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Technology-supported shared decision-making in chronic conditions: a systematic review of randomized controlled trials
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Abstract

Objectives:
To describe the role of patients with a chronic disease, healthcare professionals (HCPs) and technology in shared decision making (SDM) and the use of clinical decision support systems (CDSSs), and to evaluate the effectiveness of SDM and CDSSs interventions.

Methods:
Randomized controlled studies published between 2011 and 2021 were identified and screened independently by two reviewers, followed by data extraction and analysis. SDM elements and interactive styles were identified to shape the roles of patients, HCPs and technology.

Results:
Forty-three articles were identified and reported on 21 SDM-studies, 15 CDSS-studies, 2 studies containing both an SDM-tool and a CDSS, and 5 studies with other decision support components. SDM elements were mostly identified in SDM-tools and interactions styles were least common in the other decision support components.

Conclusions:
Patients within the included RCTs mainly received information from SDM-tools and occasionally CDSSs when it concerns treatment strategies. HCPs provide and clarify information using SDM-tools and CDSSs. Technology provides interactions, which can support more active SDM. SDM-tools mostly showed evidence for positive effects on SDM outcomes, while CDSSs mostly demonstrated positive effects on clinical outcomes.

Practice implications:
Technology-supported SDM has potential to optimize SDM when patients, HCPs and technology collaborate well together.

Keywords
chronic diseases; Shared Decision Making; clinical decision support systems; Patient-provider communication; SDM; CDSSs
1 Introduction

According to the World Health Organization (WHO), chronic diseases are the leading cause of mortality worldwide, accounting for 71% of all deaths each year [1, 2]. Common chronic diseases include cardiovascular disease, chronic respiratory disease, diabetes, cancer and mental illness [3]. Chronic diseases are slow in their progression and generally last at least one year [4, 5]. Treating a chronic disease is often a complex process influenced by patient characteristics, sociocultural factors, and patient’s self-management skills etc. [6-8]. Therefore, patients require long-term and patient-centred care including core self-management skills such as taking action, use of resources, problem-solving, decision-making, and effective collaborations between the patient and healthcare professional (HCP) [6-8].

Treatment guidelines for chronic diseases also emphasize the importance of including self-management by changing the role of the patient from passive observer to an active, responsible participant in the management of their own health [9]. This approach includes shared decision making (SDM), a collaborative process between a patient and a HCP to decide on the best treatment option, where among other things patient values, patient preferences, and the best scientific evidence are taken into account [10]. SDM can improve patient trust in medical decision-making, improve treatment adherence and patient outcomes, leading to a decrease in healthcare costs [11-13]. However, up till now, SDM has not been widely adopted in routine clinical practice [14]; in 10% of health decisions this is applied [15, 16].

Meanwhile, the role of technology in healthcare becomes more prominent, thereby also influencing SDM [17-19]. Traditional healthcare systems are facing shortages in facilitating SDM such as HCP’s lack of skills, time, and their misconceptions regarding SDM [20, 21]. Patients can use SDM-tools to facilitate shared decision making [22, 23], whereas HCPs can use information technologies such as Clinical Decision Support Systems (CDSSs) to facilitate clinical decision making [24]. It is expected that SDM-tools and CDSSs will strengthen each other by enabling technology-supported shared decision-making between a HCP and patient, as illustrated in Figure 1.

[insert Figure 1]

SDM-tools are often visual decision aids such as leaflets, booklets, videos, and interactive websites, which can be used by a patient alone before a consultation or during a patient-HCP encounter to assist in SDM [22, 25]. Increasing attention has been paid to the development of SDM tools for chronic diseases [22, 23]. In a recent systematic review, Wieringa et al. [26] identified 20 unique chronic care decision aids that were tested in randomized controlled trials (RCTs). The majority of these decision aids were primarily aimed at informing patients about treatment options, benefits and harms. However, Wieringa et al. found that they lacked initiating empathic conversations between patients and HCPs. Moreover, Wieringa et al. assessed if there was a relationship between SDM outcomes (e.g. knowledge, decision conflict) and the identified key components for SDM (i.e. situation diagnosis, choice awareness, option clarification, harms and benefits, patient preferences and making decision), but found no association between them [26]. Furthermore, a systematic review by Mathijssen et al. [27] identified interventions to support SDM specifically for medication therapy in chronic conditions. These interventions included SDM-tools, but also methods to boost SDM interactions between patients and HCPs such as informed SDM programs, training courses, and treatment protocols based on SDM. Interventions presented electronically to patients and HCPs and interventions that provided value clarification exercises appeared to have the most positive effect on patient outcomes such as decisional conflict and risk estimation. However, for the majority of identified patient outcomes (e.g. knowledge, risk estimation, attitudes, beliefs, self-efficacy), no evidence was found concerning the effectiveness of SDM interventions. So far, no overview exists on how patients, HCPs and technology collaborate in SDM, and how these collaborations may lead to more patient-centred care.
Clinical Decision Support Systems (CDSSs) also have the potential to facilitate SDM and improve health outcomes, [24]. A CDSS is a health information technology aiming to improve medical decisions by collecting all relevant data e.g. clinical knowledge, patient information and other targeted health information [28, 29]. The system presents information e.g. patient-specific assessments or recommendations to the HCP, which can then be taken into consideration when deciding on a treatment advice for the patient. They can provide a concise overview of clinical information which can initiate an effective discussion between the HCP and patient [30]. This is possible by presenting the harms and benefits of several treatment options to the patient instead of just giving treatment advice [31]. Furthermore, a data-driven CDSS can predict if a patient is suitable for a certain treatment based on patient phenotypes, which can help personalise treatment options and, thus initiate more effective SDM [30, 32]. Several systematic reviews present an overview of designed, and in some cases evaluated, CDSSs for chronic diseases, but these lack insights into how these systems could facilitate SDM [33-36].

Current research indicates that health technology can empower patients to become active participants in their health and develop SDM skills [10, 18, 37]. However, little is known on how SDM can be facilitated through patient-HCP-technology collaborations. With this review, we provide an overview of the current body of knowledge and application of SDM and CDSS in chronic care within the context of RCTs.

More specifically, the objectives of this systematic review are twofold:

(1) to describe the role of patients with a chronic disease, HCPs and technology in SDM and the use of CDSSs, and
(2) to evaluate the effectiveness of SDM and CDSSs interventions in chronic care

2 Methods

The systematic review followed the Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) guidelines [38] and the review protocol was registered in the PROSPERO database (ID:CRD42022290826). Only studies in peer-reviewed journals that reported on a RCT were included.

2.1 Search strategy

Records were identified through PubMed, Scopus, Embase, Web of Science, CINAHL, and PsychINFO. Recognizing the rapid advancements of technology in healthcare, searches were restricted to studies published between 2011 and 2021. Structured search strings were composed for each database and were based on free-text and controlled terms related to the population group, shared decision making, decision support, and the type of study (Supplementary file).

Endnote (Clarivate Analytics, USA) was used for record de-duplication, after which the dataset with unique records was imported into an Artificial Intelligence (AI)-tool (ASReview; Utrecht University, the Netherlands) for title and abstract screening. ASReview applies an active learning model by continuously training a machine learning model to predict the relevance of textual data. The model is firstly trained based on selected prior knowledge and is continuously trained based on newly presented relevant and irrelevant records, which further increases the probability to identify the most relevant records [39]. To be eligible as prior knowledge, a set of titles and abstracts from the complete dataset were selected by one reviewer (RV) based on the inclusion and exclusion criteria of this systematic review. In total, 16 records were used as prior knowledge, of which half of the records were eligible for the systematic review whereas the other half were not.
The default active learning model setup (Naïve Bayes classifier, maximum query strategy, term frequency-inverse document frequency (TF-IDF) feature extraction) was selected since it is known for its consistent high performance and low computational time in standard experiments across different datasets [39]. After the model was trained automatically in ASReview, one reviewer (RV) conducted title and abstract screening in ASReview, after which the second reviewer (EtB) independently screened the resulting set of records in Rayyan (HBKU Research Complex, Doha, Qatar) as well. Rayyan is a free web-based screening tool that was specifically chosen by the authors for its independent and simultaneous screening features by at least two reviewers, which was not possible in ASReview [40, 41].

Full text screening was done independently in Rayyan by both reviewers, whereby the second reviewer (EtB) screened 20% of the full text data set. Disagreements between the reviewers were resolved through discussion and consensus for title and abstract and full-text screening. A third reviewer (TB) was available in case of unresolved disagreements. **The inter-rater reliability was not assessed, since the approach was to thoroughly investigate and resolve any disagreements between the two reviewers, irrespective of the inter-rater reliability outcome following the assessment of their agreement** [42].

### 2.2 Study selection

Inclusion criteria were formulated based on PICOS (Patient, Intervention, Comparator, Outcome, Study design). (P) patients of at least 18 years with a clinical diagnosis of either chronic obstructive pulmonary disease (COPD), ischemic heart disease (IHD), chronic heart failure (CHF), diabetes, anxiety or depression were included because of their prevalence [1-3]. (I) Any SDM model, -tool, -aid, -instrument or CDSS designed to assist patients and HCP in decision making. (C) the intervention group was compared to a control group which received usual care, (O) any patient-reported, patient-experience, SDM or clinical outcome was measured, and (S) a RCT was conducted.

Included studies were not restricted to language, sample sizes, length of follow-up of outcomes and type of setting. Studies were marked ineligible when they included: (1) healthy participants, patients with a self-reported medical history, patients with acute chronic conditions, cancer, gestational diabetes, pre-diabetes or severe mental illnesses (2) patients younger than 18 years of age, (3) interventions for economic or end-of-life decision making, (4) interventions without usual care, and (5) interventions which only report feasibility outcome measures or protocols for a randomized controlled trial. **Nevertheless, while cancer is a chronic disease as well, it has been excluded in this review since decision-making approaches for cancer significantly differ from those applied for other chronic conditions** [43].

### 2.3 Data extraction

Data extraction was carried out by one reviewer (RV), whereby the second reviewer (EtB) verified 20% of the extracted data to assure agreement or identify discrepancies in the content of the extracted data. Similar to the screening of records, two reviewers thoroughly discussed and resolved any disagreements and consulted a third reviewer (TB) if consensus was not met.

**The first reviewer (RV) extracted all the data, whereby the second reviewer (EtB) verified 20% of the extracted data to assure agreement or identify discrepancies in the content of the extracted data. Similar to the screening of records, two reviewers thoroughly discussed and resolved any disagreements and consulted a third reviewer (TB) if consensus was not met. Subsequently, the first reviewer extracted the remaining 80% of the data by taking the resolved disagreements with the second reviewer into account as well.**

The data extraction form was based on the Cochrane template [44] and the data extraction form by Wieringa et al. [26]. It was pilot tested by two researchers (RV and TB) to ensure consistency across both reviewers which led to an updated data extraction form designed in Atlas.ti 22. The form included information concerning study eligibility, participants, intervention groups, control groups and outcome
measures. Furthermore, data concerning the roles of patients and HCPs were extracted based on the ten SDM elements defined by Clayman et al. [45], whereas data concerning the roles of technology in decision support were extracted based on five interactive styles defined by Shneiderman [46]. Both sets can be found in Table 1.

In case of missing data, corresponding authors were contacted via e-mail to complete the data extraction forms. When the corresponding authors didn’t respond after two weeks, a reminder e-mail was sent once. In case authors never respond, this will be saved in the data extraction form as not reported data.

2.4 Risk of bias assessment
The internal validity of each study was determined by assessing the risk of bias for the patient-reported, patient-experience, SDM or clinical outcome measures of each included study. This allows for the interpretation of the roles of patients, HCPs, and technology, based on SDM-elements and primary interaction styles. A data extraction form (RoB 2 tool) [42, 47] was used to assess the quality of the outcome measures with a positive effect (p-values of ≤ 0.05) of each study. Judgements on risk of bias were reported as “high risk”, “low risk” or “some concerns”. The “some concerns” judgement was reported when studies contained insufficient information to make a fair judgement. Risk of bias assessment was carried out independently by two reviewers (RV and EtB), whereby disagreements between the reviewers were resolved through discussion and consensus and a third reviewer (TB) could be consulted in case of disagreements.

2.5 Data synthesis
The intervention characteristics and findings were synthesized narratively in text and summarized in tables. The extracted data, such as study design, populations, interventions and patient outcomes, were insufficiently homogenous across the included studies for statistical data pooling and meta-analysis. Therefore, the effectiveness of SDM-tools and CDSSs was presented descriptively, as well as the roles of patients, HCPs and technology in SDM-tools and CDSSs.
3 Results

The study selection procedure resulted in 43 articles that met our inclusion criteria, as shown in the PRISMA-flow diagram in Figure 2.

[insert Figure 2]

3.1 Intervention characteristics

Participants

Out of the 43 studies, 30 reported on patients with diabetes type 1 and/or 2 [23, 48-62], and one reported on diabetes and depression [63]. Of the remaining 12 studies, 6 reported on patients with depression and/or anxiety [25, 64-68], 3 included patients with COPD [69-71], 2 with CHF [72, 73] and 1 study included patients with IHD [74].

3.1.1 Key intervention components

The included articles reported on different types of decision support studies, namely 21 SDM studies, 15 CDSS studies, 2 studies containing both an SDM-tool and a CDSS, and 5 studies with other decision support components, which assist patients and HCPs in decision making. Out of the 21 SDM studies, 16 unique SDM-tools were identified including: the ARIBBA electronic decision-aid [48, 49], statin choice decision aid [50, 51], diabetes medication choice decision aid [23, 50, 52], an interactive diabetes decision aid [53, 54] and a decision aid [55, 56]. In total, 11 unique CDSSs were identified, including: a decision-support electronic health record [57, 58, 63], a diabetes management system [75, 76], a CDSS-based u-healthcare service [77, 78], and an automated decision support tool [79, 80].

Besides decision support components, SDM interventions were often accompanied by other key intervention components, such as patient education materials [65, 77, 78, 81, 82] training sessions for patients [55, 56, 79, 80, 82], and/or HCPs [51, 52, 55, 56, 59, 60, 65, 67, 71, 74-76, 79, 80, 83], telephone/video calls [59, 65, 71, 73, 81] and/or in-person meetings between HCPs and patients [65, 73].

3.1.2 Description of decision support components

Most SDM-tools were decision aids, whereby patients had the opportunity to make one specific health decision often in collaboration with their HCP. The SDM-tools by Lauffenburger et al [59] and Slok et al. [69] were the only ones which did not focus on specific health decisions but on respectively, preparing patients for telephone consultations with the help of a decision aid, and setting up a treatment plan using the ABC-tool. The SDM-tools could be accessed before and/or in consultation by both the patients and HCPs, however in some cases only by the HCP during a consultation [48, 49]. The mode of delivery of the SDM-tools was either paper-based (e.g. printed paper sheets, booklets, cards) [23, 51, 55, 56, 59-61, 65-67, 74], web-based (website) [25, 50], computer-based (e.g. software program on a computer or integrated with Electronic Health Records (EHR)) [48, 49] or a combination of delivery modes [50, 52-54, 62, 69, 72].

The found CDSSs were mostly used by HCPs alone to provide patients with health recommendations generated by the system through, among other things, prompts and notifications on their computer-based or web-based device [57, 58, 63, 68, 75, 76, 84, 85]. In these cases, HCPs used the CDSSs to share and **discuss treatment** recommendations with their patient during a consultation. Some CDSSs were also intended to be used by the patient alone [64, 81]. In these cases, patients received health recommendations on a tablet device or smartphone in the form of an SMS (Short Message Service). The two studies containing both an SDM-tool and a CDSS emphasized that the output of the CDSSs could also be used as SDM-tools [83, 86].
Finally, the other decision support tools did not use a SDM-tool or CDSSs in their intervention. Those interventions mainly focused on providing educational tools (e.g. workbooks, manuals, DVD, sessions, trainings) to either patients or HCPs [70, 71, 73, 82]. Only the intervention by Vo et al. 2019 [87] did not deliver educational tools, but rather focused on the Pre-Visit Prioritization (PVP) secure electronic email message to patients to decide on visit priority options such as diabetes related concerns, important changes in life, medication concerns, mood/motivation, and new/important health issues [87].

3.1.3 Outcome measures
SDM-outcomes included patient knowledge [23, 25, 50-52, 54, 55, 60, 67, 80, 82, 88], decisional conflict [25, 51, 52, 54, 67, 88], (decisional) self-efficacy [53, 54, 62, 80], patient involvement [52, 66], and patient expectations [56, 60]. Patient-reported outcomes included health status [62, 70][65] and quality of life [64, 66, 68, 71, 73]. Clinical outcomes included HbA1c [23, 48, 50, 52, 56-63, 75, 81, 83-87], blood pressure (BP) [56-58, 61-63, 79, 82, 84, 85, 89], and adherence to medication and treatment goals [23, 50-52, 55, 59, 66][66][70, 75, 80]. Lastly, patient-experienced outcomes include patient satisfaction with among other things knowledge transfer, decision-making, medication, care and treatment [23, 50-52, 57, 62, 66-68, 71, 75].

[insert Table 2] presents an overview of key intervention and study characteristics, which are detailed in the following paragraphs.

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3.2 SDM-elements in decision support components
Table 3 provides an overview of the SDM-elements which are present in each unique study. Figure 3 visualizes how often the SDM-elements were present in relation to each other, whereas Figure 4 visualizes how often the SDM-elements were present per decision support category.

3.3 Interaction styles in decision support components
In addition, Table 3 provides an overview of the primary interaction styles which are present in each unique study. Figure 5 visualizes how often the interactive styles were present in relation to each other, whereas Figure 6 visualizes how often the interactive styles were present per decision support category.

3.4 Intervention effects & Risk of Bias assessment
The identified outcome measures, the reported changes in these measures from baseline values to the last follow-up, and an overview of the risk of bias assessment are reported as a supplementary file.
3.4.1 Best evidence synthesis SDM-tools

Out of the 21 SDM studies, eight studies showed evidence for a positive effect on SDM-outcomes such as knowledge [25, 51, 52, 54, 55, 60, 67, 74], three studies on expectations and risk comprehension [51, 56, 60], and two studies on patient involvement [52] and treatment intention [25]. One study showed evidence for a positive effect on decision self-efficacy [54]. Conflicting evidence was found for decisional conflict, measured with the Decisional Conflict Scale. In four SDM studies, decisional conflict showed evidence for a positive effect [25, 54, 60, 67, 74], whereas three SDM studies showed evidence for a negative effect [50-52]. Only the patient-reported outcome: health status (impact, symptoms, and total score) measured with the St. George's Respiratory Questionnaire by Slok et al. [69] showed a positive effect. Out of the 14 SDM studies that reported on clinical outcome measurements only one study by Allen et al. [72] showed evidence of a positive effect on guideline-directed medical therapies. Lastly, of the 8 SDM studies that reported on patient-experience outcomes, two studies showed evidence for a positive effect on quality of care [69] and satisfaction with received information [67].

3.4.2 Best evidence synthesis CDSSs

Out of the 14 CDSS-studies that reported on clinical outcome measurements, 9 studies [57, 63, 64, 68, 75, 79, 81, 85, 89] showed significant differences between groups for HbA1c, cholesterol levels, BP, distress, adherence, depression severity, -symptoms and -clinical remission. Only four CDSS-studies [57, 64, 68, 80] reported on patient-reported outcome measurements of which change in health related quality of life [57] was the only outcome measure which showed evidence of a positive effect. Three CDSS-studies [57, 68, 75] reported on patient experience outcomes, of which only patient treatment satisfaction [75] showed evidence for a positive effect. Lastly, out of the CDSS-studies, only one by Ramallo-Fariña et al. [80] measured two SDM-outcome measures, which were psychosocial self-efficacy and patient knowledge. These respectively showed evidence for a positive effect and no reported evidence for a positive effect.

3.4.3 Best evidence synthesis SDM-tools + CDSSs

Out of the two studies with both a SDM-tool and CDSS [86] [83], neither reported SDM-outcome measures. Similar to the CDSS-studies, clinical outcome measures were in the majority, whereby evidence of a positive effect was identified in HbA1c and systolic BP [67]. Furthermore, patient-reported outcome measures were also not performed in these studies. On the other hand, the patient-experience outcome measure, patient satisfaction was performed by Hsu et al. [86] and showed evidence of a positive effect between groups.

3.4.4 Best evidence synthesis Other decision support tools

Out of the five studies that reported on SDM outcome measures [70, 71, 73, 82, 87], evidence of a positive effect was identified in two studies [70, 87]. Granados-Santiago et al. [70] showed evidence of a positive effect for knowledge of COPD [70]. Vo et al. [87] showed evidence of a positive effect on patient-provider communication. Patient-reported outcome measures were performed in three studies [70, 71, 73] of which only Granados-Santiago et al. [70] showed evidence for perceived health status. Furthermore, [70] was also the only study which showed evidence of a positive effect on clinical outcome measures such as dyspnoea perception, adherence to treatment, general functionality and physical activity.
4 Discussion and Conclusion

4.1 Discussion

This systematic review aimed to describe the role of patients with a chronic disease, HCPs and technology in SDM and the use of CDSS, and to evaluate its effectiveness. This review revealed that patients, HCPs and technology have an active role in decision making, where the main focus respectively lies on obtaining information, clarifying information, and aiding primary interactions. SDM-tools are mostly associated with positive effects on SDM outcomes, with comparatively fewer reported instances of positive effects on clinical, patient-reported, and patient-experience outcomes. In contrast, CDSSs are recognized for their positive effects on clinical outcome measures, while their influence on SDM, patient-reported, and patient-experience outcomes is less frequently reported.

Diabetes was strongly in the majority compared to the other chronic diseases, implying a lack of tested SDM-tools and CDSSs for other included chronic diseases such as COPD, CHF and IHD.

The most frequently identified SDM-elements in SDM studies were “process or procedure”, “risk/cons”, “benefits/pros”, and “patient preferences and values”. This indicates that the role of HCPs is mostly providing and clarifying information about treatment strategies, whereby the role of the patients in SDM is mainly receiving and understanding information about treatment options. Our results show that SDM-tools can facilitate a discussion between a patient and their HCP on patients’ preferences and values in what should be the next step. However to reach this, the SDM-tools need to be accessible to both the patient and HCP [90]. The least commonly identified SDM-elements in SDM interventions were “patient self-efficacy”, “patient outcome expectations”, and “confirming patient understanding”. As we used a more extensive list of SDM-elements compared to Wieringa et al. [26], this brings new insights into the extent to which SDM is applied in the identified studies.

Compared to the SDM-tools, fewer SDM-elements were identified in CDSSs. This indicates that current CDSSs are less suitable to facilitate SDM. This was expected, because CDSSs are initially not intended to facilitate SDM. Based on the identified studies in this systematic review, HCPs mostly use CDSSs to provide patients with information and health recommendations generated by the system. This indicates that HCPs have an active role here, where mostly the elements “rationale for option”, “process or procedure” and “plan for follow-up” were applied. CDSSs were mostly only accessible to HCPs, however in two found studies, CDSSs were developed to be used by patients to receive health recommendations from the system [64, 81].

Technology has its role in facilitating SDM by providing the patient and HCP with appropriate interactions between decision support tools and users such as patients or HCPs. As SDM-elements, such as “self-efficacy”, “patient outcome expectations” and “confirming patient understanding”, are less found in the included studies, it is important that future decision support tools promote these topics through interaction styles as it is often not self-evident that all these SDM topics are discussed during a consultation. In this review, the most common interaction styles identified were form fill-in, menu-selection, and direct manipulation. For this, advised interaction styles are providing sub-tabs (menu-selection) and conversations with virtual coaches (direct manipulation) to ensure more structured conversations between the patient and the HCP. However, we must take into account that only implementing SDM-elements is not enough to optimize SDM. The delivery mode and content are important as well in the implementation of technology supported SDM. In the systematic review by Mathijssen et al. [27] it was mentioned that electronically delivered SDM interventions, and interventions with clear clarifications have a positive effect on patient outcomes.

Other important aspects are appropriate visualisations and e-health literacy [91-93]. Although most of the included studies apply visualisations in their SDM-tools and CDSSs, it is of high importance that information is visualized in such a way that it is understandable for both the patient and HCP. For this,
more emphasis should be put on guidelines on visualisation that fit well with patients with chronic diseases and low (e)-health literacy. For example, Slok et al. [94] mentioned in their qualitative study on their SDM-tool that patients prefer visual displays more than words in a consultation with their HCP, especially older patients, less educated patients, and patients with a low health literacy [94]. Bailey et al. [54] found out that most (70%) patients in their study preferred an active role in decision making of which only a few had sufficient knowledge to make good decisions. Thus, just sharing information between the patient and HCP is not sufficient and is still uninformed if the understanding of information is not highly guaranteed [56]. This highlights the importance of including SDM-elements such as “patient self-efficacy”, “patient outcome expectations” and “patient understanding confirmed”, which may contribute to clarifying information to patients. Even if patients take an active role in SDM, it is important that HCPs do that as well. Coylewright et al. [74] identified that HCPs in their study failed to apply sufficient SDM during consultations, which led to no improvements in decisional quality. They noticed that HCPs used their SDM-tool as a way to inform patients, rather than to facilitate a shared conversation. The HCPs in the study of Denig et al. [62] sometimes considered the information of their SDM-tool as unnecessary. Patients also agreed that HCPs did not share that information as expected since information was discussed briefly. The literature also shows that many HCPs live with the idea that they already apply SDM quite often, which indicates their lack of SDM skills, knowledge, and the need to target HCPs better on this matter [74]. While our results do not directly support this conclusion, as they primarily suggest that the role of HCPs is centred around providing and clarifying information about treatment strategies, it may imply such a discrepancy.

SDM-tools mainly showed positive effect on the SDM outcome measures and little to no positive effect on clinical outcome measures, which is in line with previous research by Mathijssen et al. [27]. This indicates that SDM-tools are also most effective when they are mainly able to increase patients’ knowledge, patient involvement, decisional self-efficacy and decrease decisional conflict.

This systematic review is the first review which reports on both SDM-interventions and CDSSs in chronic conditions as they are deemed equally important in facilitating technology-supported SDM. As this research consequently entails the inclusion of different research disciplines, and thus also many articles, we had the following methodological considerations and decisions. First, the screening of studies was conducted using a machine learning algorithm (ASReview). There may be a chance that a few relevant articles were excluded since we terminated screening after identifying 100 consecutive irrelevant references. However, missing relevant studies cannot be completely avoided since human reviewers also make errors in inclusion and exclusion of studies [95, 96]. In our study, this automated approach highly improved the efficiency of the screening process as there were more than 10,000 references to screen. Second, this review only reports on RCTs. It is possible that other relevant SDM and CDSS studies are available that contain well designed and developed SDM-tools and CDSSs with relevant SDM-elements and interactive styles. However, since we investigated the relationship between SDM-elements and the effectiveness of studies based on outcome measures, only RCTs were included. Third, in this study we assessed the risk of bias only for outcome measures that showed a positive effect. This could skew the interpretation of study findings and ignores potential biases in the methodological quality of RCTs, so should be taken into account when interpreting our results. However, this still allows researchers and practitioners to identify components that impacted the success of interventions and can guide efforts to improve and replicate successful components in future interventions and implementations. Furthermore, we limited this review to six common chronic diseases [1-3], for which we consider it as a strength that we also included anxiety and depression as a chronic disease in our review. These are common comorbid conditions which were not included in similar reviews we identified [27, 97, 98]. In this way, this review was the first to provide a broad but thorough overview of the current body of knowledge and application of SDM and CDSS in the context of RCTs. Future research could target statistical data pooling and meta-analysis within specific chronic conditions given the lack
of homogeneity among the included studies in this systematic review. Moreover, including other study designs besides RCTs will provide additional insights into components for SDM and CDSSs.

Reporting patient and HCPs their involvement in SDM remains a challenge in studies because there is no gold standard for this, and thus far the use of decision aids cannot accurately display SDM [55]. It should be considered that the identification of SDM-elements in the interventions was based on our own judgement. Some SDM-elements were tagged as unclear in interventions since there was no sufficient evidence as some SDM-elements were not observed in the tool itself but indefinably described in the intervention description. Finally, it's essential to consider patient decision heuristics as well when describing the role of patients in decision-making. This also reinforces the concept of technology supported SDM, where patients, HCPs, and technology have equal roles.

4.2 Conclusion
This systematic review is the first review which reports on both SDM-interventions and CDSSs in chronic conditions. Based on the identified studies of this systematic review we learned that the role of patients, HCPs and technology in SDM is as follows: 1. Patients mainly receive information from SDM-tools and occasionally CDSSs when it concerns treatment options and treatment paths. 2. HCPs provide and clarify information using SDM-tools and CDSSs and 3. Technology provides the patient and HCP with primary interactions, which can support more active SDM. SDM-tools mostly showed evidence for positive effects on SDM-outcomes (e.g. knowledge, expectations and risk comprehension, patient involvement), whereas CDSSs mostly showed evidence for positive effect on clinical outcomes (e.g. HbAc1, cholesterol levels, BP). However, as SDM-outcomes are mostly not assessed in the studies with CDSSs, there is a lack of evidence to what extent CDSSs can effectively facilitate SDM. Moreover, there is still limited evidence for a positive effect on both SDM and clinical outcomes assessed in the included studies. Finally, the desire to apply SDM implies a need for sufficient collaboration among three different actors being: the patient, HCP and technology. This can only be achieved when both the patient and HCP have an active role in the proposed technology supported SDM-process, where the understanding of information is guaranteed.

4.3 Practice implications
With the collaboration among the patient, HCP and technology and the insights into the content and use of existing tools as discussed in this review, the concept of technology supported SDM has potential to optimize SDM and to improve the care process for patients with chronic conditions. For this concept it is important to consider that only using similar tools and systems will not be enough to facilitate SDM. Furthermore, there is no hard evidence that implementing all 10 elements of SDM will ensure a more active role of both the patient and HCP in SDM-processes. However, for future research it is important that “self-efficacy”, “patient outcome expectations” and “confirming patient understanding” become more prominent in interventions to investigate the relationship between SDM-elements and outcome measures. Lastly, although HCPs have an active role in SDM, there is evidence that they still lack SDM skills and knowledge to facilitate SDM which needs improvement.

Acknowledgements
We would like to thank the information specialists of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente for their guidance in setting up the protocol for this systematic review.

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Declaration of generative AI and AI-assisted technologies in the writing process
During the preparation of this work the author(s) used ChatGPT in order to improve language and readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

5 References


[79] Y. Ramallo-Farina, M.A. Garcia-Bello, L. Garcia-Perez, M. Boronat, A.M. Wagner, L. Rodriguez-Rodriguez, P. de Pablos-Velasco, I. Llorente Gomez de Segura, H. Gonzalez-Pacheco, M. Carmona Rodriguez, P. Serrano-Aguilar, I. Team, Effectiveness of Internet-Based Multicomponent Interventions for Patients and Health Care Professionals to Improve Clinical Outcomes in Type 2 Diabetes Evaluated Through the INDICA Study: Multiarm Cluster Randomized Controlled Trial, JMI R Mhealth Uhealth 8(11) (2020) e18922.


6 Figures

Figure 1 represents the concept for technology supported SDM where patients, HCPs and technology have equal roles.
**Records identified from Databases:** n = **16,582**
- PubMed, n = 3,435
- Scopus, n = 7,370
- Web of Science, n = 2,214
- PsychINFO, n = 287
- Embase, n = 2,188
- Cinahl, n = 1,087

**Records removed before screening:**
- Duplicate records removed (n = 4,957)
- Records marked as ineligible by automation tools (ASReview) (n = 10,790)

**Records screened (n = 835)**

**Reports excluded (n = 705)**

**Reports sought for retrieval (n = 130)**

**Reports not retrieved, after authors were contacted (n = 28)**

**Reports assessed for eligibility (n = 102)**

**Articles included in this review (n = 43)**

- Irrelevant study objective (n = 3)
- Irrelevant outcome measures (n = 1)
- Irrelevant participants (n = 20)
- Letter to the editor (n = 1)
- Irrelevant intervention (n = 7)
- No usual care (n = 10)
- Not a RCT (n = 4)
- Pilot study (n = 4)
- Study Protocol (n = 4)
- No response from authors (n = 5)

*Figure 2 PRISMA flow of study selection*
Figure 3: Identified SDM-elements in studies
Figure 4: Identified SDM element per decision support category

Figure 5: Identified interactive styles in studies
7 Tables

Table 1 Elements of shared decision making and primary interactive styles with their definitions.*Provider refers to either a HCP or technology, such as SDM-tools and intervention, or CDSSs. ** User refers to either the HCP or patient.

<table>
<thead>
<tr>
<th>Elements of SDM for patient-provider* interactions with their definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rationale for option</strong></td>
</tr>
<tr>
<td><strong>Definitions for option</strong></td>
</tr>
<tr>
<td><strong>Process or procedure</strong></td>
</tr>
<tr>
<td><strong>Risks/cons</strong></td>
</tr>
<tr>
<td><strong>Benefits/pros</strong></td>
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<tr>
<td><strong>Patient self-efficacy</strong></td>
</tr>
<tr>
<td><strong>Patient preferences and values</strong></td>
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<tr>
<td><strong>Patient outcome expectations</strong></td>
</tr>
<tr>
<td><strong>Patient understanding confirmed</strong></td>
</tr>
<tr>
<td><strong>Plan for follow-up</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary interactive styles between an interactive tool and user** with their definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Menu selection</strong></td>
</tr>
<tr>
<td><strong>Form fill-in</strong></td>
</tr>
<tr>
<td>Study ID</td>
</tr>
<tr>
<td>------------------</td>
</tr>
</tbody>
</table>
medication adherence                                                                 |
| Mather et al. 2012 [60] | Diabetes Type 2 | 1. PANDAs decision aid* 2. HCP training workshop | Diabetes treatment options (make no change, lifestyle modification, insulin therapy) | Patient, HCP | Paper-based (booklet) | Before & In consultation | Decision quality (Decisional Conflict Scores, knowledge, realistic expectations), HbA1c |
| Branda et al. 2013 [50], Perestelo-Pérez et al. 2015 [51] (Statin Choice DA) | Diabetes Type 2 | 1. Statin Choice DA* 2. Statin Choice DA (Adapted Spanish version) 3. Training session for physicians | Medication choice (No statins, std dose statins, high dose statins) | Patient HCP | Website  
Paper-based version (sheet) | In & after consultation | Knowledge, perception of risk, decisional conflict, satisfaction with the decision making process, adherence [51] |
<p>| Raue et al. 2019 [65] | Depression | 1. Decision aid materials* &amp; psychoeducational handouts | Treatment option (antidepressants, psychotherapy, both, complementary approaches, or do nothing at this time) | HCP | Paper-based | In &amp; after consultation (e.g.) | Adherence, depression symptom severity |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Target audience</th>
<th>Platform</th>
<th>Mode of Communication</th>
<th>Outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slok et al. 2016 [69]</td>
<td>CO PD: ABC tool (includes ABC scale)</td>
<td>Patient, HCP</td>
<td>Paper-based &amp; computer based</td>
<td>Befor &amp; In consultation</td>
<td>Health status, quality of care</td>
</tr>
<tr>
<td>Reference</td>
<td>Disease Type</td>
<td>Intervention</td>
<td>Consultation Format</td>
<td>Outcomes</td>
<td></td>
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<tr>
<td>Coylew right et al. 2016 [74]</td>
<td>Coronary Artery Disease</td>
<td>1. PCI Choice DA* 2. Clinician DA training sessions</td>
<td>Treatment option (medicines alone or medicines + stents)</td>
<td>Patient HCP</td>
<td>Paper-based</td>
</tr>
<tr>
<td>Den Ouden et al. 2017 [61]</td>
<td>Diabetes Type 2</td>
<td>OPTIMAL decision support aid*</td>
<td>Treatment options (regular &amp; intensive) and prioritize treatment targets</td>
<td>Patient HCP</td>
<td>Paper-based</td>
</tr>
<tr>
<td>Denig et al. 2014 [62]</td>
<td>Diabetes Type 2</td>
<td>1. PORTDA-diab decision support aid, including treatment cards 2. Physician protocol</td>
<td>Treatment option (e.g. Statin, ACE-inhibitor, healthy lifestyle) based on risk-predictions</td>
<td>Patient HCP</td>
<td>Paper-based (Software complemented with a set of treatment cards)</td>
</tr>
<tr>
<td>Branda et al. 2013 [50]</td>
<td>Diabetes Type 2</td>
<td>Diabetes medication choice decision aid</td>
<td>Medication choice (e.g., increase medication dose, change, or add a medication)</td>
<td>Patient HCP</td>
<td>Paper-based (website)</td>
</tr>
<tr>
<td>Karagiannis et al. 2016 [23]</td>
<td>Diabetes Type 2</td>
<td>Greek version of Diabetes medication choice decision aid</td>
<td>Medication choice (e.g., increase medication dose, change, or add a medication)</td>
<td>Patient HCP</td>
<td>Paper-based (cards)</td>
</tr>
<tr>
<td>Kuneman et al. 2021 [52]</td>
<td>Diabetes Type 2</td>
<td>1. Diabetes medication choice decision aid 2. Clinician DA training</td>
<td>Medication choice (e.g., increase medication dose, change, or add a medication)</td>
<td>Patient HCP</td>
<td>Website (Paper-based (cards, one-page)</td>
</tr>
<tr>
<td>Study</td>
<td>Intervention</td>
<td>Treatment Option</td>
<td>HCP/Patient Contact</td>
<td>Outcome Measures</td>
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<tr>
<td>LeBlanc et al. 2015 [67]</td>
<td>Depression Medication Choice (DMC) decision aid* 2. Brief training for clinicians on how to use DA</td>
<td>Medication choice (SSRIs, SNRIs, TCAs, Others)</td>
<td>Patient</td>
<td>Paper-based (laminate cards, booklet) In &amp; after consultation Decision making quality, decisional comfort, satisfaction, medication adherence, depression symptoms</td>
<td></td>
</tr>
<tr>
<td>Perestelo-Pérez et al. 2017 [25]</td>
<td>Depression Decision making in depression DA</td>
<td>Treatment option (only pharmacotherapy, only psychotherapy, combined therapy)</td>
<td>Patient</td>
<td>Website Befor &amp; after consultation Decisional conflict, knowledge about treatment options, treatment intention, decisional control preferences</td>
<td></td>
</tr>
<tr>
<td>Ali et al. 2016 [57], Shah et al. 2019 [58], Ali et al. 2020 [63]</td>
<td>Diabetes Type 2 1. Decision-support electronic health record* 2. Nonphysician care coordinators’ contact with patients (CCs) 3. Training for CCs</td>
<td>Treatment adjustments based on system prompts recommendations (e.g. treatment intensification, and/or behavioural activation)</td>
<td>HCP/CPS</td>
<td>Computer-based (software) Befor &amp; patient visit HbA1c, BP, LDLc, HRQL, treatment satisfaction, depression symptom check, degree of depression</td>
<td></td>
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<tr>
<td>Fletcher et al. 2021 [64]</td>
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<tr>
<td>Kulzer et al. 2018, Heine mann et al. 2019 [75, 76]</td>
<td>Diabetes Type 2</td>
<td>1. Integrated personalized diabetes management process 2. Digital tools* (diabetes management system, glycaemic risk traffic lights and compliance monitor) 3. Training for physicians</td>
<td>Changes in therapy and SMBG regime based on system analysis</td>
<td>HCP</td>
<td>Computer-based</td>
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<tr>
<td>Heselm ans et al. 2020 [84] (telemonitoring group)</td>
<td>Diabetes Type 2</td>
<td>EBMeds system (evidence-based medicine decision support system)</td>
<td>Clinical decisions (supported by reminders)</td>
<td>HCP</td>
<td>Computer-based</td>
</tr>
<tr>
<td>Jeong et al. 2018 [81] (telemetry group)</td>
<td>Diabetes Type 2</td>
<td>1. Smart Care Unit (Personal tablet with video conferencing and/or text message system, auto-transmitter system) 2. Automated decision support by text 3. Patient education on diabetes self-management 4. Outpatient clinic visits</td>
<td>Self-decision-making support by text algorithm</td>
<td>Patient</td>
<td>Computer-based (tablet for text algorithm)</td>
</tr>
<tr>
<td>Lim et al. 2011, 2015 [77, 78]</td>
<td>Diabetes Type 2</td>
<td>1. Pertinent diabetes education 2. Blood glucose monitoring system 3. CDSS-based u-healthcare service</td>
<td>Lifestyle actions based on message prompts (e.g. change current diabetes medication, intensify lifestyle)</td>
<td>Patient HCP</td>
<td>Web-based (u-healthcare website) &amp; Computer-based (software)</td>
</tr>
<tr>
<td>Reference</td>
<td>Diabetes Type</td>
<td>Patient-Coach System (Mobile Diabetes Management Software &amp; web-based patient portal)</td>
<td>Provider Clinical Decision Support (Web-portal)</td>
<td>Time point not associated with specific consultation</td>
<td>Change in HbA1c, diabetes distress, depression, SBP, DBP, LDL, HDL, triglycerides, total cholesterol</td>
</tr>
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<tr>
<td>Quinn et al. 2011 [89]</td>
<td>Diabetes type 2</td>
<td>1. Patient-coaching system (Mobile Diabetes Management Software &amp; web-based patient portal)</td>
<td>2. Provider clinical decision support (Web-portal)</td>
<td>Patient decides on lifestyle actions based on message prompts (e.g. eat 15 grams of carbs) from HCPs (based on data summaries)</td>
<td>Patient decides on lifestyle actions based on message prompts (e.g. eat 15 grams of carbs) from HCPs (based on data summaries)</td>
</tr>
<tr>
<td>Welch et al. 2015 [85]</td>
<td>Diabetes Type 2</td>
<td>1. One-on-one diabetes education visits</td>
<td>2. The diabetes dashboard*</td>
<td>3. Training for the diabetes</td>
<td>Recommendations for changes in medication management for hyperglycaemia, hypertension, and dyslipidaemia</td>
</tr>
<tr>
<td>Intervention team</td>
<td>SDM-tool + CDSS</td>
<td>Changes in insulin dose</td>
<td>Patient HCP</td>
<td>Computer/ tablet</td>
<td>No face-to-face consultation (virtual interactions)</td>
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<tr>
<td>O’Connor et al. 2011[83]</td>
<td>Diabetes Type 2</td>
<td>1. Diabetes Wizard* 2. Training session for nursing staff and physicians</td>
<td>Changes in medication treatments (supported by system recommendations)</td>
<td>H C P</td>
<td>Comput er &amp; paper-based</td>
</tr>
<tr>
<td>Granados-Santiago et al. 2019 [70]</td>
<td>COPD</td>
<td>COPD goals (self-management, pharmacological management, symptomatic control, healthy lifestyle promotion)</td>
<td>Health care</td>
<td>No materia ls reporte d</td>
<td>Durin g hospit al stay</td>
</tr>
<tr>
<td>Study ID</td>
<td>SDM-element in intervention</td>
<td>User-interaction style in Decision support tools</td>
<td>Rationale for option</td>
<td>Definitions for option</td>
<td>Process or procedure</td>
</tr>
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<tr>
<td>Mathers et al. 2012 [60]</td>
<td>? ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td></td>
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<tr>
<td>Branda et al. 2013 [50] (Diabetes)</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
<td>✓ ✓ ✓ ✓ ✓ ✓</td>
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</tbody>
</table>

**Table 3:** Identified SDM elements in interventions and identified user-interaction styles in decision support tools. A check mark (✓) indicates that the SDM element was identified in the intervention, whereas a cross mark (✗) indicates the opposite. Meanwhile, a question mark (?) indicates that it was unclear if the SDM element was present in the intervention.
<table>
<thead>
<tr>
<th>Medication</th>
<th>CDSSs</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA)</td>
<td></td>
</tr>
<tr>
<td>Branda et al. 2013 [50] (Statin Choice DA)</td>
<td>✓</td>
</tr>
<tr>
<td>Perestelo-Pérez et al. 2015 [51]</td>
<td>✓</td>
</tr>
<tr>
<td>Perestelo-Pérez et al. 2017 [25]</td>
<td>✓</td>
</tr>
<tr>
<td>Raue et al. 2019 [65]</td>
<td>✓</td>
</tr>
<tr>
<td>Slok et al. 2016 [69]</td>
<td>✓</td>
</tr>
<tr>
<td>Aljumah et al. 2015 [66]</td>
<td>?</td>
</tr>
<tr>
<td>Allen et al. 2021 [72]</td>
<td>✓</td>
</tr>
<tr>
<td>Bailey et al. 2016, 2018 [53, 54]</td>
<td>✓</td>
</tr>
<tr>
<td>Buhse et al. 2015, 2018 [55, 56]</td>
<td>✓</td>
</tr>
<tr>
<td>Coylewright et al. 2016 [88]</td>
<td>x</td>
</tr>
<tr>
<td>Den Oudenaarden et al. 2017 [61]</td>
<td>x</td>
</tr>
<tr>
<td>Denig et al. 2014 [62]</td>
<td>✓</td>
</tr>
<tr>
<td>Karagiannis et al. 2016 [23]</td>
<td>x</td>
</tr>
<tr>
<td>Kunneman et al. 2021 [52]</td>
<td>x</td>
</tr>
<tr>
<td>LeBlanc et al. 2015 [67]</td>
<td>✓</td>
</tr>
</tbody>
</table>

<p>| Balestrieri et al. 2020 [68] | ✓ | x | ✓ | x | x | ? | x | x | ✓ | ✓ | ✓ | x | x | ✓ |
| Fletcher et al. 2021 [64] | x | x | ? | ? | ✓ | ✓ | x | x | ✓ | ✓ | ✓ | x | x | ✓ |
| Kulzer et al. 2018, Heinemann et al. 2019 [75, 76] | x | x | x | x | x | x | x | x | ✓ | ✓ | ✓ | x | x | ✓ |
| Heselmann et al. 2020 [84] | x | x | x | x | x | x | x | x | ✓ | ✓ | ✓ | x | x | ✓ |</p>
<table>
<thead>
<tr>
<th>Study</th>
<th>SDM-tools</th>
<th>CDSSs</th>
<th>Other decision support tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeong et al. 2018 [81]</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lim et al. 2011, 2015 [77, 78]</td>
<td>✓</td>
<td></td>
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<tr>
<td>Quinn et al. 2011 [89]</td>
<td>✓</td>
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<tr>
<td>Ramallo-Fariña et al. 2020, 2021 [79, 80]</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Welch et al. 2015 [85]</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hsu et al. 2016 [86]</td>
<td>x</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>O’Connor et al. 2011 [83]</td>
<td>✓</td>
<td></td>
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<tr>
<td>Fitzpatrick et al. 2016 [82]</td>
<td>✓</td>
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<td></td>
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<tr>
<td>Granados-Santiago et al. 2019 [70]</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Srisuk et al. 2016 [73]</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vo et al. 2019 [87]</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Walters et al. 2013 [71]</td>
<td>?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

✓ → present, ? → unclear, x → not present

**Declaration of Competing Interest**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Highlights**

- Patients mainly receive information from SDM-tools and occasionally CDSSs.
- HCPs mostly provide and clarify information using SDM-tools and CDSSs.
- Technology provides the patient and HCP with primary interactions.
- SDM-tools mostly showed evidence for positive effects on SDM outcomes.
- If patients, HCPs and technology collaborate well together, SDM can be optimized.