare health literacy between live- and deceased-donor kidney transplant recipients and live kidney donors</td>
<td>Retrospective chart review</td>
<td>Transplant recipients and donors at single transplant center surveyed for health literacy preoperatively</td>
<td>65% White LDR (n=103) DDR (n=152)</td>
<td>&lt;18; No recorded answer to BHLS</td>
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<td>Donor type, Education and demographics</td>
<td>12 (LDRs: 9%; DDRs: 14%)</td>
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<td>104</td>
<td>[53] 61</td>
<td>Dialysis (n=14) and non-dialysis CKD (n=90)</td>
<td>Characteristics of attenders vs absentees for kidney transplant evaluation appointments</td>
<td>Cross-sectional</td>
<td>Convenience sample of patients scheduled for initial evaluation for kidney transplant at a single center</td>
<td>46% White</td>
<td>&lt;18, Non-English speakers, cognitive impairment.</td>
<td>BHLS (0-15)</td>
<td>Attendance vs non-attendance 23 (14% dialysis; 24% CKD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devraj [39]</td>
<td>2015</td>
<td>USA</td>
<td>150</td>
<td>45% over 60 47</td>
<td>Non-dialysis CKD1-4</td>
<td>Relationship between health literacy and eGFR</td>
<td>Cross-sectional</td>
<td>Adults attending follow-up nephrology</td>
<td>40% White 41% Hispanic</td>
<td>&lt;21, Non-English speaking, AKI, cognitive impairment defined by medical notes, or if &lt;4 on cognition screening test, Poor visual acuity.</td>
<td>NVS</td>
<td>eGFR (MDRD formula)</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Foster (40)</td>
<td>2011</td>
<td>USA</td>
<td>238</td>
<td>[58] 54</td>
<td>Prevalent Dialysis (HD or PD)</td>
<td>Assess disaster preparedness in dialysis patients</td>
<td>Cross-sectional</td>
<td>Adults approached during dialysis at 6 dialysis units</td>
<td>57% Black 6% Spanish-speaking, 94% English Speaking</td>
<td>&lt;18, unable to understand consent process</td>
<td>STOFHLA (English or Spanish)</td>
<td>Disaster preparedness 49.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gordon* (19)</td>
<td>2011</td>
<td>USA</td>
<td>124</td>
<td>[47] 57</td>
<td>Transplant</td>
<td>Relationship between health literacy, transplant knowledge and graft function</td>
<td>Cross-sectional</td>
<td>Sequential transplant recipients from a single center recruited at post-transplant clinic visit for 30-minute interview.</td>
<td>&lt;18, Non-English-speaking; Visually impaired, Too unwell to participate</td>
<td>STOFHLA and REALM-T</td>
<td>Demographics and graft function 9</td>
<td></td>
<td></td>
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<tr>
<td>Green* (20)</td>
<td>2011</td>
<td>USA</td>
<td>260</td>
<td>64 57</td>
<td>Prevalent HD</td>
<td>Describe prevalence and associations of limited health literacy</td>
<td>Cohort (baseline data)</td>
<td>Patients from 9 dialysis units included in an RCT of strategies for managing pain, sexual dysfunction and depression</td>
<td>40% Black</td>
<td>&lt;18, less than thrice-weekly dialysis, non-English Speakers, Cognitive impairment, considering switch to PD or transplantation</td>
<td>REALM</td>
<td>Demographics, SES, Comorbidity 16</td>
<td></td>
<td></td>
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<tr>
<td>Grubbs* (21)</td>
<td>2009</td>
<td>USA</td>
<td>62</td>
<td>[52] 66</td>
<td>Prevalent HD</td>
<td>Association of poor health literacy with access to transplantation</td>
<td>Cross-sectional</td>
<td>Adults approached during dialysis session in 5 dialysis units.</td>
<td>73% Black</td>
<td>&lt;18, &gt;75, ethnicity other than Black or White, &lt;9 months on dialysis, previous transplant, cognitive impairment</td>
<td>STOFHLA</td>
<td>Referral for transplant evaluation, wait-listing or transplantation 32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McNaughton (41)</td>
<td>2014</td>
<td>USA</td>
<td>851^</td>
<td>55 57</td>
<td>CKD3-5, including dialysis or transplant if eGFR&lt;60ml/min/1.73m²</td>
<td>Relationship between limited health literacy and BP at ED presentation</td>
<td>Cross-sectional</td>
<td>Adults attending ED at a large quaternary hospital screened for health literacy as part of admission nursing assessment.</td>
<td>Study included 31902 patients, of whom 851 (3%) had kidney disease. 60% White</td>
<td>&lt;18, Nursing assessment or health literacy measure not completed, Admitted with pre-eclampsia or alcohol withdrawal.</td>
<td>BHLS (0-15)</td>
<td>BP at hospital presentation (in all ED attenders) 26^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Year</td>
<td>Location</td>
<td>n</td>
<td>Median age (years) [mean]</td>
<td>Male (%)</td>
<td>CKD stage</td>
<td>Aim</td>
<td>Design</td>
<td>Setting &amp; recruitment method</td>
<td>Participants</td>
<td>Exclusion criteria</td>
<td>Health literacy measure</td>
<td>Outcome variables tested</td>
<td>Prevalence of limited health literacy (%)</td>
</tr>
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</tr>
<tr>
<td>Miller-Matero (42)</td>
<td>2015</td>
<td>USA</td>
<td>95</td>
<td>-</td>
<td>-</td>
<td>Referred for transplant (dialysis or advanced CKD)</td>
<td>Evaluate health literacy of patients referred for solid-organ transplantation</td>
<td>Cross-sectional</td>
<td>Patients considered for solid organ transplantation at a single center.</td>
<td>-</td>
<td>-</td>
<td>REALM</td>
<td>Demographics, cognitive impairment, reading ability, numeracy (in all organ transplant recipients)</td>
<td>37.8</td>
</tr>
<tr>
<td>Ricardo (43)</td>
<td>2014</td>
<td>USA</td>
<td>2340</td>
<td>[58]</td>
<td>54</td>
<td>Non-dialysis CKD1-4</td>
<td>Association of limited health literacy with kidney function and CV risk factors</td>
<td>Cross-sectional</td>
<td>Adults with CKD recruited from 7 clinical centers.</td>
<td>52% White 48% Black</td>
<td>&lt;21 or &gt;74 years; Polycystic Kidney Disease; Hispanic Ethnicity</td>
<td>STOFHLA</td>
<td>eGFR (MDRD formula), BP, LDL cholesterol &lt;100mg/dL, HbA1c &lt;7%, self-reported CV disease</td>
<td>16 (Black 28%; White 5%)</td>
</tr>
<tr>
<td>Robinson (44)</td>
<td>2015</td>
<td>USA</td>
<td>170</td>
<td>[50]</td>
<td>59</td>
<td>Prevalent Transplant</td>
<td>Validate a sun-protection education program</td>
<td>RCT (baseline data)</td>
<td>Adults from 2 transplant programs</td>
<td>35% Black; 28% Hispanic; 36% White</td>
<td>&lt;2 or &gt;24 months after transplant; Non-Spanish speakers; &lt;18 or &gt;70; poor vision; ethnicity other than Black, White or Hispanic</td>
<td>STOFHLA (English or Spanish)</td>
<td>-</td>
<td>36 (Black 58%; Hispanic 54%; White 0%)</td>
</tr>
<tr>
<td>Taylor (45)</td>
<td>2015</td>
<td>UK</td>
<td>5520</td>
<td>54</td>
<td>62</td>
<td>Incident Dialysis (HD or PD), Incident Transplant and Transplant wait-listed (Prevalent dialysis- and non-dialysis CKD)</td>
<td>Describe prevalence and associations of limited health literacy</td>
<td>Cohort (baseline data)</td>
<td>Adults approached for notes review and survey from all 71 UK renal units</td>
<td>Representative nationwide sample. 79% White. Non-dialysis CKD patients were all pre-emptively wait-listed for transplant</td>
<td>&lt;18 or &gt;75 years or unable to provide informed consent</td>
<td>SLS</td>
<td>Demographics, SES, Comorbidty</td>
<td>16 (Dialysis 18%; CKD Wait-listed 9%; Incident Transplant 12%)</td>
</tr>
<tr>
<td>Weng (46)</td>
<td>2013</td>
<td>USA</td>
<td>252</td>
<td>[55]</td>
<td>60</td>
<td>Prevalent Transplant</td>
<td>Prevalence and correlates of medication non-adherence</td>
<td>Cross-sectional</td>
<td>Adults approached during a transplant clinic visit at a single center. Offered $15</td>
<td>58% White 27% Black Median 2.9 years post-transplant</td>
<td>&lt;6 months post-transplant, &lt;18, Non-English speakers, Unable to consent. Dual organ transplant.</td>
<td>STOFHLA</td>
<td>Medication non-adherence</td>
<td>2.4</td>
</tr>
<tr>
<td>Study</td>
<td>Year</td>
<td>Location</td>
<td>n</td>
<td>Median age (years)</td>
<td>Male (%)</td>
<td>CKD stage</td>
<td>Aim</td>
<td>Design</td>
<td>Setting &amp; recruitment method</td>
<td>Participants</td>
<td>Exclusion criteria</td>
<td>Health literacy measure</td>
<td>Outcome variables tested</td>
<td>Prevalence of limited health literacy (%)</td>
</tr>
<tr>
<td>---------------------</td>
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<td></td>
</tr>
<tr>
<td>Wright* (48)</td>
<td>2011</td>
<td>USA</td>
<td>401</td>
<td>58</td>
<td>53</td>
<td>Non-dialysis CKD1-5</td>
<td>Measure awareness and knowledge of CKD to develop a CKD knowledge survey</td>
<td>Cross-sectional</td>
<td>Adults attending a follow-up nephrology clinic appointment at a single center. Offered $10</td>
<td>83% White</td>
<td>&lt;18, Non-English speakers, kidney transplant or dialysis, vision or cognitive impairment</td>
<td>REALM</td>
<td>Kidney disease knowledge</td>
<td>18</td>
</tr>
<tr>
<td>Wright-Nunes (47)</td>
<td>2013</td>
<td>USA</td>
<td>154</td>
<td>58</td>
<td>54</td>
<td>Non-dialysis CKD1-5</td>
<td>Assess feasibility and impact of a physician-delivered education tool to increase CKD knowledge</td>
<td>Clinical trial, (baseline data)</td>
<td>Adults at single center asked to complete a survey (written or read aloud). Offered monetary compensation.</td>
<td>77% white, 78% CKD3-5.</td>
<td>&lt;18, Non-English speakers, kidney transplant or dialysis, vision or cognitive impairment</td>
<td>REALM</td>
<td>-</td>
<td>22</td>
</tr>
</tbody>
</table>

Outcome variables are listed only if statistical models included health literacy as an exposure variable. * Studies included in Fraser 2012 review. α Frequencies from personal communication with the authors.

CKD- Chronic Kidney Disease; HL-Health Literacy; HD- Hemodialysis; PD- Peritoneal Dialysis; BP- Blood Pressure; BMI- Body Mass Index; PVD- Peripheral Vascular Disease; LDR-Live-donor recipient; DDR- deceased-donor recipient; AKI- Acute Kidney Injury; MDRD: Modification of Diet in Renal Disease; ED- Emergency Department; LDL- Low density lipoprotein; SES- Socioeconomic status
<table>
<thead>
<tr>
<th>Health literacy measure</th>
<th>Number of studies using measure (%)</th>
<th>Form</th>
<th>Approximate time taken</th>
<th>Health literacy categorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Test of Functional Health Literacy in Adults (STOFHLA)</td>
<td>9 (45)</td>
<td>36 reading comprehension items- select from four choices to replace missing words in text (modified Cloze procedure)</td>
<td>12 minutes</td>
<td>0-22 Limited 23-36: Adequate</td>
</tr>
<tr>
<td>Rapid Estimate of Adult Literacy in Medicine (REALM)</td>
<td>6 (30)</td>
<td>125 health-related words (66 in more commonly used form) tested for pronunciation accuracy</td>
<td>3 minutes</td>
<td>0-44 Inadequate 45-60: Marginal 61-66: Adequate (Limited= Inadequate + marginal)</td>
</tr>
<tr>
<td>REALM-T (Transplant-specific version of REALM)</td>
<td>1 (5)</td>
<td>69 kidney transplant-related terms tested for pronunciation accuracy</td>
<td>3 minutes</td>
<td>Not clearly defined</td>
</tr>
<tr>
<td>Brief Health Literacy Screen (BHLS)</td>
<td>4 (20)</td>
<td>Three questions: How confident are you filling out forms by yourself? How often do you have someone help you read hospital materials? How often do you have problems learning about your medical condition because of difficulty reading hospital materials? All graded 1-5, scores range 3-15 (or 0-12 in one study(64)</td>
<td>&lt;1 minute</td>
<td>3-8 (or 0-5): Lower 9-14 (or 6-12): Moderate/Higher (&lt;10/15 or &lt;6/12 indicates limited health literacy)</td>
</tr>
<tr>
<td>Newest Vital Sign (NVS)</td>
<td>1 (5)</td>
<td>Six-item assessment of reading comprehension from an ice-cream nutrition label</td>
<td>6 minutes maximum (average 2.9 minutes)(56)</td>
<td>0-1: High likelihood marginal/inadequate 2-3: Possible marginal/inadequate 4-6: Adequate (Score &lt;4 indicates limited health literacy(39))</td>
</tr>
<tr>
<td>Single-Item Literacy Screener (SILS)</td>
<td>2 (10)</td>
<td>‘How often do you need to have someone help you when you read instructions, pamphlets or other written material from your doctor or pharmacy’, answered on a 5-point Likert scale from ‘1- Never to ‘5- Always’</td>
<td>&lt;1 minute</td>
<td>&lt;3: Adequate ≥3: Limited</td>
</tr>
<tr>
<td>Two-Item Literacy Screener (TILS)</td>
<td>1 (5) (English or Spanish)</td>
<td>Two questions: What was the last (educational) grade you completed? Can you estimate your reading ability with one of the following: ‘I frequently read complete books’, ‘I read the newspaper’, ‘I occasionally need help with the newspaper’, or ‘I frequently need help with the newspaper’ Scored from -4 to +5</td>
<td>&lt;1 minute</td>
<td>Sensitivity/specificity of different cut-off points was tested. Use of TILS&gt;1 to indicate limited health literacy is suggested.</td>
</tr>
</tbody>
</table>
Table 3: Summary of univariate and multivariate associations with limited health literacy

<table>
<thead>
<tr>
<th>Univariate Associations</th>
<th>Demographics</th>
<th>Socioeconomic</th>
<th>Comorbidity</th>
<th>Biochemistry</th>
<th>Drugs</th>
<th>Dialysis</th>
<th>Transplant</th>
<th>Knowledge/education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old age</td>
<td>Male</td>
<td>Ethnicity</td>
<td>Veteran</td>
<td>Renal unit</td>
<td>Non-Employment</td>
<td>Lower income</td>
<td>Non car ownership</td>
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<tr>
<td>Adenseun</td>
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<td></td>
</tr>
<tr>
<td>Cavanaugh</td>
<td>*†</td>
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<tr>
<td>Dageforde</td>
<td>1</td>
<td></td>
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<tr>
<td>Devraj</td>
<td>* ‡</td>
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<td>Gordon</td>
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<td>Green</td>
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<tr>
<td>Grubbs</td>
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</tr>
<tr>
<td>Ricardo</td>
<td>* †</td>
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<tr>
<td>Taylor</td>
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</tr>
<tr>
<td>Wright</td>
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</table>

<table>
<thead>
<tr>
<th>Multivariate Associations</th>
<th>Study</th>
<th>Model</th>
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<tr>
<td>Adeseun</td>
<td>1</td>
<td></td>
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<td></td>
<td>2</td>
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<tr>
<td>Cavanaugh</td>
<td>1</td>
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<td>2</td>
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<tr>
<td>Dageforde</td>
<td>1</td>
<td></td>
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<td>2</td>
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<tr>
<td>Devraj</td>
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<tr>
<td>Green</td>
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<tr>
<td>Grubbs</td>
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<tr>
<td>Ricardo</td>
<td>1</td>
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<td>2</td>
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</tr>
<tr>
<td>Taylor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wright</td>
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</tr>
</tbody>
</table>

Markers indicate statistically significant associations with limited health literacy. Shaded boxes indicate covariates included in multivariate models. * African-American, † Non-white; ‡ Hispanic § South Asian, Chinese.
Figure legends

Figure 1: Study selection process.

CKD: Chronic Kidney Disease; HL: Health literacy.

Identification

524 abstracts identified from database searches (2011-present) -> 91 duplicates removed

Screening

433 abstracts screened -> 397 abstracts excluded (Included <50 people with CKD)

Eligibility

36 full text articles reviewed

15 articles met all three inclusion criteria

5 articles from the 2012 review included

Inclusion

20 articles included

21 articles excluded (No validated HL measure or prevalence value available)
Figure 2: Forest plot showing the pooled prevalence of limited health literacy, grouped by the health literacy measure used. Dashed reference line indicates pooled prevalence value.

HL: Health literacy; CI: Confidence Interval; CKD: Chronic Kidney disease; BHLS: Brief Health Literacy Screener; REALM: Rapid Evaluation of Adult Literacy in Medicine; SILS: Single-Item Literacy Screener; STOFHLA: Short Test of Functional Health Literacy in Adults.

### Prevalence of Limited Health Literacy (%)

<table>
<thead>
<tr>
<th>Study</th>
<th>Treatment</th>
<th>n</th>
<th>Prevalence of Limited HL % (95% CI)</th>
<th>Weight</th>
</tr>
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<tbody>
<tr>
<td>REALM</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Green</td>
<td>Dialysis</td>
<td>260</td>
<td>15.8 (11.8, 20.7)</td>
<td>5.22</td>
</tr>
<tr>
<td>Wright</td>
<td>Non-dialysis CKD</td>
<td>401</td>
<td>17.7 (14.3, 21.7)</td>
<td>5.29</td>
</tr>
<tr>
<td>Wright-Nunes</td>
<td>Non-dialysis CKD</td>
<td>154</td>
<td>22.1 (16.3, 29.3)</td>
<td>4.94</td>
</tr>
<tr>
<td>Boulware</td>
<td>Non-dialysis CKD</td>
<td>130</td>
<td>24.6 (18.0, 32.7)</td>
<td>4.81</td>
</tr>
<tr>
<td>Cavanaugh 1</td>
<td>Dialysis</td>
<td>480</td>
<td>32.1 (28.1, 36.4)</td>
<td>5.25</td>
</tr>
<tr>
<td>Miller-Matero</td>
<td>Non-dialysis CKD and Dialysis</td>
<td>95</td>
<td>37.9 (28.8, 47.9)</td>
<td>4.41</td>
</tr>
<tr>
<td></td>
<td>Subtotal (I^2 = 89.0%, p&lt;0.001)</td>
<td></td>
<td>24.5 (17.9, 31.1)</td>
<td>29.91</td>
</tr>
<tr>
<td>STOFHLA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weng</td>
<td>Transplant</td>
<td>252</td>
<td>2.4 (1.1, 5.1)</td>
<td>5.43</td>
</tr>
<tr>
<td>Cavanaugh 2</td>
<td>Dialysis</td>
<td>143</td>
<td>8.4 (4.9, 14.1)</td>
<td>5.21</td>
</tr>
<tr>
<td>Gordon</td>
<td>Transplant</td>
<td>124</td>
<td>8.9 (5.0, 15.2)</td>
<td>5.15</td>
</tr>
<tr>
<td>Ricardo</td>
<td>Non-dialysis CKD</td>
<td>2340</td>
<td>16.3 (14.8, 17.8)</td>
<td>5.45</td>
</tr>
<tr>
<td>Adeseun</td>
<td>Dialysis</td>
<td>72</td>
<td>20.8 (13.1, 31.6)</td>
<td>4.47</td>
</tr>
<tr>
<td>Grubbs</td>
<td>Dialysis</td>
<td>62</td>
<td>32.3 (22.0, 44.6)</td>
<td>4.07</td>
</tr>
<tr>
<td>Robinson</td>
<td>Transplant</td>
<td>170</td>
<td>35.9 (29.1, 43.3)</td>
<td>4.84</td>
</tr>
<tr>
<td>Brice</td>
<td>Dialysis</td>
<td>227</td>
<td>45.4 (39.0, 51.9)</td>
<td>4.96</td>
</tr>
<tr>
<td>Foster</td>
<td>Dialysis</td>
<td>238</td>
<td>49.6 (43.3, 55.9)</td>
<td>4.97</td>
</tr>
<tr>
<td></td>
<td>Subtotal (I^2 = 98.1%, p&lt;0.001)</td>
<td></td>
<td>24.1 (15.0, 33.2)</td>
<td>44.54</td>
</tr>
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<td>BHLS</td>
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<td></td>
</tr>
<tr>
<td>Dageforde 1</td>
<td>Transplant</td>
<td>255</td>
<td>11.8 (8.4, 16.3)</td>
<td>5.27</td>
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<tr>
<td>Dageforde 2</td>
<td>Non-dialysis CKD and Dialysis</td>
<td>104</td>
<td>23.1 (16.0, 32.0)</td>
<td>4.69</td>
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<tr>
<td>McNaughton</td>
<td>All</td>
<td>851</td>
<td>28.3 (23.5, 32.9)</td>
<td>5.36</td>
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<tr>
<td></td>
<td>Subtotal (I^2 = 94.0%, p&lt;0.001)</td>
<td></td>
<td>20.3 (9.8, 30.8)</td>
<td>15.32</td>
</tr>
<tr>
<td>NVS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devraj</td>
<td>Non-dialysis CKD</td>
<td>150</td>
<td>63.3 (55.4, 70.6)</td>
<td>4.76</td>
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<tr>
<td>SILS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor</td>
<td>All</td>
<td>5520</td>
<td>16.3 (15.4, 17.3)</td>
<td>5.47</td>
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</tbody>
</table>

Heterogeneity between groups: p<0.001
Overall (I^2 = 97.4%, p<0.001) 25.0 (20.4, 29.6) 100.00
Figure 3: Forest plot showing the pooled prevalence of limited health literacy, grouped by CKD treatment stage. Two studies where treatment stage was not defined are not shown.

HL: Health literacy; CI: Confidence Interval.

<table>
<thead>
<tr>
<th>Study</th>
<th>HL measure</th>
<th>n</th>
<th>Prevalence of Limited HL % (95% CI)</th>
<th>Weight</th>
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<tr>
<td><strong>Non-dialysis CKD</strong></td>
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<td>Taylor (non-dialysis CKD)</td>
<td>SILS</td>
<td>264</td>
<td>8.7 (5.9, 12.7)</td>
<td>15.03</td>
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<tr>
<td>Ricardo</td>
<td>STOFHLA</td>
<td>2340</td>
<td>16.3 (14.8, 17.8)</td>
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<tr>
<td>Wright</td>
<td>REALM</td>
<td>401</td>
<td>17.7 (14.3, 21.7)</td>
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<td>Wright-Nunes</td>
<td>REALM</td>
<td>154</td>
<td>22.1 (16.3, 29.3)</td>
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<td>Dageforde 2 (non-dialysis CKD)</td>
<td>BHLS</td>
<td>90</td>
<td>24.4 (16.7, 34.2)</td>
<td>13.16</td>
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<tr>
<td>Boulware</td>
<td>REALM</td>
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<td>24.6 (18.0, 32.7)</td>
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<tr>
<td>Devraj</td>
<td>NVS</td>
<td>150</td>
<td>63.3 (55.4, 70.6)</td>
<td>13.65</td>
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<td><strong>Subtotal (I^2 = 96.5%, p&lt;0.001)</strong></td>
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<td><strong>Dialysis</strong></td>
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<tr>
<td>Cavanaugh 2</td>
<td>STOFHLA</td>
<td>143</td>
<td>8.4 (4.9, 14.1)</td>
<td>12.01</td>
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<tr>
<td>Dageforde 2 (Dialysis)</td>
<td>BHLS</td>
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<td>14.3 (4.0, 39.8)</td>
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<td>Green</td>
<td>REALM</td>
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<td>15.8 (11.8, 20.7)</td>
<td>12.04</td>
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<td>Taylor (Dialysis)</td>
<td>SILS</td>
<td>3497</td>
<td>18.9 (17.7, 20.3)</td>
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<tr>
<td>Adeseun</td>
<td>STOFHLA</td>
<td>72</td>
<td>20.8 (13.1, 31.6)</td>
<td>10.70</td>
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<tr>
<td>Cavanaugh 1</td>
<td>REALM</td>
<td>480</td>
<td>32.1 (28.1, 36.4)</td>
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<tr>
<td>Grubbs</td>
<td>STOFHLA</td>
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<td>32.3 (22.0, 44.6)</td>
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<tr>
<td>Brice</td>
<td>STOFHLA</td>
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<td>45.4 (39.0, 51.9)</td>
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<tr>
<td>Foster</td>
<td>STOFHLA</td>
<td>238</td>
<td>49.6 (43.5, 55.9)</td>
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<td><strong>Subtotal (I^2 = 96.2%, p&lt;0.001)</strong></td>
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<tr>
<td><strong>Transplant</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Weng</td>
<td>STOFHLA</td>
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<td>2.4 (1.1, 5.1)</td>
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<tr>
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<td>BHLS</td>
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<td>11.8 (8.4, 16.3)</td>
<td>20.16</td>
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<tr>
<td>Taylor (Transplant)</td>
<td>SILS</td>
<td>1759</td>
<td>12.3 (10.8, 13.9)</td>
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<td>Robinson</td>
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<td>35.9 (29.1, 43.3)</td>
<td>17.80</td>
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<tr>
<td><strong>Subtotal (I^2 = 96.7%, p&lt;0.001)</strong></td>
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</table>
Supplementary Material

Search terms

The search terms used in electronic database searches are shown in Figure S1.

Sensitivity analysis: inclusion of conference abstracts

In a sensitivity analysis, searches were widened to include conference abstracts. Abstracts from the American Transplant Congress, World Transplantation Congress, International Congress of the Transplantation Society, National Kidney Federation, Australia and New Zealand Society of Nephrology and American Society of Transplant Surgeons were identified by the original database searches. Abstracts archives 2011-2016 from the UK Renal Association, European Renal Association/European Dialysis and Transplant Association, International Society of Nephrology and American Society of Nephrology were searched separately for the terms ‘health liter*’ and ‘literacy’. The UK Health Literacy Network (32) and Health Literacy Research Conferences (33) 2011-2016 were searched for CKD-related terms.

Sixty conference abstracts were identified by these searches. These included 14 studies of more than 50 patients with CKD. Eleven of these used a validated health literacy measure and provided a prevalence value for limited health literacy, so were included in this sensitivity analysis and summarised in Table S1.

Conference abstracts were analysed along with the 20 studies included in the primary analysis. Of 31 studies, 19 were cross-sectional surveys, eight used baseline data from cohort studies, three used baseline data from clinical trials and one was a review of patient notes where health literacy was measured during routine care. One study presented UK data, one from multiple countries (see Table S1 caption), one from New Zealand and 28 from the USA. Study quality was low for 24 studies and moderate for seven studies.

In total, 25,532 patients were studied, including 1,405 patients included in the 2012 review. This included 4,903 patients with non-dialysis CKD from 13 studies, 17,125 dialysis patients from 15 studies, and 2,560 transplant patients from 5 studies. Five studies included patients from multiple treatment stages. Limited health literacy prevalence by treatment stage was not available for 946 patients from two studies, (1, 2) (47, 48) even after communication with authors. Studies included a median of 170 patients (IQR: 107-330.5).
The median prevalence of limited health literacy by study was 23% (IQR: 16-35%). The overall pooled prevalence of limited health literacy was 25.2% (95% CI: 21.7-28.6%). A high degree of heterogeneity was present between studies ($I^2 = 97.5\%$). Pooled prevalence of limited health literacy was 25.1% (95% CI: 19.0-31.3) among patients with non-dialysis CKD, 24.9% (95% CI: 20.5-29.2) among dialysis patients, and 13.6% (95% CI: 6.5-20.6) among transplant patients. Overall, there was significant between-group heterogeneity ($p=0.02$), although this appears to be related to the lower prevalence of limited health literacy in transplant patients: when patients with non-dialysis CKD and dialysis patients were compared separately, no significant between-group heterogeneity was present ($p=0.95$).

Univariate meta-regression analysis by proportion of non-White patients and mean or median patient age showed that higher proportion of non-White participants was associated with higher limited health literacy prevalence ($\beta: 0.31; 95\% \text{ CI: } 0.1-0.5; p=0.005$), although significant residual between-study heterogeneity was present. Age of study participants was not significantly associated with the prevalence of limited health literacy ($\beta: 0.38; 95\% \text{ CI: } -0.6-1.4; p=0.4$).
References


Search Strategy for Medline, Embase and Ovid fulltext (including Psycharticles) [via Ovid SP]

1. (Health adj3 litera*).tw.
2. (literacy or literate).tw.
3. HL.tw
4. Health Education/
5. Consumer Health Information/
6. educational status/
7. Patient Education as Topic/
8. Health Knowledge, Attitudes, Practice/
9. comprehension/
11. or/3-10
12. and/2,11
13. numeracy.tw.
17. Slosson oral reading test.tw.
20. (medical terminology and achievement).tw.
22. adult basic education test.tw.
25. Health literacy Screening Question Methodologies.tw.
28. Medical Term Recognition Test.tw.
29. Short Literacy Survey.tw.
30. Brief Health literacy Screen.tw.
31. or/14-30
32. (SORT and read).tw.
33. (REALM and read).tw.
34. [MART and read].tw.
35. TOFHLA.tw.
36. STOFHLA.tw.
37. WRAT.tw.
38. PIAT.tw.
39. NART.tw.
40. AMNART.tw.
41. NVS.tw.
42. SAHLSA.tw.
43. HLSQM.tw.
44. SLS.tw.
45. HLSI.tw.
46. HLSI-SF.tw.
47. METER.tw.
48. SAHL-S&E.tw.
49. SLS.tw.
50. BHLS.tw.
51. or/32-50
52. and/2,51
53. 1 or 12 or 13 or 31 or 52
54. Kidney diseases/
55. exp Renal replacement therapy/
56. renal insufficiency/
57. exp renal insufficiency, chronic/
58. renal replacement therapy/
59. dialysis.tw.
60. (hemodialysis or haemodialysis).tw.
61. (hemofiltration or haemofiltration).tw.
62. (hemodiafiltration or haemodiafiltration).tw.
63. peritoneal dialysis/
64. (peritoneal and dialysis).tw.
65. (kidney disease* or renal disease* or kidney failure or renal failure).tw.
66. [ESRF or ESRF or ESRD or ESKD].tw.
67. [CKF or Ckd or CRF or CRD].tw.
68. (CAPD or CCPD or APD).tw.
69. [predialysis or pre-dialysis].tw.
70. Kidney transplantation/
71. (renal transplant* or kidney transplant*).tw.
72. or/54-71
73. and/53,72
Search Strategy for Health Management Information Consortium, Cinahl, Psychinfo [via NICE Healthcare databases]

1. (Health adj3 litera*).tw
2. (literacy OR literate).tw
3. HL.tw
4. HEALTH EDUCATION/
5. CONSUMER HEALTH INFORMATION/
6. EDUCATIONAL STATUS/
7. PATIENT EDUCATION/
8. ATTITUDES/ OR KNOWLEDGE/
9. COMPREHENSION/
10. Patient AND Education.tw
11. 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10
12. 2 AND 11
13. numeracy.tw
14. Wide AND Range AND Achievement AND Test.tw
15. Rapid AND Estimate AND of AND Adult AND Literacy AND in AND Medicine.tw
16. Peabody AND Individual AND Achievement AND Test.tw
17. Slosson AND oral AND reading AND test.tw
18. National AND Adult AND Reading AND Test.tw
19. (Woodcock-Johnson AND test).tw
20. (medical AND terminology AND achievement).tw
21. literacy AND assessment AND for AND diabetes.tw
22. adult AND basic AND education AND test.tw
23. Newest AND Vital AND Sign.tw
24. Short AND Assessment AND of AND Health AND Literacy.tw
25. Health AND literacy AND Screening AND Question AND Methodologies.tw
26. Single-Item AND Literacy AND Screening.tw
27. Health AND Literacy AND Skills AND Instrument.tw
28. Medical AND Term AND Recognition AND Test.tw
29. Short AND Literacy AND Survey.tw
30. Brief AND Health AND Literacy AND Screen.tw
31. 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30
32. (SORT AND read).tw
33. (REALM AND read).tw
34. (MART AND read).tw
35. TOFHLA.tw
36. STOFHLA.tw
37. WRAT.tw
38. PIAT.tw
39. NART.tw
40. AMNART.tw
41. NVS.tw
42. SAHLSA.tw
43. HLSQM.tw
44. SILS.tw
45. HLSI.tw
46. HLSI-SF.tw
47. METER.tw
48. SAHL-SandE.tw
49. SLS.tw
50. BHLS.tw
51. 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38 OR 39 OR 40 OR 41 OR 42 OR 43 OR 44 OR 45 OR 46 OR 47 OR 48 OR 49 OR 50
52. 2 AND 51
53. 1 OR 12 OR 13 OR 31 OR 52
54. KIDNEY DISEASES/
55. (renal replacement therapy).af
56. dialysis.tw
57. (hemodialysis OR haemodialysis).tw
58. (hemofiltration OR haemofiltration).tw
59. (hemodiafiltration OR haemodiafiltration).tw
60. PERITONEAL DIALYSIS/
61. (peritoneal AND dialysis).tw
62. (kidney AND disease* OR renal AND disease* OR kidney AND failure OR renal AND failure).tw
63. (ESRF OR ESRF OR ESRD OR ESKD).tw
64. (CKF OR CKD OR CRF OR CRD).tw
65. (CAPD OR CCPD OR APD).tw
66. (predialysis OR pre-dialysis).tw
67. KIDNEY TRANSPLANTS/
68. (renal AND transplant* OR kidney AND transplant*).tw
69. exp KIDNEY DISEASES/
70. exp RENAL SERVICES/ OR exp KIDNEY DISEASES/ OR exp KIDNEY TRANSPLANTS/ OR exp HYPOGLYCEMIA/
71. 54 OR 55 OR 56 OR 57 OR 58 OR 59 OR 60 OR 61 OR 62 OR 63 OR 64 OR 65 OR 66 OR 67 OR 68 OR 69 OR 70
72. 53 AND 71

Figure S1: Search terms used for electronic databases.
Table S1: Characteristics of conference abstracts meeting the inclusion criteria.

Outcome variables are listed only if statistical models included health literacy as an exposure variable. * Studies included in Fraser 2012 review. α Frequencies from personal communication with the authors β Australia, New Zealand, Canada, UK, USA, Belgium, France, Countries of the former Gulf Cooperation Council', Germany, Italy, Japan, Russia, Spain, Sweden, and Turkey.

CKD: Chronic Kidney Disease; HD: Haemodialysis; PD: Peritoneal Dialysis; CV: Cardiovascular; CVD: Cardiovascular disease; BP: Blood Pressure; BMI: Body Mass Index; MAP: Mean Arterial Pressure; DBP: Diastolic Blood Pressure; PVD: Peripheral Vascular Disease; LDR-Live-donor recipient; DDR- deceased-donor recipient; AKI- Acute Kidney Injury; MDRD: Modification of Diet in Renal Disease; CPR: Cardiopulmonary resuscitation; ED- Emergency Department; LDL- Low density lipoprotein; SES- Socioeconomic status.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>n</th>
<th>Median age (years)</th>
<th>Male (%)</th>
<th>CKD stage</th>
<th>Aim</th>
<th>Design</th>
<th>Setting &amp; recruitment method</th>
<th>Participants</th>
<th>Exclusion criteria</th>
<th>Health literacy measure</th>
<th>Outcome variables tested</th>
<th>Limited health literacy prevalence (%)</th>
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<tbody>
<tr>
<td>Blandon (3)(37)</td>
<td>2011</td>
<td>USA</td>
<td>225</td>
<td>-</td>
<td>49</td>
<td>Non-dialysis CKD 2-4</td>
<td>Health literacy and BP control in Hispanic Americans</td>
<td>Cross-sectional</td>
<td>Adults from nephrology outpatients clinic</td>
<td>91% Hispanic 73% low income 61% diabetic</td>
<td>None stated</td>
<td>STOFHLA (English /Spanish)</td>
<td>BP control</td>
<td>46</td>
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<tr>
<td>Cavanaugh 3* (4)</td>
<td>2010</td>
<td>USA</td>
<td>50</td>
<td>51</td>
<td>48</td>
<td>Prevalent HD</td>
<td>Association of health literacy and type of dialysis access used</td>
<td>Cross-sectional</td>
<td>Adults from a single dialysis unit</td>
<td>74% Black 33% dialysis catheter</td>
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<td>REALM</td>
<td>Mortality</td>
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<td>2015</td>
<td>Multiple countries</td>
<td>11476</td>
<td>-</td>
<td>-</td>
<td>Prevalent HD</td>
<td>Assess International variation in health literacy and association with mortality</td>
<td>Cohort</td>
<td>International sample from the DOPPS4 and DOPPS5 cohorts- randomly selected patients from dialysis units in participating countries</td>
<td>-</td>
<td>BHLS (0-12)</td>
<td>Mortality</td>
<td>25</td>
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<td>Eneanya (6)(43)</td>
<td>2015</td>
<td>USA</td>
<td>152</td>
<td>68</td>
<td>60</td>
<td>Non-dialysis CKD 4-5</td>
<td>Investigate health literacy as a mediator of racial disparities in CPR knowledge</td>
<td>Cross-sectional</td>
<td>Adults at a single center</td>
<td>56% White 44% Black</td>
<td>&lt;45, Non-English-speaking, Ethnicity other than Black or White, Listed for transplant, Dementia</td>
<td>REALM</td>
<td>CPR Knowledge</td>
<td>Black 62%; White 14%</td>
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<td>Jang (7)(45)</td>
<td>2014</td>
<td>USA</td>
<td>110</td>
<td>&gt;65 (exact figure not known)</td>
<td>58</td>
<td>Prevalent HD</td>
<td>Compare medication label understanding to REALM-SF</td>
<td>Cross-sectional</td>
<td>Adults from 3 dialysis centers</td>
<td>83% White, 11% hadn’t completed high school</td>
<td>&lt;18, Non-English speaking, ‘unable to reasonably manage medications’</td>
<td>REALM-SF</td>
<td>Medication label understanding</td>
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<td>Marshall (8)(46)</td>
<td>2015</td>
<td>NZ</td>
<td>99 *</td>
<td>56</td>
<td>63</td>
<td>Prevalent dialysis (PD and HD)</td>
<td>Validate BHLS in multi-ethnic NZ population</td>
<td>Cohort (baseline data)</td>
<td>Random sample from single dialysis center, stratified to include equal groups by ethnicity (NZ Māori/Pacific Peoples/Other) and 35% NZ Māori; 35% Pacific Peoples; 30% White or other</td>
<td>&lt;17. Logistic or safety risk to interviewers, severe mental illness, severe communication difficulty, unable to give informed consent</td>
<td>BHLS</td>
<td>-</td>
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<tr>
<td>Study</td>
<td>Year</td>
<td>Location</td>
<td>n</td>
<td>Median age (years) [mean]</td>
<td>Male (%)</td>
<td>CKD stage</td>
<td>Aim</td>
<td>Design</td>
<td>Setting &amp; recruitment method</td>
<td>Participants</td>
<td>Exclusion criteria</td>
<td>Health literacy measure</td>
<td>Outcome variables tested</td>
<td>Limited health literacy prevalence (%)</td>
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<td>Nelson (9)[49]</td>
<td>2015</td>
<td>USA</td>
<td>208</td>
<td>[72]</td>
<td>56</td>
<td>Non-dialysis CKD 3b-5</td>
<td>Relationship between health literacy, medicines management capacity and treatment adherence</td>
<td>Cross-sectional</td>
<td>Adults under regular nephrology care in a single unit</td>
<td>-</td>
<td>REALM</td>
<td>Medicines management capacity and self-reported medication adherence</td>
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<td>Puher (10)[50]</td>
<td>2014</td>
<td>USA</td>
<td>512</td>
<td>[66]</td>
<td>50</td>
<td>Non-dialysis CKD 3-5</td>
<td>Assess relationship between health literacy and patient understanding</td>
<td>Cross-sectional</td>
<td>Nephrology outpatients surveyed on understanding of kidney tests via an online portal</td>
<td>97% White</td>
<td>-</td>
<td>&lt;2 clinic attendances. Patients who don’t use online portal.</td>
<td>BHLS (0-15)</td>
<td>Self-reported understanding of test results</td>
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<tr>
<td>Singh (11)[53]</td>
<td>2012</td>
<td>USA</td>
<td>101</td>
<td>-</td>
<td>49</td>
<td>Prevalent HD</td>
<td>Association of health literacy with dialysis quality measures</td>
<td>Cross-sectional</td>
<td>Adults in a single dialysis center</td>
<td>-</td>
<td>None stated</td>
<td>STOFHLA</td>
<td>Lab values, infections, hospitalization, dialysis access</td>
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<td>Singla (12)[54]</td>
<td>2016</td>
<td>USA</td>
<td>74</td>
<td>[58]</td>
<td>57</td>
<td>Non-dialysis CKD 3-4</td>
<td>Identify prevalence and associations of low health literacy</td>
<td>Cohort</td>
<td>Participants already recruited to a clinical trial.</td>
<td>38% Black; 8% White; 48% Hispanic</td>
<td>None stated</td>
<td>REALM</td>
<td>Demographics, hospitalization, dialysis initiation at 2 years</td>
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<td>Weng 2 (13)</td>
<td>2014</td>
<td>USA</td>
<td>499</td>
<td>[54]</td>
<td>65</td>
<td>Non-dialysis CKD (n=203) and Prevalent dialysis (n=296)</td>
<td>RCT of an educational intervention to increase knowledge of live donor kidney transplantation</td>
<td>Clinical trial (baseline data)</td>
<td>Single transplant center.</td>
<td>Potential transplant candidates referred for evaluation</td>
<td>None stated</td>
<td>NVS</td>
<td>-</td>
<td>(Non-dialysis CKD 5%; Dialysis 11%)</td>
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