The Impact of Clinical Decision Support on Health Disparities and the Digital Divide

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Summary

Objectives: This literature review summarizes relevant studies from the last three years (2020-2022) related to clinical decision support (CDS) and CDS impact on health disparities and the digital divide. This survey identifies current trends and synthesizes evidence-based recommendations and considerations for future development and implementation of CDS tools.

Methods: We conducted a search in PubMed for literature published between 2020 and 2022. Our search strategy was constructed as a combination of the MEDLINE®/PubMed® Health Disparities and Minority Health Search Strategy and relevant CDS MeSH terms and phrases. We then extracted relevant data from the studies, including priority population when applicable, domain of influence on the disparity being addressed, and the type of CDS being used. We also made note of when a study discussed the digital divide in some capacity and organized the comments into general themes through group discussion.

Results: Our search yielded 520 studies, with 45 included at the conclusion of screening. The most frequent CDS type in this review was point-of-care alerts/reminders (33.3%). Health Care System was the most frequent domain of influence (71.1%), and Blacks/African Americans were the most frequently included priority population (42.2%). Throughout the literature, we found four general themes related to the technology divide: inaccessibility of technology, access to care, trust of technology, and technology literacy.

Conclusions: This survey revealed the diversity of CDS being used to address health disparities and several barriers which may make CDS less effective or potentially harmful to certain populations. Regular examinations of literature that feature CDS and address health disparities can help to reveal new strategies and patterns for improving healthcare.

Keywords

Data sharing, federated learning, encryption, common data models, cancer

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1 Introduction

Population differences in physical health, mental health, and life expectancy are well-documented [1-4]. These disparities are a result of several factors, including prejudice against racial, ethnic, and sexual minorities, socioeconomic disadvantages, disability, and others [5]. Several groups have prioritized work to narrow the gaps created by these disparities, including government and professional agencies. Since 2011, the Centers for Disease Control and Prevention (CDC) has regularly released reports and strategies that highlight effective public health programs which have reduced disparities [6]. The US National Institutes of Health (NIH) also supports these efforts throughout all of its agencies, especially through the aptly named National Institute on Minority Health and Health Disparities (NIMHD), which provided over $390,000,000 in 2021 to support research on this topic. One approach to address health disparities utilizes technology, such as clinical decision support (CDS). Many organizations and researchers recognize the need for CDS to be equitable and designed to ameliorate disparities, such as the Agency for Healthcare Research and Quality (AHRQ) [7]. While such calls for CDS design considerations are made, it is not entirely clear to what quantity CDS is engaged in improving health disparities, and what opportunities exist to improve our current-state CDS systems. As we are unaware of any such studies, we found an opportunity to explore the intersection between CDS and health disparities within the literature and quantify some of effort and existing opportunities to improve healthcare and patient engagement in these areas.

1.1 Clinical Decision Support (CDS)

Whether clinician-facing or patient-facing, CDS provides support to help the end-user make informed decisions, at the appropriate time, to enhance health and healthcare [8]. CDS is implemented in many formats, including electronic health record (EHR)-based tools, mobile apps, and web-based applications. As technology has become

ubiquitous in both healthcare and everyday life, delivering interventions via CDS is becoming increasingly viable and could be used as a tool to help reduce disparities. CDS, however, is not without challenges. If not implemented properly, it is possible that CDS could heighten disparities [9].

1.2 Digital Divide

In addition to the health disparities outlined by the NIMHD and others (such as socioeconomic status, race/ethnicity, disability, etc.), access to information and technology is an important part of quality health care, creating a "digital divide" [10-12]. As our health care system creates a greater reliance on digital tools [13], differences in health outcomes can be seen between those with access to tools and the skills and knowledge on how to use them, and those without such access. This digital divide could exist on the patient level given the framework described above (i.e., individual barrier in accessing technology), or even on an institutional level (i.e., resources of the healthcare system) where organizations have differing access to health information technology (HealthIT) resources, informatics, and even CDS, all of which could affect health care quality and outcomes. While the digital divide is not a new concept, it was particularly exacerbated during the recent COVID-19 pandemic where health care was quickly transitioned to a more virtual and online format with telehealth visits [14-16].

1.3 The Intersection of Health Disparities, CDS, and the Digital Divide

While CDS may help to improve health disparities, those who are impacted by the digital divide could miss these benefits, possibly deepening disparities among those individuals. It is important to highlight where CDS may be improved in this aspect, and to gain a better understanding on how we may simultaneously implement CDS while widening its accessibility to patients. For this reason, it is imperative that we regularly assess CDS implemented to address health disparities and disseminate considerations and strategies which may improve efficacy of future tools.

2 Methods

We carried out a rapid review of publications from the past three years (2020 to 2022) related to CDS and their impact on health disparities and the digital divide to identify current trends and synthesize evidence-based recommendations or considerations for any CDS project.

To find relevant literature, we conducted a search in PubMed for studies published in the past three years (2020-2022).

2.1 Search Strategy

We developed our search strategy by first using existing published strategies. To identify publications about CDS, we adopted the strategy developed by Bright *et al.* [17], then expanded to include additional search terms identified through more recent reviews [18, 19], such as "best practice advisory." We then limited the publications using the MEDLINE®/PubMed® Health Disparities and Minority Health Search Strategy [20] and search terms for digital divide. Our final search strategy is included as a supplemental material.

2.2 Inclusion Criteria

We included studies that met the following two criteria:

1) *Describes a CDS tool*. Our definition of CDS follows the findings of Bright *et al.*[17], which includes tools that support health care process measures, clinical outcomes, and measured costs. CDS tools were required to be implemented, which included pilot and prototype testing. We also required that the authors report some degree of formal evaluation, which could include outcome measurement or usability testing.
2) *Targeted to reduce health disparities*. We required that included articles address at least one health disparity either in the purpose of the CDS or in their analysis. To operationalize the definition of disparity, we used the five domains of influence described by the NIMHD Research framework [21], which included:
   a. Biological: Physiological indicators (age, race, sex, sexual orientation, co-morbidities, inflammation, cardiovascular system), genetic stability (epigenetic alterations), and cellular function and communication;
   b. Behavioral: Coping factors (active coping, problem solving, stress management), psychosocial risk/resilience (social support, pessimism/optimism, control), and health behaviors (smoking, alcohol/drug use, nutrition, physical activity);
   c. Physical/Built Environment: Geographical and political factors (location, structural bias, segregation, crime, urban/rural, toxins/exposures), socioeconomic factors (education, income/wealth, occupation), and health care factors (access to healthcare, insurance, literacy, numeracy);
   d. Sociocultural Environment: Cultural factors (traditions, religion, prejudice), social factors (various forms of stress, mobility, and social network), and psychological factors (stigma, bias, loneliness, stereotypes);
   e. Health Care System: Insurance coverage, health literacy, treatment preferences, patient-clinician/shared decision making, availability of services, policies, and quality of care.

Our title and abstract screening mainly focused on excluding articles (criteria below) based on topic (i.e., if CDS was not used). Full text screening was focused to determine if either the focus of the article was to address health disparities, or if the methods explicitly assessed for, or accounted for, the health disparities mentioned above. These findings were based on discussion and consensus among these authors.

2.3 Exclusion Criteria

Studies were excluded if their relevance could not be determined (e.g., abstract was not available), if the CDS was not related to technology (e.g., a paper worksheet), or if the tool was used exclusively for teaching. Studies were also excluded if they were not original research (e.g., literature

reviews, brief communications), did not have full-text available, or were not available in English. Studies were also excluded if a CDS tool was not evaluated in the study. Evaluation is operationalized as "used in practice with clinicians or patients", which may include full-scale implementations or feasibility testing. We required at least one disparity included in either the focus of the CDS or within the evaluation to be included. Studies that did not exhibit the consideration of a disparity in these sections were excluded.

2.4 Screening Process

We used Covidence (Melbourne, Australia) to manage screening activities. Covidence is a web-based literature review management system allowing for collaboration among several participants. After importing the references, the authors reviewed the titles and abstracts independently, with each citation receiving two reviews. We reviewed conflicts and assessed eligibility based on group consensus. We reviewed and extracted full-text studies and confirmed final decisions by consensus.

2.5 Data Extraction

After identifying the full-text studies to be included, we extracted each study's overall objective, CDS category, the implementation of the CDS, its evaluation, disparity domains, priority populations included, and any considerations of the study towards the digital divide. CDS categories included medication dosing support, order facilitators, point-of-care alerts/reminders, relevant information display, expert systems, and workflow support, which were derived from a previously described taxonomy of CDS [22]. Disparity domains mirrored those found in the NIMHD research framework [21], which are detailed above. Priority populations were categorized by those identified in the National Institute on Aging's Health Disparities Framework [23] when present, which includes Hispanics/Latinos, American Indians/Alaskan Natives, Blacks/African Americans, Native Hawaiians and other Pacific islanders, socioeconomically disadvantaged populations, rural populations, disability populations, and sexual and gender minorities. Finally, we recorded any considerations noted in the study addressing the digital divide. We summarized these findings by general themes through group discussion.

3 Results

Our search in PubMed initially yielded 520 references. We excluded 430 studies through the title and abstract screening and 45 studies through full-text review; 45 papers remained inclusion (Figure 1).

Table 1 depicts the counts and percentages of the three major features for which we assessed each article: CDS category and target, domain of influence, and priority population. Multiple domains of influence and priority populations were possible for each study. The most frequent CDS type in this review was point-of-care alerts/reminders (33.3%). Targets of the CDS were split evenly between clinicians and patients, with three studies targeting both. Health Care System was the most frequent domain of influence (71.1%), and Blacks/African Americans were the most frequently included priority population (42.2%). Notably, all CDS categories, domains of influence, and priority populations were represented in the literature included in this review.

Table 2 depicts the abbreviated results from the data extraction. The supplemental table includes additional content for each study, including the study objectives and evaluation methods. When assessing for information related to the digital divide among the included literature, we found four major themes: inaccessibility of technology, access to care, trust of technology, and technology literacy. Notably, some studies did not include priority populations, and some did not address the digital divide.

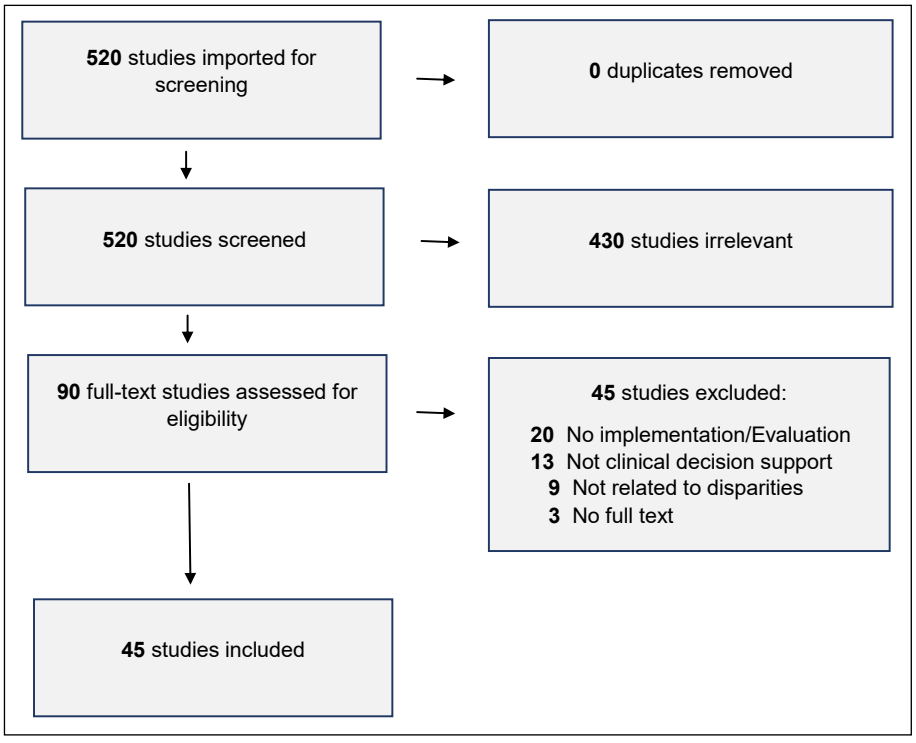

Fig. 1 PRISMA [24] diagram for screening results.

Table 1 Counts and percentages of CDS category and target, domain of influence, and priority population for the 45 included studies

CDS Category	Count (%)	CDS Target	Count (%)	Domain of Influence	Count (%)	Priority Population	Count (%)
Medication dosing support	2 (4.4%)	Clinician-facing	21 (46.7%)	Biological	14 (31.1%)	Hispanics/ Latinos	12 (26.7%)
Order facilitators	3 (6.7%)	Patient-facing	21 (46.7%)	Behavioral	12 (26.7%)	American Indians/ Alaskan Natives	1 (2.2%)
Point-of-care alerts/ reminders	15 (33.3%)	Both	3 (6.7%)	Physical/ Built Environment	5 (11.1%)	Blacks/ African Americans	19 (42.2%)
Relevant information display	8 (17.8%)			Sociocultural Environment	21 (46.7%)	Asian Americans	3 (6.7%)
Expert systems	12 (26.7%)			Health Care system	32 (71.1%)	Native Hawaiians and Other Pacific Islanders	2 (4.4%)
Workflow support	5 (11.1%)					Socio-economically Disadvantaged Populations	11 (24.4%)
						Rural Populations	5 (11.1%)
						Disability Populations	1 (2.2%)
						Sexual and Gender Minorities	2 (4.4%)

4 Discussion

4.1 CDS Infrastructure

This literature survey revealed the diversity of work being carried out in healthcare to address health disparities via CDS. CDS can be built in many formats and on different platforms depending on the use case. Within the included studies, all categories of CDS were represented, with point-of-care alerts/ reminders being the most common. In many institutions, the ability to make alerts within the EHR is an established process that can be rapidly implemented, which may be another reason for the high frequency of this format [25]. This review contained examples of alerts/reminders outside of the formal health care system, such as texts or alerts from a mobile app. Positively, there was an even split between patient and clinician facing CDS. It is important to continue developing patient facing CDS so that patients may be empowered to make their own decisions; giving tools to patients which have limited access to healthcare can help to narrow this equity gap [26, 27].

While most CDS remains EHR-driven, it is important to understand the implications of its use and underlying patterns. Recent and continuing research has shown that data-driven algorithms may be biased and are in fact widening disparities, especially among racial subgroups [28, 29]. While these biases exist, a number of strategies have been put forth to aid in remedying this unintended harm [30-32]. Remaining sensitive to these possibilities and testing for such outcomes in implemented CDS is imperative to ensuring health equity. It is also important to recognize that most CDS remains in the formal care system, which may present a challenge when attempting to reach patients in rural areas or in areas with less access to health care. Among the examples found in this review, the solution to this issue was to implement a technology infrastructure in these areas. In one example, this included an entire EHR with embedded CDS [33], but others utilized mobile technologies to disseminate CDS interventions and tools. Socioeconomically disadvantaged patients and those in rural populations, however, may not have the ability to purchase or sustain such technologies. Even today, approximately 7% of adults do not have access, or subscribe to, internet services [34]. Recognizing that not all patients have or use the internet is important to begin the conversation on how we may bring CDS to these individuals when it is needed.

4.2 Bridging Evidence to Address Disparities

In general, the literature addressed disparities in one of two ways: by developing a CDS intervention aimed to improve a disparity or by assessing for disparities post-implementation. While it is positive to see such studies occurring, strategies to address disparities need to co-occur with all CDS implementation. Post-implementation assessment is a positive step in recognizing disparities, but CDS should be guaranteed to not disproportionately affect certain subgroups prior to implementation. A number of methods are available to simulate outcomes, and we should begin to employ these in CDS development prior to implementation, especially when we have access to EHR data in the formal care setting [35, 36].

To identify studies that widened disparities was more difficult, however. Our search strategy focused on finding studies which mentioned health disparities or associated high-risk groups. We hypothesize that due to the need for these explicit tags, the inherent consideration of disparities within these studies made it less likely disparities were widened; but instead that they

Table 2 Abbreviated table of literature data extraction

Title	CDS Category	Implementation	CDS Target	Domain(s)	Priority Population(s)	Digital Divide
Pharmacogenomics decision support in the U-PGx project: Results and advice from clinical implementation across seven European countries.	Medication dosing support	EHR and tablet-based alert	Both	Biological, Behavioral, Physical, Sociocultural, Health Care System, Digital Divide		
Longitudinal assessment of racial disparities in juvenile idiopathic arthritis disease activity in a treat-to-target intervention.	Expert systems	Use of Redcap to display branching logic to give clinicians guidance for care planning (medications, tests, etc.).	Clinician-facing	Health Care System, Biological	Black/African American	
Perspectives on the Implementation of Screening and Treatment for Depression and Alcohol Use Disorder in Primary Care in Colombia.	Expert systems	Use of a mobile tablet to assist in screening, diagnosis, and initial care orders	Clinician-facing	Behavioral; Health Care System	Socioeconomically Disadvantaged Populations; Hispanics/Latinos	Assuring implementation in low technology-literature areas
Development of a Plain Language Decision Support Tool for Cancer Clinical Trials: Blending health literacy, academic research, and minority patient perspectives.	Relevant Information Display	Web-based tool	Patient-facing	Sociocultural Environment	Hispanics/Latinos; Blacks/African Americans	Language Barriers; Accessibility and Literacy
Medication risk management and health equity in New Zealand general practice: a retrospective cross-sectional study.	Point-of-care alerts/reminders	EHR-based alert system to notify clinicians of a patient's risk of harm	Clinician-facing	Health Care System	Socioeconomically Disadvantaged Populations; Native Hawaiians and Other Pacific Islanders	
Rheumatic?-A Digital Diagnostic Decision Support Tool for Individuals Suspecting Rheumatic Diseases: A Multicenter Pilot Validation Study.	Expert systems	Web-based diagnostic tool	Patient-facing	Sociocultural Environment		Language Accessibility
A digital health registry with clinical decision support for improving quality of antenatal care in Palestine (eRegQual): a pragmatic, cluster-randomized, controlled, superiority trial.	Workflow support	Electronic registry with logic components	Clinician-facing	Sociocultural Environment	Socioeconomically Disadvantaged Population	
Development of a Smartphone App for Regional Care Coordination Among High-Risk, Low-Income Patients.	Workflow support	Smartphone app	Patient-facing	Sociocultural Environment	Socioeconomically Disadvantaged Population; Hispanics/Latinos	Care access
Decision-making by laypersons equipped with an emergency response smartphone app for opioid overdose.	Expert systems	Smartphone app (UnityPhilly)	Patient-facing	Physical/Built Environment; Health Care System; Sociocultural Environment		
Low Burden Strategies Are Needed to Reduce Smoking in Rural Healthcare Settings: A Lesson from Cancer Clinics.	Point-of-care alerts/reminders	ELEVATE Epic module (In-EHR tool)	Clinician-facing	Physical/Built Environment; Behavioral	Rural Populations	Care Access
A Best Practice Alert for Identifying Hepatitis B-Infected Patients.	Order facilitators	EHR-based alert	Clinician-facing	Biological		

Table 2 (continued) Abbreviated table of literature data extraction

Title	CDS Category	Implementation	CDS Target	Domain(s)	Priority Population(s)	Digital Divide
Randomized comparative study of child and caregiver responses to three software functions added to the Japanese version of the electronic Pediatric Quality of Life Inventory (ePedsQL) questionnaire.	Point-of-care alerts/ reminders	EHR-based alert for high-risk country born patients	Patient-facing	Health Care System		
Reducing pediatric asthma hospital length of stay through evidence-based quality improvement and deployment of computerized provider order entry.	Order facilitators	Paper and EHR-based Order sets	Clinician-facing	Health Care System	Hispanics/Latinos; Blacks/African Americans	
A Smartphone App for Self-Management of Heart Failure in Older African Americans: Feasibility and Usability Study.	Relevant information display	Mobile App	Patient-facing	Sociocultural Environment; Health Care System	Blacks/African Americans	
mUzima Mobile Electronic Health Record (EHR) System: Development and Implementation at Scale.	Expert systems	Full EHR with CDS	Clinician-facing	Physical/Built Environment; Health Care System; Sociocultural Environment	Socioeconomically Disadvantaged Populations; Rural Populations	Technology access in low-income areas
Effectiveness of an insurance enrollment support tool on insurance rates and cancer prevention in community health centers: a quasi-experimental study.	Relevant information display	Electronic form used during registration	Patient-facing	Health Care System; Sociocultural Environment	Socioeconomically Disadvantaged Populations; Hispanics/Latinos	
Differences in Implementation Outcomes of a Shared Decision-Making Program for Men with Prostate Cancer between an Academic Medical Center and County Health Care System.	Workflow support	Web-based, patient facing care decision aid	Patient-facing	Health Care System; sociocultural Environment	Rural Populations	Discussed technology access in rural areas
Implementation and Impact of a Risk-Stratified Prostate Cancer Screening Algorithm as a Clinical Decision Support Tool in a Primary Care Network.	Point-of-care alerts/ reminders	EHR-based alert	Clinician-facing	Biological; Health Care System	Black/African Americans	
Lung Cancer Screening Knowledge, Perceptions, and Decision Making Among African Americans in Detroit, Michigan.	Expert systems	Web-based screening tool	Patient-facing	Sociocultural Environment	Blacks/African Americans	Half did not trust the online survey and requested paper
Improving contraceptive use among Latina adolescents: A cluster-randomized controlled trial evaluating an mHealth application, Health-E You/ Salud iTu.	Expert systems	Mobile App	Patient-facing	Sociocultural Environment; Health Care System	Hispanics/Latinos	
Effectiveness of clinical decision support to enhance delivery of family planning services in primary care settings.	Point-of-care alerts/ reminders	EHR-based reminder	Clinician-facing	Sociocultural Environment; Health Care System	Hispanics/Latinos; Blacks/African Americans	
Decreasing Chlamydial Reinfections in a Female Urban Population.	Point-of-care alerts/ reminders	EHR-based alert	Clinician-facing	Sociocultural Environment; Biological; Health Care System	Blacks/African Americans	

Table 2 (continued) Abbreviated table of literature data extraction

Title	CDS Category	Implementation	CDS Target	Domain(s)	Priority Population(s)	Digital Divide
Human Papillomavirus vaccination clinical decision support for young adults in an upper midwestern healthcare system: a clinic cluster-randomized control trial.	Point-of-care alerts/ reminders	Web-based and EHR-based CDS	Both	Biological; Health Care System	Rural Populations; Hispanics/Latinos; Blacks/African Americans; Asian Americans	
Home-Based Intervention to Test and Start (HITS): a community-randomized controlled trial to increase HIV testing uptake among men in rural South Africa.	Expert systems	Tablet-based decision/ screening aid	Patient-facing	Biological; Behavioral; Sociocultural Environment	Rural Populations;	
Effects of Testing and Disclosing Ancestry-Specific Genetic Risk for Kidney Failure on Patients and Health Care Professionals: A Randomized Clinical Trial.	Point-of-care alerts/ reminders	EHR-based alert during follow-up visits for patients who had screening	Both	Biological; Health Care System	Blacks/African Americans	
Clinical Decision Support to Address Racial Disparities in Hypertension Control in an Integrated Delivery System: Evaluation of a Natural Experiment.	Workflow support	Tool to notify nursing aids to call patients to encourage medication use and to monitor BP	Clinician-facing	Biological; Health Care System; Sociocultural Environment	Blacks/African Americans	
Improving Depression Screening in Underserved Populations in a Large Urban Academic Primary Care Center: A Provider-Centered Analysis and Approach.	Point-of-care alerts/ reminders	EHR-based alert to remind clinicians to complete yearly screening	Clinician-facing	Behavioral; Health Care System	Blacks/African Americans	
"Take Charge, Get Cured": Pilot testing a targeted mHealth treatment decision support tool for methadone patients with hepatitis C virus for acceptability and promise of efficacy.	Expert systems	Web-based and mobile app-based	Patient-facing	Biological; Health Care System	Hispanics/ Latinos; Blacks/ African Americans; Socioeconomically Disadvantaged Populations	
Impact of a Clinical Genomics Program on Trial Accrual for Targeted Treatments: Practical Approach Overcoming Barriers to Accrual for Underserved Patients.	Workflow support	Pathway with automated emailing to support in the targeted recruitment of patients for genetic studies	Clinician-facing	Biological; Health Care System	Hispanics/Latinos; Blacks/African Americans	
Electronic Health Record Reminders for Chlamydia Screening in an American Indian Population.	Point-of-care alerts/ reminders	EHR-based reminder	Clinician-facing	Behavioral, Health Care System	American Indians/ Alaskan Natives	
Decision support for men with prostate cancer: Concordance between treatment choice and tumor risk.	Relevant information display	Web-based informational tool	Patient-facing	Behavioral	Blacks/African Americans; Socioeconomically Disadvantaged Populations	
Health Within Reach-a Patient-Centered Intervention to Increase Hepatitis B Screening Among Asian Americans: a Randomized Clinical Trial.	Expert systems	Mobile app screening tool	Patient-facing	Biological; Behavioral	Asian Americans	Addressing language accessibility
What is the effect of a decision aid in potentially vulnerable parents? Insights from the head CT choice randomized trial.	Relevant information display	Paper/Screen-based decision aid	Patient-facing	Sociocultural Environment; Health Care System	Blacks/African Americans	

Table 2 (continued) Abbreviated table of literature data extraction

Title	CDS Category	Implementation	CDS Target	Domain(s)	Priority Population(s)	Digital Divide
Effectiveness of an Opt-Out Electronic Heath Record-Based Tobacco Treatment Consult Service at an Urban Safety Net Hospital.	Point-of-care alerts/ reminders	EHR-based generated consult	Clinician-facing	Behavioral; Health Care System	Blacks/African Americans; Hispanics/Latinos; Socioeconomically Disadvantaged Populations	
Applicability of Pharmacogenomically Guided Medication Treatment during Hospitalization of At-Risk Minority Patients.	Order facilitators	EHR-based aid to guide medication prescription	Clinician-facing	Biological; Health Care System	Blacks/African Americans	
Videos to reduce racial disparities in ICD therapy Via Innovative Designs (VIVID) trial: Rational, design and methodology.	Relevant information display	Contextual video decision aids	Patient-facing	Behavioral; Sociocultural Environment	Blacks/African Americans	
Linking Technology to Address the Social and Medical Determinants of Health for Safe Medicines Use.	Expert systems	Web-based decision aid to alert users to drug interactions and high-risk medications	Clinician-facing	Physical/Built Environment; Health Care System	Socioeconomically Disadvantaged Populations	
Experience with antiretroviral electronic adherence monitoring among young African American men who have sex with men living with HIV: findings to inform a triaged real-time alert intervention.	Point-of-care alerts/ reminders	Smart drug-storage device which sends compliance notifications as text messages	Patient-facing	Behavioral; Sociocultural Environment; Health Care System	Blacks/African Americans; Sexual and Gender Minorities	
Pharmaceutical mobile application for visually-impaired people in Thailand: development and implementation.	Relevant information display	Smartphone app	Patient-facing	Health Care System	Disability Populations	Addressing visually-impaired accessibility
Effect of a Reminder System on Pre-exposure Prophylaxis Adherence in Men Who Have Sex With Men: Prospective Cohort Study Based on WeChat Intervention.	Point-of-care alerts/ reminders	Text message-based reminder system	Patient-facing	Behavioral	Sexual and Gender Minorities	
Improved Detection of Child Maltreatment with Routine Screening in a Tertiary Care Pediatric Hospital.	Point-of-care alerts/ reminders	EHR-based alert and associated order set	Clinician-facing	Sociocultural Environment; Health Care System		
Clinical Effectiveness of Decision Support for Prescribing Opioids for Chronic Noncancer Pain: A Prospective Cohort Study.	Medication dosing support	An opioid health maintenance tool to display status of risk mitigation; and medication order embedded morphine equivalent daily dose (MEDD) calculator and hyperlink to the pharmacy drug monitoring program.	Clinician-facing	Health Care System	Socioeconomically Disadvantaged Populations	
MINDSET: Clinic-based decision support demonstrates longitudinal efficacy for increased epilepsy self-management adherence among Spanish speaking patients.	Expert systems	Tablet-based app to assess self-management strategies and provide medication monitoring	Patient-facing	Sociocultural Environment	Hispanics/Latinos	
Aiding shared decision making in lung cancer screening: two decision tools.	Relevant information display	Web-based decision tools	Patient-facing	Behavioral; Health Care System	Blacks/African Americans	
Electronic health record alerts enhance mass screening for chronic hepatitis B.	Point-of-care alerts/ reminders	EHR-based alert	Clinician-facing	Health Care System	Asian Americans; Native Hawaiians and Other Pacific Islanders	

were central to their CDS development or implementation. As a result of conducting this review, we now believe that a more effective search strategy for identifying widening disparities as a result of CDS would be to identify smaller subsections of literature (perhaps by disease state), and conduct meta-analyses to determine if outcomes were equitable. However, using the framework put forth by the NIMHD, we can quantify the number of studies that omitted priority groups and did not address the digital divide. While there is not conclusive evidence to suggest that these omissions widened disparities, we can at least recognize that future studies may benefit from explicitly recognizing these topics in their design and evaluation methods.

Several CDS tools were developed using culturally and socioeconomically sensitive evidence which showed to improve health among these subpopulations. From these studies, it is apparent that changing the approach to CDS development (depending on the disparity) can result in greater efficacy for groups that have been historically disadvantaged. In most health care settings, we vie for creating standardized solutions that can be used across all levels of the health system. However, we are now in an age of "precision medicine" where we are leveraging patient-level data to maximize health for the individual, rather than creating a one-size-fits-all solution [37, 38]. CDS is uniquely poised to deliver personalized interventions, yet we continue to see CDS widen disparities. The informatics community should prioritize formalizing the culturally and socioeconomically sensitive approaches found in these studies for easier dissemination. CDS interventions could then be tailored to individuals whether that be on the premise of race, socioeconomic status, disability, or others to maximize their health outcomes. We should be aware, however, that these highly individualized approaches may come at the cost of scalability and interoperability, leading to costly implementations. Striking a balance between customization and scalability is difficult but should be considered in current design and in future research to address these barriers and make such implementations more feasible.

4.3 Addressing the Digital Divide

We recognized four major themes in the literature: inaccessibility of technology, access to care, trust of technology, and technology literacy. Inaccessibility of technology refers to barriers that prevent end users from using or fully benefiting from the CDS. A common barrier was language accessibility, which is a common barrier among all industries in the USA, as most of our technology is centric on the English language. When developing CDS, especially patient facing CDS and mobile applications, language accessibility is an important design consideration. Another accessibility issue was related to those with visual impairment, which can also be overcome with careful design.

Access to care was another common theme, relating to the ability of CDS to bridge the gap between healthcare providers and those who have difficulty accessing it. Most of these examples related to apps or web-based applications which can be accessed from the patient's smartphone, reducing the need to travel to clinics or hospitals for evaluation or targeted interventions. While these technologies can help close the gap, we must again be considerate of the fact that these technologies may also be inaccessible for the socioeconomically disadvantaged, and for those without the internet. Making CDS a mobile application does not automatically guarantee its accessibility.

Trust of technology was mentioned in one article, where half of the participants did not want to use a web-based application but instead wanted paper forms because of their distrust of technology [39].Distrust of technology can have serious consequences for CDS efficacy, extending beyond CDS in many cases. For example, AI is becomingly more frequent in CDS tools, but has garnered criticism and mistrust among clinicians and patients alike [40] Gauging the intended audience and their likelihood to interact with the CDS in the intended manner is a difficult but important factor in successful implantation. Distrust among a subset of patients may also lead to widening disparities in that group.

Finally, we found that technology literacy was a barrier to some CDS implementations in the literature. While health literacy has the potential to be boosted with the use of technology [41, 42], technology literacy itself can be a difficult problem to ameliorate. It could also be argued that technology literacy is not the responsibility of the health system as it does not fall under the umbrella of "health", but this can have impact on design, implementation, and effectiveness. Again, knowing baseline aptitude among the intended audience is important, but it is also crucial to not over-engineer CDS and make the technological requirements for use higher than needed. HealthIT developers and implementers must ensure that CDS does not widen health disparity gaps and are designed carefully to maximize their impact to all patients.

5 Conclusions

This review revealed the diversity of CDS being used to address health disparities and several barriers which may make CDS less effective or potentially harmful to certain populations. Inaccessibility of technology, access to care, trust of technology, and technology literacy are all important to consider and have tangible changes which can make CDS more effective in preventing health disparities. Regular examinations of literature that feature CDS and address health disparities can help to reveal new strategies and patterns for improving healthcare.

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